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Fiscal policy in the US: Sustainable after all?

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ABSTRACT

The sustainability of US public debt has been widely discussed since the Great Recession. Using annual data since 1940, we estimate and compare different specifications of fiscal rules. Estimates of constant-parameter fiscal rules show no evidence of sustainability. This may be due to the instability of government's behaviour over time. Thus, we estimate a Markov-switching fiscal rule in order to identify periods of unsustainable and sustainable fiscal policies. First, we show that the government stabilizes public debt only periodically. Second, during these periods, the government's reaction is sufficiently tight to stabilize public debt over the entire horizon. We conclude that a relatively short-lived but tight fiscal contraction can be sufficient to ensure long-run US debt sustainability.

1. Introduction

Following the Global Financial Crisis and the Great Recession, countercyclical fiscal policies led to substantial increases in public debt in most OECD countries. It raised concerns about fiscal sustainability and a debate arose between Auerbach and Gorodnichenko (2017), Elmendorf and Sheiner (2017), on the one hand, and Mehrotra (2017) on the other hand on optimal future fiscal policy in this respect. While the former argued that a fiscal stimulus would not deteriorate fiscal sustainability despite high debt levels, the latter argued for a reduction of public debt because of high debt levels. Auerbach and Gorodnichenko (2017) use local projections on a panel of OECD countries to compute the reactions of a set of macro variables to government spending shocks. Following their econometric exercise, they show that fiscal shocks do not produce adverse effects on measures of fiscal sustainability like interest rates, CDS spreads, and the debt to GDP ratio. Mehrotra (2017) argues that under the secular stagnation scenario where the real interest rate falls short of the real GDP growth rate, higher levels of debt "allow the government to raise real resources without resorting to taxation". Meanwhile, he also argues on a "moderate probability" that the real interest rate goes beyond the real growth rate over a 5–10-year horizon. Consequently, he recommends austerity measures because he finds that the tax maximizing level of public debt is lower than the actual average level since 1870. In contrast with Mehrotra (2017), Elmendorf and Sheiner (2017) expect low interest rates in the US over a long period and despite their first sentence: "The federal budget is on an unsustainable path", they argue for larger public debt and public investment in the US in the short run, hence for a postponement of deficit reduction measures.

The aim of this paper is to assess fiscal sustainability in the US under two different regimes. The first one will show a positive response of the government's primary surplus to growing debt, whereas the second regime will show no response at all, or even a negative one. As the previous debate recalls, fiscal sustainability and fiscal policy are interconnected. If sustainability is at stake as Mehrotra (2017) reports, fiscal contraction is the optimal policy. Otherwise, public debt will be unsustainable. On the contrary, fiscal expansion can be the optimal policy when higher growth is possible and sustainability is granted as Auerbach and Gorodnichenko (2017) argue. The existence of sustainable and unsustainable fiscal regimes has been recently studied by Cassou et al. (2017) who report frequent shifts from one regime to another that they relate to the economic situation. Under weak economic conditions, fiscal sustainability is not fulfilled whereas it is when economic conditions are strong.

Our contribution to the existing literature is to link periodic fiscal regimes, either sustainable or unsustainable, with a *global* (or long-run) indicator of fiscal sustainability. Hence we do not only identify regime switches but we also implement an empirical test of the global fiscal sustainability in the US. As a matter of fact, the existence of periodic

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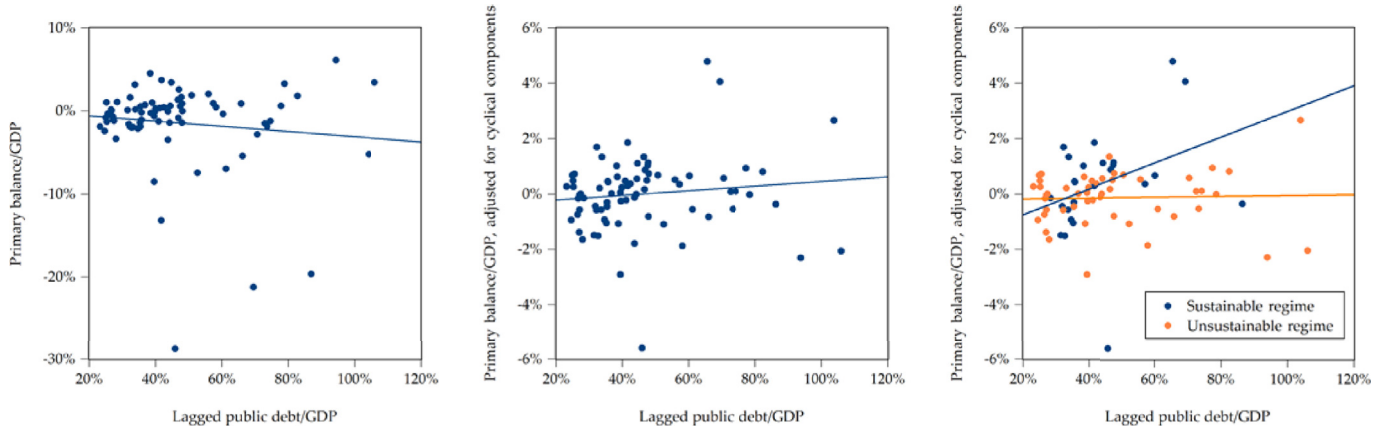

Fig. 1. Surplus-debt correlations (United States, 1940–2016). Note: The left panel plots the simple correlation between primary surplus-to-GDP and lagged debt-to-GDP. The center panel plots the correlation between the primary surplus adjusted for cyclical components (output gap and cyclical spending), using a simple linear regression as explained in footnote 1. Finally, the right panel plots correlations of primary surplus (adjusted for cyclical components) depending on the two fiscal regimes identified in this paper, using Markov-Switching techniques. Finally, for each panel, we display an OLS regression line.
Source: Office of Management and Budget, authors' calculations.

sustainable or unsustainable fiscal regimes does not inform about the global assessment of fiscal sustainability. Once a periodic unsustainable regime is identified, the following question is usually raised: how long can the necessary fiscal adjustment be delayed without threatening the global sustainability of public debt? This is typically the question that Elmendorf and Sheiner (2017) deal with. Despite short-run fiscal unsustainability, the economic situation may make it possible to raise public debt further and improve long-run debt sustainability, they argue. In a sustainable fiscal regime, the important question pertaining to global sustainability is: are the properties of the regime in terms of the reaction of fiscal policy towards public debt and/or in terms of frequency sufficient to ensure the long-run sustainability of public debt? Actually if the government is reacting only weakly and/or very infrequently towards debt variations, the debt-to-GDP ratio may not decline and a new crisis may push debt into unsustainable territories in the long run.

This paper addresses the properties of global sustainability and gives an answer to the previous questions. We apply to US annual data from 1940 to 2016 the Regime-Switching test developed in a companion paper. Aldama and Creel (2017) extend Bohn (1998)'s fiscal policy feedback rule to the regime-switching case and derive conditions under which fiscal policy is *globally* sustainable while allowing for persistent unsustainable regimes. These conditions are based on the properties of fiscal rules under the two regimes.

We follow a two-step empirical strategy. First, we estimate constant-parameter fiscal policy rules. We also control for non-linearities using a quadratic and cubic specifications of Bohn's fiscal rule. These baseline regressions do not give significant evidence of a sustainable fiscal regime, i.e. a strictly and significant positive response of primary balance to lagged public debt. Still, these results may be triggered by the fundamental instability in the relationship between primary surplus and lagged public debt identified by Bohn (1998). Fig. 1 gives a snapshot of this instability. It shows the surplus-debt correlations without and with adjustment for cyclical components.[1] When considering the first two panels in Fig. 1, it appears that the cyclical adjustment suggested by Bohn is not sufficient to exhibit a strong and significant positive correlation between primary surplus and lagged debt. In the third panel, we split our sample in two, using the two fiscal regimes identified in this paper and show that one regime displays a strong positive surplus-debt correlation while the other displays a non-significant one.

Hence, in a second-step, we estimate a two-state Markov-switching fiscal policy rule in order to account for differentiated responses of primary surplus to public debt. We find significant evidence of a sustainable regime that displays a positive and strongly significant feedback effect of public debt. In contrast, the unsustainable regime is characterized by a non-significant feedback effect. Drawing on the estimated Markov-switching fiscal rule, we directly assess the global sustainability conditions developed in Aldama and Creel (2017). Results indicate that US fiscal policy has been globally sustainable, despite persistent unsustainable fiscal regimes.

The paper is organized as follows. Section 2 reviews the literature. Section 3 presents the paper's methodological framework and describes the dataset. Section 4 presents the empirical results. Section 5 draws policy implications from the analysis. Section 6 concludes.

2. Related literature

A first approach to fiscal sustainability consists in testing for unit-roots and stationarity or for cointegration relations between fiscal variables. This approach abstracts from an explicit modelling of fiscal policy behaviour. Seminal contributions are Hamilton and Flavin (1986), Wilcox (1989), Trehan and Walsh (1988, 1991) and Quintos (1995). More recently, Afonso and Jalles (2016) compute panel unit-root tests and cointegration tests on revenues, spending, primary deficits and debts of a group of OECD countries. They find that public debts are not sustainable. Chen (2016) achieves an opposite conclusion on the US. He also studies nonlinearities in the relationship between fiscal instruments which are either related to the business cycles or to changes in the fiscal legislation.[2] Chen (2016) concludes that the higher public spending the lower the sustainability of US public finances.

Another way of dealing with fiscal sustainability hinges on the dynamic properties of fiscal shocks on real GDP and measures of fiscal sustainability (debt-to-GDP ratio, short-term and long-term interest rates, CDS spreads, real GDP and inflation). In this respect, Auerbach and Gorodnichenko (2017) study the asymmetric and nonlinear effects of fiscal policy shocks during expansions or recessions and in a low-debt

[1] We follow Bohn (1998) and we use an OLS regression of primary balance against an intercept, output gap x_t and cyclical government spending $\tilde{g}_t$. Then, we extract the estimated residuals $\hat{v}_t$: $\hat{v}_t = s_t - \hat{\alpha} + \hat{\alpha_x} x_t + \hat{\alpha_g} \tilde{g}_t$ and interpret it as the primary surplus-to-GDP, adjusted for the cyclical components of fiscal policy.

[2] Chen (2016) argues that a change in the debt ceiling may well change the evolution of tax policy or that of public spending.

environment or a high-debt environment. They show that government spending shocks can have an important positive effect on growth in recessions and can lead to a reduction in public debt-to-GDP ratio, hence improving fiscal sustainability. Moreover, when controlling for the level of public debt, they do not find significant evidence of strong penalties for fiscal stimulus when the public debt-to-GDP ratio exceeds 100%.

Another strand of the literature builds on the explicit modelling behaviour of governments (Bohn, 1998).[3] After depicting a fiscal policy feedback rule, Bohn (1998) argues that a positive response of the fiscal instrument –usually the primary balance-to-GDP ratio or tax receipts-to-GDP– to the lagged public debt-to-GDP ratio ensures fiscal sustainability. Furthermore, if the response to lagged debt is larger than the real interest rate,[4] fiscal policy follows a debt-stabilizing rule, see (Bohn 1998; Mendoza and Ostry, 2008; Daniel and Shiamptanis, 2013). Bohn (1998) and Mendoza and Ostry (2008) both conclude that US public debt is sustainable. Although he reports a lower response of fiscal policy towards debt, Claeys (2006) concludes that US debt is sustainable. Bohn (1998) also estimates nonlinear specifications of fiscal policy rules which include quadratic and cubic terms of debt-to-GDP ratios. Results indicate a significant and positive feedback effect of quadratic debt on primary surplus, but a non-significant negative cubic term, showing an "increasing marginal response of surpluses to changes in debt". In an attempt to shed light on these nonlinearities, Ghosh et al. (2013a, b) introduce the concept of "fiscal fatigue" in policy behaviour. They argue that the reaction of the primary surplus may be "flatter" at high levels of public debt. Using the fiscal fatigue property of cubic fiscal policy rules, they propose a method to compute maximum debt limits depending on policy behaviour and risk-neutral lenders. After having estimated a cubic fiscal policy rule on a panel of OECD countries, they estimate country-specific debt limits under two scenarios –historical vs projected– for the growth-adjusted real interest rate. Their results suggest that most of OECD countries still have large fiscal spaces. In a similar vein, Fournier and Fall (2017) show that the US still have a large fiscal space. However, the fiscal space becomes undetermined after a change in the specification of the fiscal rule (with less fiscal tightening at a high debt level).

Alternatively to quadratic or cubic fiscal policy rules, the literature also turned towards time-varying and regime-switching specifications because of multiple evidence of structural breaks and regime shifts in standard constant-parameter specifications. Drawing on a time-varying parameter (TVP) model of US fiscal policy rule, Nguyen et al. (2017) show that fiscal sustainability was achieved until 2005 but not after that. The application of Markov-switching fiscal policy rules to the US dates back the mid-2000s. Favero and Monacelli (2005) investigate the instability of monetary and fiscal policy rules using Markov-switching dynamic regressions. They notably challenge the common wisdom (at the time) of a continuously *passive* or *Ricardian* fiscal policy in the US after WWII. They note, in addition, that regime-switching fiscal rules are better fitting policy behaviour than constant-parameter specifications. Contributing to the so-called Fiscal Theory of Price-Level, (Chung et al. 2007; Davig and Leeper, 2007, 2011; Bianchi, 2012) also estimate monetary and fiscal Markov-switching policy rules and provide evidence of unsustainable (or passive) fiscal regimes in the US. Cassou et al., (2017) introduce asymmetric reactions of the fiscal instrument to lagged debt and output gap that depend on good or bad economic conditions. They also report MS-VAR estimations. They notably show that sustainable regimes occur during good economic conditions whereas unsustainable regimes occur during bad economic conditions.

There are also many applications of regime-switching specifications to OECD countries. Here we mention only a few studies. For example, Burger and Marinkov (2012) and Afonso and Toffano (2013) apply regime-switching fiscal policy rules respectively to OECD and EU countries and find periodic unsustainable regimes. Ko and Morita (2015) apply a Markov-switching trivariate SVAR model to Japanese public debt.[5] They find evidence of two fiscal regimes between 1970 and 2011 and a single regime switch at the beginning of the 1990s. Hence, the first regime displaying a sustainable situation ended early in the 1990s whereas the second unsustainable fiscal regime has been in place ever since. According to their simulations, fiscal sustainability in Japan could be achieved either through a higher nominal growth or via a shift towards the Ricardian regime. Ricci-Risquete et al. (2016) apply Markov-switching fiscal policy rules to Spain and the Euro area. They find evidence of regime switches in fiscal policy, both in Spain and at the Euro area level. Their results indicate that the Spanish fiscal policy has committed to its fiscal sustainability requirements, irrespective of fiscal regimes, while the Euro area fiscal stance has been more countercyclical and sometimes unsustainable.

3. Methodology and dataset

Empirical studies on time-varying and regime-switching fiscal policy rules generally and successfully identify sub-periods during which the government does not stabilize public debt and sometimes even displays a negative feedback effect to lagged public debt. However, these studies do not conclude on whether the time-varying or regime-switching feature of fiscal policy threatens (or not) the long-run sustainability of public debt. In the empirical part of the paper, we will thus hinge on the test by Aldama and Creel (2017) to assess long-run fiscal sustainability.

3.1. Methodological framework

The data of Fig. 2 straightforwardly show a sharp increase in US public debt-to-GDP ratio since 2009 and the persistence of primary deficits eight years after the Great Recession. At first glance, US historical data suggest two distinct fiscal regimes which nicely fit a Markov-switching representation (and better fit than a TVP approach with continuous-time change). Indeed, we observe several episodes characterized by an increasing public debt-to-GDP ratio without a clear improvement of the primary surplus, which signal unsustainable fiscal regimes, and episodes of increasing primary surplus following public debt build-ups. For instance, in the early 1980s, primary deficits and debts respectively increased in proportion to GDP whereas they fell quite substantially in the early 1990s.

In light of these peaks and troughs in public debt evolution, our point of departure is that a locally or periodically unsustainable fiscal policy may not necessarily threaten the global or long-run sustainability of public debt. In particular, under sufficient conditions on regime-specific response of primary surplus to lagged public debt and on expected durations of regimes, (i) the No-Ponzi Game (NPG) condition or (ii) the Debt-Stabilizing condition may hold on the entire period despite periodically unsustainable policies.

NPG condition holds when

$$\gamma_S > \left|\gamma_{NS}\right|\frac{d_{NS}}{d_S} \tag{1}$$

with γ_S and γ_{NS} the respective responses of the primary surplus to public

[3] Bohn (2007) develops strong criticisms towards the econometric analyses of the first approach. His main argument is that high-order integration, dismissed by this approach, is conducive to sustainability because it is consistent with the intertemporal government budget constraint. He labels this situation as "weakly sustainable".

[4] Generally adjusted for the real GDP growth rate after using GDP-scaled fiscal variables.

[5] This SVAR approach was initiated by Canzoneri et al. (2001) on US data without regime-switching parameters. Creel and Le Bihan (2006) extended Canzoneri et al. (2001)'s methodology with the introduction of cyclically-adjusted primary balance data and applied it to a panel of advanced OECD countries.

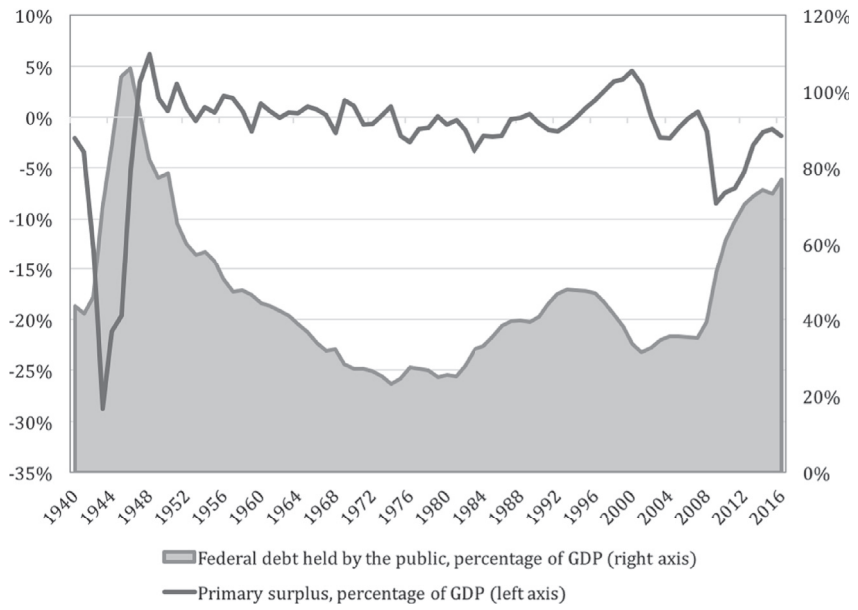

Fig. 2. Federal debt and primary federal surplus in the US (1940–2016).
Source: Office of Management and Budget.

debt in the sustainable regime (S) and the non-sustainable regime (NS), and d_S and d_{NS} the respective average duration of the sustainable and unsustainable regimes.

The NPG condition requires that the initial public debt-to-GDP ratio is backed by the sum of future expected and discounted real primary surpluses-to-GDP. The NPG condition *per se* does not impose any stationarity restriction, see Bohn (2007). Then an ever-increasing public debt-to-GDP ratio will eventually reach the fiscal limit on the level of primary surplus governments can run (Daniel, 2014; Daniel and Shiamptanis, 2013). As a consequence, a stronger sustainability constraint requires a *stable* public debt-to-GDP ratio around a long-run value with a sufficient safety margin with respect to the fiscal limit.

The Debt-Stability condition therefore holds when

$$\gamma_S > |\gamma_{NS}| \frac{d_{NS}}{d_S} + \frac{r-y}{1+y} \frac{d_S + d_{NS}}{d_S} \tag{2}$$

where r and y are the long-run average real interest rate and the growth rate of real GDP.

The Debt-Stabilizing condition may not be stricter than the NPG condition. First, the Debt-Stabilizing condition will be looser than the NPG condition if the real interest rate on public debt is lower than the growth rate of real GDP –which *does not imply* that the economy is dynamically inefficient. Abel et al. (1989) have shown that, in a stochastic economy with risk-free and risky assets, the correct theoretical condition for dynamic efficiency is that the *risky* interest rate, not the safe rate, must be larger than the growth rate of output. Empirically, Abel et al. (1989) address the difficulty of measuring the actual rate of return on risky capital by suggesting to test whether investment is lower (resp. higher) than capital income at the aggregate level, hence concluding in favour of dynamic efficiency (resp. dynamic inefficiency). They find that 7 advanced OECD economies including the US were dynamically efficient at the end of the 1980s. Geerolf (2013) recently updated their empirical work and overturned their results. He finds that OECD advanced economies have over-accumulated capital. Second, if the economy is actually dynamically efficient, the correct sustainability condition is the NPG condition and not the Debt-Stabilizing condition. Otherwise the government could simultaneously stabilize its debt *and* run a Ponzi Scheme against its creditors which would be a source of sub-optimality for rational creditors.

3.2. Dataset

We use historical data from the Office of Management and Budget (OMB) on federal debt, expenditures, receipts, primary budget, nominal and real GDP, and GDP implicit deflator. The dataset covers years ranging from 1940 to 2016.[6]

Following most studies on US fiscal policy, we use the federal debt *held by the public* as a measure of consolidated gross public debt rather than total gross federal debt; this choice is motivated by the fact that total gross federal debt includes intragovernmental obligations to social security and other trusts funds, see Bohn (2008). We measure the nominal interest rate on public debt by the ratio of net interest payments on public debt held by the public, as in Bohn (1998, 2008); this measure is generally called the *apparent* or *effective* interest rate on public debt. Finally, the real interest rate will be calculated as the *ex post* real rate deflated by the GDP implicit deflator. The choice of annual data is dictated by the nature of fiscal policy: it is set at an annual frequency, although revisions within the year are possible (Claeys, 2006). It is also dictated by the availability of data on the OMB database. The long-run nature of sustainability requires a long sample. Quarterly data for all the variables in the model start being available at least 15 years after 1940.

We follow the literature on Model-Based Sustainability analysis (Bohn, 1998; Mendoza and Ostry, 2008) and use the output gap and a measure of cyclical real public spending as regressors in the fiscal policy rule. Congressional Budget Office's estimates of potential real GDP are not available for years prior to 1949. As a result, we use a standard HP filtered output gap measure taking the cyclical component of log real GDP over the entire sample. Similarly, cyclical real public spending is defined as the cyclical component of log real public spending. In the HP filter, we choose a smoothing parameter $\lambda = 100$. Fig. 3 describes the series of output gap and cyclical real public spending.

[6] Data are available at https://www.whitehouse.gov/omb/budget/Historicals.

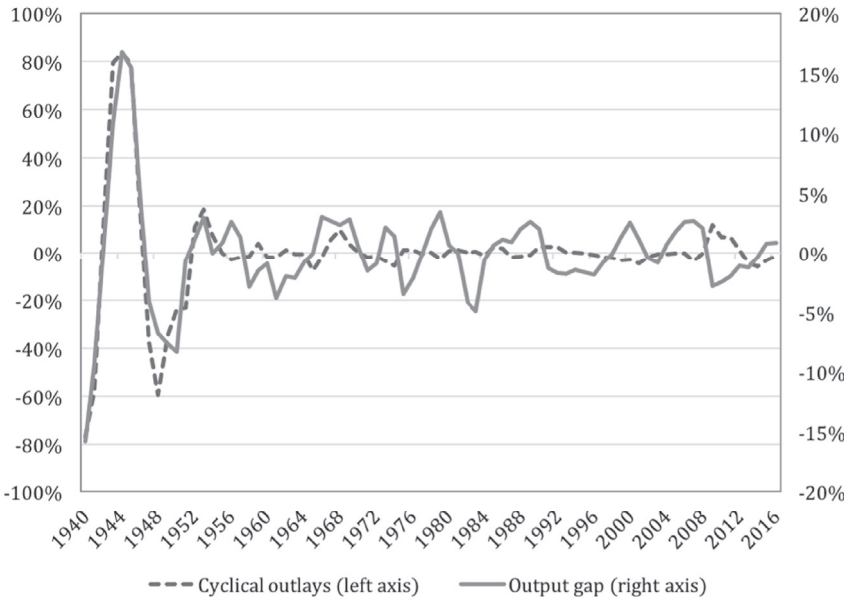

Fig. 3. HP filtered output gap and cyclical real public spending (1940–2016).
Source: Office of Management and Budget (OMB).

4. Empirical results

We follow a two-step empirical strategy. First, we estimate constant-parameter fiscal policy rules and perform standard Model-Based Sustainability tests. Strikingly, the constant-parameter estimates do not allow to conclude in favour of the sustainability of US public debt. Second, we estimate a two-state Markov-switching fiscal policy rule and assess the global sustainability of US public debt.

4.1. Standard Model-Based Sustainability tests

We estimate the following fiscal policy rule

$$s_t = \alpha + \gamma b_{t-1} + \alpha_x x_t + \alpha_g \tilde{g}_t + u_t \tag{3}$$

where s_t is the primary surplus-to-GDP ratio, b_{t-1} is the end-of-period public debt-to-GDP ratio, x_t is the output gap and $\tilde{g}_t$ is cyclical real public spending. Estimates of linear fiscal policy rules generally display a strong auto-correlation in the residuals hence we estimate a model with first-order autoregressive residuals $u_t = (1-\rho L)^{-1}\varepsilon_t$ with ε_t i.i.d. $\mathcal{N}(0, \sigma^2)$. Thus, we estimate equation (3) with non-linear least squares (NLS) and using a Cochrane-Orcutt procedure.

In addition, we also estimate non-linear specifications (4), (5) and (6) of the fiscal policy rule, including quadratic and cubic terms and also a kinked specification where the primary surplus only reacts to positive deviations of lagged public debt from its mean $\overline{b}$:

$$s_t = \alpha + \gamma_1 b_{t-1} + \gamma_2 b_{t-1}^2 + \alpha_x x_t + \alpha_g \tilde{g}_t + u_t \tag{4}$$

$$s_t = \alpha + \gamma_1 b_{t-1} + \gamma_2 b_{t-1}^2 + \gamma_3 b_{t-1}^3 + \alpha_x x_t + \alpha_g \tilde{g}_t + u_t \tag{5}$$

$$s_t = \alpha + \gamma_k \max\left(b_{t-1} - \overline{b}; 0\right) + \alpha_x x_t + \alpha_g \tilde{g}_t + u_t \tag{6}$$

We therefore account for a variety of non-linearities in the relationship between primary surplus and public debt. Polynomial specifications that include quadratic or cubic terms are meant to allow either for an *increasing* or a *decreasing* reaction of primary surplus when the level of public debt increases. In the quadratic specification (4), a positive coefficient associated to squared debt-to-GDP ratio would indicate that the response of the primary surplus *increases* with the level of public debt whereas a negative coefficient would testify for "fiscal fatigue". In the cubic specification (5), "fiscal fatigue" would result in a negative coefficient associated to cubic lagged debt-to-GDP ratio. Finally, the kinked specification is motivated by the non-linear specification estimated by Bohn (1998, Table 3) and assumes that fiscal policy increases the primary surplus to meet its intertemporal budget constraint only when the public debt-to-GDP ratio is above its long-run average $\overline{b}$.

Column (1) in Table 1 shows the results for the baseline specification (3). First, we do not find significant evidence of a strictly positive feedback effect of public debt on primary surplus. Hence, standard MBS analysis would conclude in favour of the unsustainability of US fiscal policy all over the period: large build-ups of public debt do not seem positively correlated with a significant increase of primary surplus between 1940 and 2016. In comparison with former evidence of a sustainable regime (Bohn, 1998, 2008), these results can *probably* be interpreted as evidence of instability in the coefficient estimates of linear

Table 1
Standard model-based sustainability tests (1942–2016).

Dependent variable: s_t	(1) Linear	(2) Quadratic	(3) Cubic	(4) Kinked
Constant	−0.0077	0.0119	−0.0327	−0.0075
	(0.0181)	(0.0316)	(0.0640)	(0.0093)
Lagged debt b_{t-1}	0.0049	−0.0720	0.1782	
	(0.0377)	(0.1047)	(0.3405)	
Quadratic lagged debt b_{t-1}^2		0.0650	−0.3470	
		(0.0770)	(0.5552)	
Cubic lagged debt b_{t-1}^3			0.2015	
			(0.2735)	
max $(b_{t-1} - \overline{b}\,; 0)$				0.0372
				(0.0484)
Output gap x_t	0.3372***	0.3435***	0.3480***	0.3240***
	(0.0812)	(0.0816)	(0.0823)	(0.0801)
Cyclical government spending g_t	−0.2394***	−0.2353***	−0.2377***	−0.2315***
	(0.0187)	(0.0183)	(0.0190)	(0.0185)
Adjusted R^2	0.93	0.93	0.93	0.93
Nb. of obs	75	75	75	75
DW stat	2.2202	2.2895	2.2664	2.2639

Notes: standard errors are reported in parenthesis. Reported estimates are significant at 1% level (***), 5% level (**) or 10% level (*). All models control for first-order serially correlated residuals using a Cochrane-Orcutt procedure.
Source: authors' calculations.

Table 2
Estimated baseline Markov-switching fiscal rule (1942–2016).

Dependent variable: s_t	Regime 1	Regime 2	Long-run estimates
Constant	−0.0189	−0.0245*	−0.0207*
	(0.0122)	(0.0127)	(0.0113)
Lagged debt b_{t-1}	0.0221	0.0865***	0.0423**
	(0.0219)	(0.0242)	(0.0205)
Output gap x_t	0.2871***	0.8671***	0.4690***
	(0.0545)	(0.1158)	(0.0528)
Cyclical government spending g_t	−0.1758***	−0.4137***	−0.2504***
	(0.0130)	(0.0239)	(0.0105)
Regime properties	Transition prob. p_{ii}	Ergodic prob. π_i	Expected duration d_i
$i = 1$	0.92	0.69	12.47
$i = 2$	0.82	0.31	5.70
Durbin-Watson statistic	1.76	Log Likelihood	241.5045

Notes: standard errors are reported in parenthesis. Reported estimates are significant at 1% level (***), 5% level (**) or 10% level (*). The model controls for regime-invariant first-order serially correlated residuals.
Source: authors' calculations.

Table 3
Average growth-adjusted real interest rate.

	1941–1952	1953–1981	1982–2016	Full sample (1941–2016)
Estimated mean μ	−0.0806	−0.0315	0.0036	−0.0231
Robust standard-error	(0.0121)	(0.0078)	(0.0071)	(0.0079)

Notes: sub-sample averages are determined using a Bai-Perron breakpoints regression; full-sample (1941–2016) average is obtained from a simple OLS regression. HAC robust standard-errors are reported in parenthesis.
Source: authors' calculations.

fiscal policy rules.[7]

Regarding non-linear specifications (4)–(6), results are shown in columns (2)–(4). Overall, we find no evidence in favour of fiscal sustainability. In the quadratic specification, the coefficient γ_2 term is positive but not statistically different from zero. The cubic specification displays a negative quadratic term γ_2 and a positive cubic term γ_3, but both are non-significant. While being not significant, point estimates of quadratic and cubic specifications do not provide any evidence of "fiscal fatigue" in US fiscal policy. Finally, the estimated kinked fiscal rule does not show a significant positive reaction to deviations of lagged public debt from its long-run average.

4.2. Regime-switching Model-Based Sustainability tests

Constant-parameter estimates of fiscal policy rules, be they linear or non-linear, do not give significant evidence in favour of a sustainable fiscal regime in the US between 1940 and 2016. Cassou et al. (2017) find similar shortcomings with a linear specification on an updated and longer sample than Bohn (2008). In this section, we argue that our former results may be driven by the instability, i.e. regime-switching properties, of fiscal policy rules' estimates.

We estimate the following Markov-switching fiscal rule in equation (7) by direct maximization of the log likelihood, following Hamilton (1989):

$$s_t = \alpha(z_t) + \gamma(z_t)b_{t-1} + \alpha(z_t)_x x_t + \alpha(z_t)_g \tilde{g}_t + u_t \tag{7}$$

where z_t is an unobserved two-state Markov process with constant transition probabilities. We estimate our model with first-order autocorrelated residuals $u_t = (1-\rho L)^{-1}\sigma\varepsilon_t$ where ε_t is i.i.d. $\mathcal{N}(0,1)$ and regime-invariant standard error σ of residuals. We use 10 000 random draws of initial values for the ML algorithm in order to avoid a local maximum and reduce the dependence of final results on initial values. We also define the long-run estimate α of regime-switching parameters using ergodic probabilities (π_1, π_2)

$$\alpha \equiv \alpha_1\pi_1 + \alpha_2\pi_2 \tag{8}$$

as well as its estimated standard-deviation

$$\sigma_\alpha \equiv \sqrt{(\sigma_{\alpha_1}\pi_1)^2 + (\sigma_{\alpha_2}\pi_2)^2 + 2\mathbb{C}ov(\alpha_1,\alpha_2)} \tag{9}$$

We report estimation results in table Table 2 and smoothed and filtered probabilities in Fig. 4.

First, the estimated Markov-switching fiscal policy rule identifies two regimes. There is a strongly significant positive response of primary surplus to lagged public debt in regime 2 which we label *sustainable*, whereas the response of primary surplus to lagged public debt is non-significant but positive in regime 1, which we label *unsustainable*. Second, the sustainable regime appears less persistent than the unsustainable one, a feature which can also be found in Cassou et al. (2017). Estimated probabilities of the fiscal regimes suggest that US fiscal policies have periodically been non-Ricardian since 1940 and over relatively long periods of time, particularly between the mid-1950s and mid-1960s or between the early 1970s and the early 1990s. Actually, the sustainable regime has an expected duration of 5.7 years compared with 12.5 years for the unsustainable regime. Evidence of recurring and persistent regime switches may explain *ex post* why constant-parameter estimates of fiscal policy rules (in section 4.1) cannot identify a significant positive reaction of the primary surplus to lagged public debt. Third, the occurrence of sustainable regimes between 1940 and 1945, 1952 and 1955 and between 1966 and 1971 matches WWII, the Korean War, and the Johnson Administration. These periods have been found sustainable in other contributions (Nguyen et al., 2017; Afonso and Jalles, 2014). Quite interestingly, they are consistent with institutional changes in US federal budget legislation like the adoption in 1946 (but prepared before) of the Legislative Reorganization Act, the Omnibus Appropriations Act for fiscal year 1951, or the implementation of the Report of the President's Commission on Budget Concepts since 1967 (Nguyen et al., 2017). Despite high spending, fiscal policy was also oriented towards the limitation of public debt increases. Finally, the long-run estimate of the feedback effect of public debt on the primary surplus is significantly positive and consistent with former results by Bohn (1998, 2008).

Given γ_{NS} is not statistically different from zero, the NPG condition depends exclusively on the sign of γ_S. The Debt-Stabilizing condition includes the average growth-adjusted real interest rate $r^{ga} = (r-y)/(1+y)$ and implies to choose an adequate measure for it. We estimate the average growth-adjusted real interest rate using a Bai-Perron regression:

$$r_t^{ga} = \mu + \varepsilon_t \tag{10}$$

allowing for structural breaks in the mean μ. Results suggest different significant average growth-adjusted real rates by sub-periods in the US, see Fig. 5 and Table 3. Hence, we present full-sample and sub-sample tests for the Debt-Stabilizing condition, using estimated average growth-adjusted real rates. Finally, we test NPG and Debt-Stabilizing conditions using one-sided Student tests (Table 4).

All tests conclude that the estimated Markov-switching fiscal policy rule meets both NPG and Debt-Stabilizing conditions. Regarding the

[7] There are at least two reasons for the differences between the first set of results and former results in Bohn (1998, 2008). First, the sample are not similar. Bohn (1998) uses data between 1916 and 1995 and Bohn (2008) between 1791 and 2012 (or 2003). Cassou et al. (2017) also show that the extension of Bohn (1998)'s sample gives different results. Second, Bohn uses military spending as a proxy for cyclical government spending.

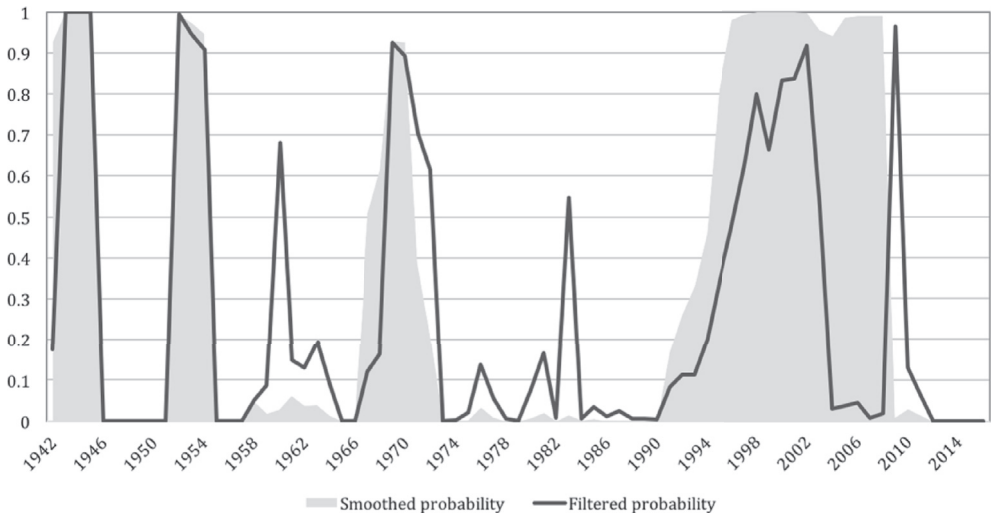

Fig. 4. Baseline model, estimated probabilities of sustainable regime.
Source: authors' calculations.

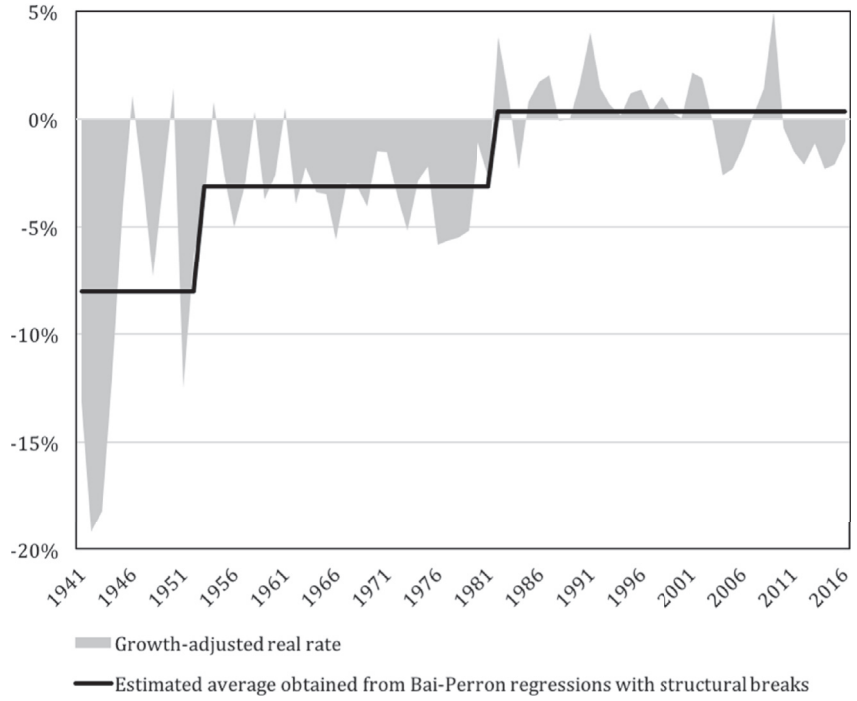

Fig. 5. Growth-adjusted real interest rate (1941–2016).
Source: Office of Management and Budget (OMB), authors' calculations.

Table 4
Regime–switching MBS tests results.

	NPG condition	Debt-Stabilizing condition			
	Full-sample	Full sample	1941–1952	1953–1981	1982–2016
t-stat	3.5768	4.5327	6.9120	4.8798	3.4293
Unilateral p-value	0.0003	0.0000	0.0000	0.0000	0.0005

Notes: these student tests assume that γ_{NS} is virtually equal to zero from estimates obtained in Table 2.
Source: authors'calculations.

latter condition, this is true whatever the period considered to estimate the long-run growth-adjusted real rate. In particular, our results suggest that US fiscal policy has not used the fiscal rooms for maneuver stemming from negative growth-adjusted real rates to run a Ponzi Scheme. Finally, despite recurring and persistent unsustainable (or non-Ricardian) regimes, we find evidence of a globally sustainable fiscal policy in the US: sustainable regimes are *sufficiently* tight and *sufficiently* frequent to ensure that public debt will be backed by future expected present-value primary surpluses.

5. Policy implications

This research yields specific implications for fiscal policy. First, fiscal

sustainability requirements could likely be less demanding than commonly believed. Our regime-switching approach revives the argument by Canzoneri et al. (2001) that a (globally) Ricardian fiscal policy could be more plausible. The "worries" expressed by Fed Chairwoman J. Yellen about the "sustainability of the US debt trajectory" (reported in Financial Times, 29 November 2017) highlight the short run-long run nexus about fiscal sustainability. In the short run, US fiscal policy may well deteriorate fiscal sustainability but maybe not sufficiently to generate unsustainability in the long run.

A usual criticism against Canzoneri et al. (2001) points to the fact that they do not study bounded equilibria for public debt-to-GDP ratio, but only focus on the NPG condition. Hence, if the real interest rate on public debt is larger than the growth rate of real GDP, satisfying the NPG condition would not be a sufficient condition for achieving fiscal sustainability because the public debt-to-GDP ratio would eventually reach its maximum level, implied by the fiscal limit on primary surplus (Bi, 2012; Daniel and Shiamptanis, 2013 among others).

The analysis developed in Aldama and Creel (2017) and used in this paper extends Canzoneri et al. (2001)'s approach to a debt-stabilizing condition and answers this criticism by proposing a condition ensuring the long-run stability of public debt-to-GDP ratio. But what is probably more important is the fact that the *apparent* real interest rate has been on average *lower* than the growth rate of real GDP over the period 1941–2016, see Table 3 and Fig. 5. This empirical fact implies that the NPG condition is actually sufficient to ensure a stable public debt-to-GDP ratio in the long run. As a result, an infrequent sustainable fiscal regime can ensure the long-run stability of public debt-to-GDP ratio despite long periods of gradually increasing debt due to the relatively high persistence of the unsustainable fiscal regime.

Yet, we implicitly assume that private creditors expect fiscal policy will turn back to a sustainable path with a certain probability in the future: stated differently, we assume that the government commits to a stable long-run probability distribution of regimes, i.e. the ergodic probabilities.

6. Conclusions

This paper investigates the global (or long-run) sustainability of US public debt. The ups and downs of public debt raise two concerns: first, how long is it possible to postpone fiscal consolidation before public debt becomes unsustainable? And when fiscal consolidation occurs, is it tight enough to ensure long-run fiscal sustainability? We draw on Aldama and Creel (2017) and test the sufficient conditions on regime-switching fiscal policy feedback rules that permit to achieve a No-Ponzi Game and a Debt-Stabilizing condition. When these conditions are met, global sustainability is ensured despite persistent unsustainable fiscal regimes.

The main outcome of the paper is that fiscal policy in the US has been globally sustainable since 1940. On average, a 12-year period of fiscal consolidation's postponement does not preclude global fiscal sustainability, provided periods of fiscal consolidation last almost 6 years on average and embed a sharp reaction of primary balance towards lagged public debt (the semi-elasticity is equal to 8.7%). Introducing the possibility of an instability in the relationship between primary balance and public debt via fiscal regimes enables to highlight periods of sustainability and unsustainability and gives contrasting results *vis-à-vis* those obtained with a linear (or non-linear) fiscal feedback rule without regime switches.

Future research on US fiscal sustainability may go in two mutually non-exclusive directions. First, the use of quarterly data may reinforce the tests' statistical properties. The limitation with the use of quarterly data relates to public debt. Usually, they are only genuinely annual in that they reflect the annual flows of deficits and annual revaluations. In the US case, it should be possible however to use genuine public debt quarterly data, i.e. data which have not been transformed into quarterly data *a posteriori*. The sample would be shortened though, true quarterly data being available 15 years later than annual data. Second, the estimations of global sustainability abstract from the monetary regime and a richer set of macroeconomic variables. Introducing macroeconomic feedbacks, like inflation dynamics and a monetary policy rule, could be done in a dynamic stochastic general equilibrium model as advised recently by Leeper and Li (2017). It would permit to highlight the possible endogeneity of fiscal policy to the macroeconomic context and to embed the test of global sustainability into a comprehensive framework.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.econmod.2018.03.017.

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