

Unconventional monetary policy and debt sustainability in Japan¹

Enrique Alberola² Gong Cheng³ Andrea Consiglio⁴ Stavros A. Zenios⁵

October 2022.

Abstract

We adapt to the Japanese case a model of stochastic debt sustainability embedded in a macro framework with monetary policymaking. A unique feature of the model is that it incorporates the effects of unconventional monetary policy, and its potential unwinding, on sovereign debt dynamics. The model uses a scenario tree to represent stochastic and correlated macroeconomic and fiscal variables, and a coherent risk measure to draw inferences on sustainability with high probability. We calibrate the model based on the series of unconventional measures put in place the Bank of Japan, especially the launch of the Quantitative and Qualitative Easing (QQE) in 2013. With a series of retrospective analyses and forward-looking simulations under different QQE exit strategies, we show the significant positive effect of the Bank of Japan's unconventional monetary policy on sovereign debt dynamics and show that the termination and unwinding of QQE could raise sustainability concerns. We also show that a global monetary tightening conditions has an equivalent impact to the end of QQE.

Keywords: Debt sustainability analysis; risk management; Quantitative and Qualitative Easing; Yield Curve Control; monetary-fiscal mix; CVaR optimisation.

¹The views in this paper are those of the authors and do not necessarily reflect those of the Bank for International Settlements. The authors thank the participants in the 29th NBER-TCER-CEPR (TRIO) Conference, especially Junko Koeda, for their constructive comments and suggestions. We also thank Kohei Matsumura and his co-authors for data sharing. We thank Jimmy Shek for his excellent research assistance.

²Bank for International Settlement, Basel, Switzerland.

³Corresponding author. gong.cheng@bis.org. Bank for International Settlement, Basel, Switzerland.

⁴University of Palermo, Palermo, Italy.

⁵University of Cyprus, Nicosia, CY, Cyprus Academy of Sciences, Letters, and Arts, Non-Resident Fellow, Bruegel, Brussels.

1 Introduction

Japan is the country with the highest ratio of public debt-to-GDP globally, standing at 259% at the end of 2020. And the Bank of Japan (BoJ) is the central bank that holds the largest stock of public debt in the world, both in absolute values and as a proportion of debt. It holds more than 50% of the Japanese government debt corresponding to more than 100% of the country's GDP. Two natural questions arise from these related facts: To what extent does the BoJ's purchases of sovereign securities contribute to sovereign debt sustainability? And, more importantly, what would be the impact on sovereign debt of an eventual exit from unconventional monetary policy measures? To answer these questions we adapt and calibrate for the case of Japan a model of *stochastic debt sustainability analysis* (DSA) with monetary policymaking, including unconventional measures. A retrospective what-if analysis and a forward-looking simulation provide answers.

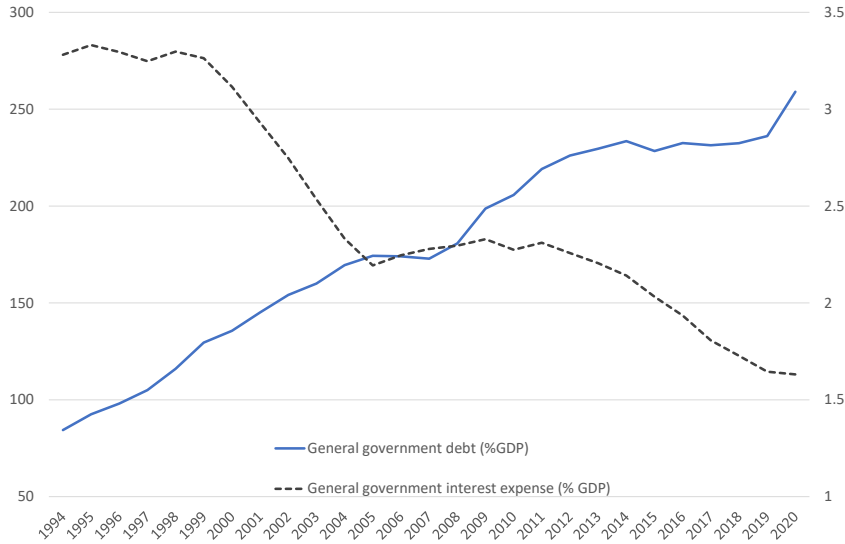
The experience of Japan has for long caught the attention of researchers interested in sovereign debt sustainability. On the one hand, the sovereign's debt, which is primarily composed of Japanese government bonds (JGB), has been on an upward trajectory since the 1990s (Figure 1). The general government debt rose from 100% of GDP before the Asian Financial Crisis to the current levels, more than twice the average of 95% of GDP among OECD countries¹. On the other hand, despite a deterioration of its rating from AAA in the 1970s to A+ (S&P) currently, the Japanese government continues to enjoy solid support from investors and the interest expense is on a declining path.

Why is Japanese debt deemed safe despite its massive and ever increasing level? For one thing, the JGB issuance is mostly absorbed by ample domestic savings in Japan, with very small holdings by foreign investors. The Japanese government has also large assets, including financial investments, which bring down the general government net debt to 162% in 2020. More importantly, in the context of this paper, the government has benefited from the unconventional monetary policy by the BoJ, leading to persistent low interest rates. Since the mid-1990s, inflation has been a challenge for the Japanese economy, with interest rates hovering around zero or below. After several unsuccessful attempts to revive inflation, the BoJ institutionalised a policy of low interest rates across the yield curve with the launch of the Quantitative and Qualitative Monetary Easing (QQE) in April 2013 and the subsequent introduction of the Negative Interest Rate Policy and the Yield Curve Control (YCC) in 2016 (Westelius, 2020). These policy measures entail large-scale asset purchases of government securities to bring inflation to the 2% target. Government financing has thus benefited from very favourable interest rates. The very low yields of Japanese public debt have limited the explosion of debt dynamics in spite of the large debt stock and persistent fiscal deficits.

¹OECD data: <https://data.oecd.org/gga/general-government-debt.htm>

Figure 1 – Japan: rising debt stock but declining interest expense

The figure displays the debt-to-GDP ratio (left axis) and the general government interest rate expenses (right axis) as a proportion of the country’s GDP. Data from the IMF World Economic Outlook and the Japanese Government Finance Statistics.



Against this backdrop, we adapt our stochastic debt sustainability analysis from Alberola et al. (2022) to the case of Japan to address the impact of unconventional monetary policy measures on debt sustainability.

Our DSA model embeds the model of Zenios et al. (2021) into a macro framework to account for monetary policymaking, including unconventional one. It accounts for stochastic correlated deviations from the steady-state equilibrium of the economy using a discrete time- and state-space *scenario tree*. The tree is calibrated to match expectations from institutional forecasts of the key variables, that satisfy the equilibrium conditions, under the historically observed volatilities and correlations. In line with current practices (Dias, Richmond, and Wright, 2014; Irwin, 2015), we model both debt stock and flow. If stock is on an increasing trajectory the sovereign will eventually hit its budget constraint and debt can be considered unsustainable. If flow exceeds a threshold that markets can finance, the sovereign can face a liquidity crisis. We employ a measure of tail risk (Conditional Value-at-Risk of Artzner, Delbaen, Eber, and Heath (1999)) of the stochastic variables to draw inferences about sustainability with high confidence level (e.g., 0.75). The model optimizes debt financing to trade off financing cost with refinancing risk. An extension of the model estimates the fiscal effort required to stabilise debt or reduce it to a desired level. A unique feature of our model is that it allows for granular debt maturities, preserving the realism of public debt management office decisions.

Standard DSA models (Bouabdallah et al., 2017; European Commission, 2020; IMF,

2021; Zenios et al., 2021) assume monetary policy as given, but in the current context of unconventional monetary policies across the world this is not a realistic assumption because one of their (implicit or explicit) purposes is to maintain interest rates on public debt low. In our model we include monetary policy explicitly. Conventional monetary policy is introduced through a macro-monetary block that also allows to assess the impact of inflation shocks. Unconventional policy works through public asset purchases by the central bank. Purchases of public debt by the central bank withdraw a part of the supply of government bonds from the market, increasing their price and reducing their yields. In the case of Japan, we assume, and test, that the impact of unconventional monetary policy on JGB yields is determined by the share of 10-year JGB held by the BoJ.²

We take the model to the data, using actual data, current forecasts, and the *counterfactual* data estimated by Kawamoto et al. (2021). This allows us to assess the implications of unconventional monetary policies in Japan for debt sustainability through two exercises, both backward- and forward-looking.

In the backward-looking, or retrospective, exercise, we compare the debt trajectory since 2013 with the counterfactual of no QQE/YCC,³ which implies higher long-term yields. With the QQE, Japanese debt appears sustainable, i.e., on a stable or declining path with 75% probability within a ten- or twenty-year horizon. On the contrary, the debt trajectory would have been on an unsustainable path without the QQE. To counteract the upward debt trajectory fiscal consolidation would have been required.

The forward-looking simulation considers the implications of ending the QQE programme. We assume that the continuation of the QQE would imply to keep the BoJ share of JGB holdings constant, with a concomitant reduction of JGB yields, while its discontinuation implies a reduction of the share. We consider two possible strategies for the QQE exit. The first is called *unwinding*, whereby maturing debt is removed from the balance sheet. The second *rolls over* the debt as it matures but any future increase in Japanese debt is not matched by larger holdings, so that the share decreases but at a slower rate than in the case of unwinding.

The results are consistent among the two exercises, building confidence in our conclusions. With the QQE going forward debt is sustainable, while the risks to sustainability are large if the QQE ends and the central banks unwinds. If the QQE stops but debt is rolled over, the debt dynamics remain very similar to the QQE case.

Finally, we consider a permanent tightening of monetary policy in the United States. Debt dynamics worsens and become unsustainable in case the US Federal Reserve (the Fed) increases its policy rates by more than 275 bps. On top of that, if tighter external

²Our original paper Alberola et al. (2022) develops the model with unconventional policy in the context of the euro area's Pandemic Emergency Purchase Programme. There, the channel of purchases was the compression of credit spreads in high indebted countries.

³For simplicity, hereafter we will refer the BoJ's ongoing unconventional monetary policy measures, including the QQE, the negative interest rate policy and the YCC, under the generic name of QQE.

conditions force the BoJ to exit from the QQE, government debt dynamics could worsen further, in particular if the central bank unwinds the public debt purchases.

Our work is closely related to three stands of literature on Japanese: the BoJ’s unconventional monetary policies, their implications for sovereign debt sustainability, and government debt management in Japan.

Westelius (2020) provides an overview of the evolution of the BoJ’s unconventional monetary policies in the past two decades and highlight the motives for the introduction of the QQE and for the shift to YCC, partly to address the concern of running out of JGBs to purchase. Borrallo Egea and del R o (2021) shed light on the introduction of various unconventional monetary policy measures and find that the speed and the magnitude of the BoJ purchases affect long-term government bond yields. Stenfors et al. (2022) show that the JGB yields have become a focal point for the monetary policy transmission in Japan since the introduction of YCC and that financial market participants anchored their expectations of the 10-year JGB yield. Based on on these works we take the 10-year bond as our reference maturity.

The literature also offers much insight into the impact of unconventional monetary policy, mostly focusing on the effects on growth and inflation dynamics. Koeda (2019) estimate the impact of the QQE increased output through the “quantitative” branch. In the same vein, Kawamoto et al. (2021) conduct counterfactual analyses to examine the macroeconomic effect of BoJ unconventional monetary policy since the introduction of the QQE and conclude that the QQE compressed 10-year JGB rates and pushed up real GDP by 0.9-1.3%. Koeda and Kimura (2022) are among a few scholars who have examined the changes in government bond maturities during monetary policy easing. The latest research, especially since the introduction of YCC, contrasts with an earlier strand of the literature that emerged around the Global Financial Crisis and that found no conclusive effects of asset purchases on JGB yields (Baba et al., 2005; McCauley and Ueda, 2012; Oda and Ueda, 2007; Ueda, 2012). We embed the counterfactual of Kawamoto et al. (2021) in our DSA, taking their work a step further to assess the implications of the QQE for debt sustainability.

Our study is also related to an extensive literature on the determinants of sustainable sovereign debt levels (D’Erasmus, Mendoza, and Zhang, 2016),⁴ although the literature on debt sustainability in Japan is still developing. Cohen-Setton and Oikawa (2022) is the most recent paper on fiscal sustainability in Japan before and after the pandemic. The authors conclude that the negative interest rate–growth rate differential helps the country to stabilise the debt-to-GDP ratio while allowing the government to run primary deficits. The IMF annual Article IV consultation reports (IMF, 2022) have called for fiscal

⁴See Angeletos (2002); Arellano and Ramanarayanan (2012); Bocola and Dovis (2019); Chatterjee and Eyigungor (2012); Conesa and Kehoe (2017); Fern andez and Martin (2014); Hatchondo and Martinez (2009); Missale (2012); Niepelt (2014), among others.

consolidation in Japan given the sheer size of debt stock and gross financing needs relative to the country’s GDP. However IMF DSA shows a low risk of debt distress in Japan in the near term. Fournier et al. (2022) assess Japan’s fiscal stance using a stochastic structural model, warn about fiscal risks, and recommend a gradual fiscal consolidation in the medium run. The existing literature mostly relies on deterministic DSA frameworks and takes monetary policy as given. Our work contributes to this literature a stochastic approach to debt sustainability and an endogenised central bank.

The paper is organised as follows: Section 2 presents the stochastic DSA model enriched with monetary policy. Section 3 discusses the data and presents the estimation and calibration of our model. Section 4 puts the model at work, first in the backward looking dimension and then, looking ahead, under the assumption of discontinuation of the QQE and the impact of other shocks, such as a tightening of global conditions. In Section 5, we conclude and frame our results in the policy debate on the QQE in Japan.

2 The DSA model with monetary policy

We adapt the DSA model with a macro and monetary framework of Alberola et al. (2022) to the Japanese context. Unconventional monetary policy for Japan is introduced in the DSA through the impact of BoJ holdings of JGBs on their long-term yield.

2.1 Debt dynamics and optimal public debt management

We consider a sovereign that at period t is endowed with nominal output Y_t , owes debt stock D_{t-1} , and runs a primary balance PB_t , with the *legacy* debt D_0 as an initial condition. The sovereign’s *gross financing needs* are given by the *flow* variable GFN_t as follows:

$$GFN_t = i_{t-1}D_{t-1} + A_t - PB_t, \quad (1)$$

where i_{t-1} is the *effective nominal interest rate* on debt, and A_t denotes the part of debt stock D_{t-1} that comes due. The *debt stock* is given by

$$D_t = (1 + i_{t-1})D_{t-1} - PB_t. \quad (2)$$

The sovereign finances its expenditures by issuing debt instruments of different maturities, denoted by $j = 1, 2, \dots, J$, with *financing decisions* $X_t(j)$ denoting the nominal amount of debt issued at t . The *debt financing equation* satisfies

$$\sum_{j=1}^J X_t(j) = GFN_t. \quad (3)$$

The nominal interest rate on the issued debt is determined by the policy short-term risk-free rate (i_{ft}) plus credit risk and term premia. Credit risk could depend on the level of debt, as it incorporates a probability of default (Bassanetti, Cottarelli, and Presbitero, 2018). Term premia is related to the maturity of the issued instrument. We model *risk* and *term premia* as a function of the debt-to-GDP ratio, $d_t = D_t/Y_t$, and of the maturity of the issued instrument. The interest rate for instrument j issued at t is given by

$$r_t(j) = i_{ft} + \rho(d_t, j), \quad (4)$$

where $\rho(d, j)$ captures the premia for the j th instrument maturity. The *effective interest rate* paid on debt in (2) is a function of the debt financing decisions

$$i_t = \frac{i_{t-1}(D_{t-1} - A_t) + \sum_{j=1}^J r_t(j)X_t(j)}{D_t}. \quad (5)$$

We introduce uncertainty in economic output, primary balance, inflation, and debt financing rates using a discrete time- and state-space *scenario tree*. Time is indexed by $t = 0, 1, \dots, T$, where T is the risk horizon, and $n \in \mathcal{N}_t$ denotes the *state* at t . The number of states at t is N_t , with total number of states N . Not all states at t can be reached from every state at $t - 1$, and $\mathcal{P}(n)$ denotes the set of states on the *path* from the *root state* 0 to n . Each path leading to a terminal state $n \in \mathcal{N}_T$ is a *scenario*, with probability Prob^n , which we set to $1/N$. All information at states m on the path $\mathcal{P}(n)$ is known since m precedes n .

With this representation the dynamics of debt stock and flow are defined for each state of the tree, thus providing a distribution of debt-to-GDP ratio and gross financing needs across time. From these distributions we can assess, for instance, if refinancing needs are likely to remain low, with a given probability, avoiding a liquidity crisis, or if the debt ratio is on a non-increasing trajectory and hence sustainable.

We quantify the information from these distributions using a tail risk measure (*Conditional Value-at-Risk* of Artzner et al. (1999)) of the ratio of gross financing needs to GDP. That is, we compute the expected value of the right tail of the distribution of financing needs (α). Letting gfn denote the stochastic flow variable over all time periods, we define the risk function $\Psi(\cdot)$

$$\Psi(gfn) \doteq \mathbb{E}(gfn \mid gfn \geq gfn^\diamond). \quad (6)$$

gfn^\diamond is the right α -percentile of the gross financing needs, i.e., the Value-at-Risk of gfn such that the probability of gross financing needs less or equal to gfn^\diamond is greater or equal to α . $\Psi(gfn)$ measures the *refinancing risk*, with higher values making it more difficult to refinance debt.

The model for optimal debt management determines optimal financing decisions to minimize the expected *interest payment* on the tree within acceptable refinancing risk.

Interest payments on state n of the tree consist of interest on legacy debt I_t^n plus service payments on debt created by the financing decisions. We let $CF_t^n(j, m)$ denote the nominal amount of interest payment due at state n of period t , per unit of debt $X_{\tau(m)}^m(j)$ issued at state m of an earlier period $\tau(m)$ on path $\mathcal{P}(n)$. This amount is computed from scenarios of the term structure of interest rates, the term of the issued debt, and the premia equation (4), and is given by

$$IP_t^n = I_t^n + \sum_{m \in \mathcal{P}(n)} \sum_{j=1}^J X_{\tau(m)}^m(j) CF_t^n(j, m). \quad (7)$$

The model minimises the expected cost of debt subject to a flow risk constraint:

$$\begin{aligned} & \underset{X}{\text{Minimise}} && \sum_{n \in \mathcal{N}_t,} \text{Prob}^n IP_t^n && (8) \\ & && \text{for all } t=0,1,2,\dots,T. \end{aligned}$$

s.t.

$$\Psi(gfn) \leq \omega. \quad (9)$$

This is a parametric model with an embedded trade-off between debt financing cost and debt refinancing risk. Constraint (9) bounds the refinancing risk by a parameter ω as a percentage of GDP, at an acceptable confidence level (α). If it is below some threshold that the markets can finance, then we can ascertain, with high confidence (e.g., 0.75), that debt financing needs can be met.⁵ For very high values, the sovereign may face a liquidity crisis. Varying this parameter we can trace the efficient frontier of debt cost vs refinancing risk. For the purpose of our empirical work we chose a point on the efficient frontier with intermediate cost-risk profile, as is the international best practice by public debt management offices.

Lower refinancing risk, typically through issuance of long-maturity debt, increases the cost of debt financing and the dynamics of debt-to-GDP ratio shift upwards. If the debt stock dynamics follow a stable or decreasing trajectory over a 10-year horizon with a high probability (0.75), then we deem sovereign debt to be sustainable. On the contrary, increasing debt dynamics can lead to insolvency and debt is unsustainable.

2.2 Macroeconomic framework and monetary policy

We now describe the macroeconomic framework and introduce conventional and unconventional monetary policy.

⁵We take the threshold to be 15% of GDP for emerging and 20% for developed economies, following the risk approach of the International Monetary Fund's DSA.

2.2.1 Macroeconomic framework

Inflation (π_t) is driven by the Phillips curve, that includes inflation expectations

$$\pi_t = \beta_\pi \pi_{t-1} + (1 - \beta_\pi) \mathbb{E} \pi_{t+1} + \gamma \hat{y}_t + \epsilon_{\pi,t}, \quad (10)$$

where $\mathbb{E}_t \pi_{t+1}$ is the expectation at time t of inflation at $t + 1$, \hat{y}_t is the output gap, β_π and γ are parameters, with β_π denoting persistence, and $\epsilon_{\pi,t}$ is a centred error term.

For the output gap (\hat{y}_t) we use the Mundell-Fleming IS curve

$$\hat{y}_t = \delta_{\hat{y}} \hat{y}_{t-1} + (1 - \delta_{\hat{y}}) \mathbb{E} \hat{y}_{t+1} - \alpha_{\hat{y}} (i_{ft} - r^*) + \epsilon_{\hat{y},t}, \quad (11)$$

Solving (10)–(11) we obtain equilibrium inflation and output gap. Assuming constant potential growth, the dynamics of real GDP growth (g_t^*) are determined by output gap changes

$$g_{t+1}^* = g_t^* + \Delta \hat{y}_t. \quad (12)$$

DSA works with nominal economic output, since debt is in nominal values, given by $Y_t = Y_{t-1}(1 + g_t)$ where $g_t = g_t^* + \pi_t$.

2.2.2 Conventional and unconventional monetary policy

To introduce conventional monetary policy into the model we make the standard assumption that the policy interest rate follows a Taylor rule

$$i_{ft} = \theta_i i_{ft-1} + (1 - \theta_i) [\pi_{t-1} + r_t^* + \alpha_\pi (\pi_{t-1} - \pi_t^*)] + \alpha_i \hat{y}_{t-1} + \epsilon_{i,t}, \quad (13)$$

where α_π, α_i are parameters, θ_i denotes persistence, and $\epsilon_{i,t}$ is a centred error term.

Unconventional monetary policy works through the asset purchases of the central bank. The holdings of public debt at the central bank's balance sheet reduces the total supply of debt in the market, thus exerting a downward pressure on the yields. We use the premia of equation (4) to incorporate the effects of asset purchases on yield, and, subsequently, the debt dynamics. The equation incorporates both credit and term premia. In the case of Japan, the credit risk premium is insensitive to the level of debt, so we set $\rho(d_t) = 0$. On the contrary, a positive term premia $\rho(j)$ exists as yields on long-term bonds (JGB) are higher than the risk-free policy rate. Following Kawamoto et al. (2021) we assume that the holdings of 10-year JGB at time t (h_t), as a share of the JGB stock, is what determines the impact on the yields. We defer for the next section the estimation of this effect on the reference 10-year bond yield, which we denote by $\Delta i_{10,t}$.

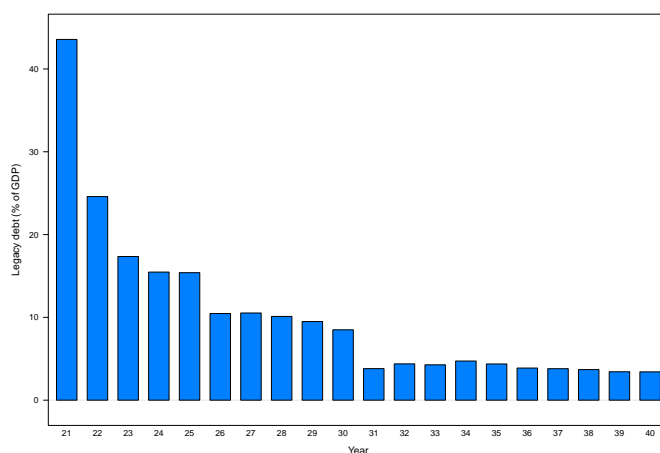
3 Data, estimation, and model calibration

3.1 Data

We collect three sets of data for our model calibration.

First, data on Japanese government bonds, including issuance amounts and the maturity structure, come directly from the Ministry of Finance of Japan.⁶ The amortisation schedule of the public debt of Japan at the time of our simulations is shown in Figure 2 as a percentage of GDP.

Figure 2 – Public debt of Japan by maturity



Second, we obtain the JGB 10-year sovereign bond yields from Bloomberg from 2013 to 2021. For our counterfactual exercise, we use the estimated 10-year government bond rates in the absence of the QQE from Kawamoto et al. (2021).⁷ The actual and counterfactual bond yields are displayed later in Figure 4 (Panel A), together with our calibrated fan charts of factual and counterfactual debt dynamics.

Third, we obtain macroeconomic variables and fiscal projections from the IMF World Economic Outlook (WEO) database, including both historical data and forecasts. We also obtain estimates of the standard deviations and correlations of the macroeconomic variables, which are needed for the calibration of scenario trees. Those are calculated from the historical yearly data from the WEO over the period 1998 to 2019, and are given in Table 1.

⁶See <https://www.mof.go.jp/english/policy/jgbs/reference/gbb/index.htm>.

⁷The data were obtained directly from the authors.

Table 1: Moments for the calibration of a scenario tree

Factors	Standard deviation	Correlations			
Real growth	2.41	1	0.60	0.62	0.41
Output gap	3.32		1	0.81	0.44
Primar balance	2.00			1	0.60
Inflation	1.30				1

3.2 Estimation of the impact of asset purchases on yields

Kawamoto et al. (2021) estimate the impact of BoJ holdings ($h_{10,t}$), as a share of the stock, on JBG nominal yield ($i_{10,t}$). The analysis is carried out on the 10-year bond holdings and stocks and controlling for expected GDP growth (g_t^e) and the level of US 10-year Treasury bonds (i_t^{US}). The OLS regression, using monthly data from January 2005 to October 2020, renders the following functional relation, with an adjusted R^2 of 0.95:

$$i_{10,t} = 0.26 - 2 \frac{h_t}{\text{JGB}_t} + 0.40g_t^e + 0.18i_t^{US} \quad (14)$$

This implies that one percentage increase in the ratio of BOJ 10-year holdings to the total 10-year JGB, reduces *ceteris paribus* the 10-year yield by two basis points:

$$\Delta i_{10,t} = -2 \left[\frac{h_t}{\text{JGB}_t} - \frac{h_{t-1}}{\text{JGB}_{t-1}} \right]. \quad (15)$$

We also compute the average term premia across the yield curve. The term premium is zero at the policy rate and increases with bond maturity. We construct the no-QQE implied yield curve by adjusting for the impact of the purchases from estimated relation and adding the average term premium to each maturity. This becomes the expected input interest rate to calibrate a scenario tree for our DSA analysis, so that we obtain calibrated scenario trees under different QQE strategies. (For the retrospective analysis we take the interest rates as given with certainty.)

3.3 Calibration of the DSA model

To calibrate the model we need scenarios of real GDP growth, output gap, primary balance, and inflation. We use the mean values from the IMF World Economic Outlook, and the standard deviations and correlations given earlier. We build the scenario tree for Japan to match the projected mean values and the historically estimated moments using moment matching (Consiglio et al., 2016). Thus, by construction, the expected values

of the correlated stochastic fiscal variables and inflation on the scenario tree represent equilibrium values. The policy rate is derived from the inflation and output variables using the Taylor rule as in Alberola et al. (2022). For computational tractability we calibrate a tree of 256 scenarios over five years and after that we assume that the variables converge to their long-term trends. The scenario tree is calibrated for 2021–2040 and we display in Figure 3 the fan charts of the state variables. The dashed lines show the equilibrium mean values. We also show the 10-year nominal interest rate obtained by applying the Taylor rule on states of the tree, using the parameters from Alberola et al. (2022).

4 The impact of unconventional monetary policy on debt sustainability

We now use the model ifrom Section 2 to showcase the impact of unconventional monetary policy on debt sustainability. First, we conduct a retrospective exercise, examining the period from 2013, when the QQE was first introduced, to 2020. We compare debt dynamics under the QQE (factual) and in the absence of it (counterfactual). From there, we conduct our main test of a forward-looking exercise. We project the impact of BoJ asset purchase programme during the pandemic on future sovereign debt sustainability, and shed light on the potential effect of different exit strategies. Finally, we take a step further to look at another factor that affects debt dynamics, namely the effects of the US Federal Reserve’s rate hikes and the resulting changes in monetary policy stance in Japan.

4.1 Retrospective analysis: Government debt without the QQE

We start with the counterfactual analysis of the impact of the QQE on debt sustainability between 2013 and 2022. For this, we take the actual and counterfactual 10-year JGB interest rates as inputs to our DSA model. In line with Kawamoto et al. (2021), long-term interest rates are depressed due to the BoJ’s increased holdings of government debt, captured in our model through equations (4) and (14). We display the results of the retrospective analysis in Figure 4.

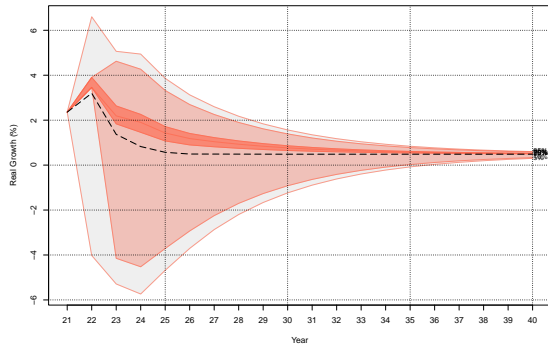
Panel A shows the actual 10-year JBG yields from Bloomberg and the counterfactual estimates from Kawamoto et al. (2021) until 2020. From there we assume that they remain at their previous/last level

Using this differential input as the reference debt refinancing rate, we show in Panel B the debt trajectories from 2013 onward with the QQE versus the counterfactual in the absence of the QQE. The fan chart in red (with the dashed black line representing the mean value) shows the actual debt projection (that is, with the QQE), taking on board the current forecast projections and assuming that the QQE continues. That is,

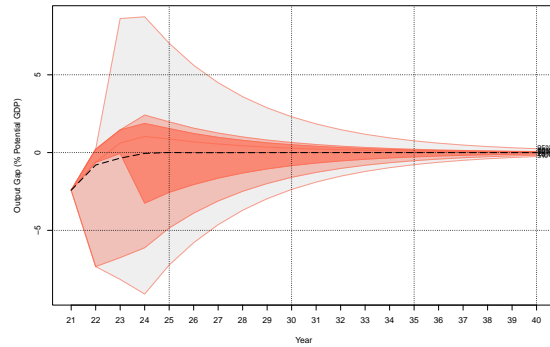
Figure 3 – Fan charts from the calibrated scenario tree

This figure displays the fan charts of the macroeconomic and fiscal variables (Panels A-D) calibrated so that they mean values match the available forecasts and the standard deviations and correlations matching the historical observed moments. Panel E displays the nominal interest rate on the 10-year JGB obtained by applying the Taylor rule on the states of the tree for output gap and inflation.

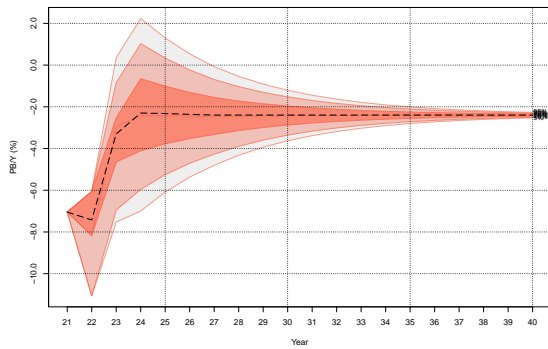
(a) Real GDP growth



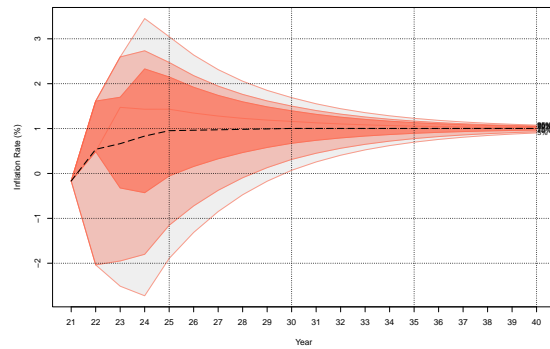
(b) Output gap



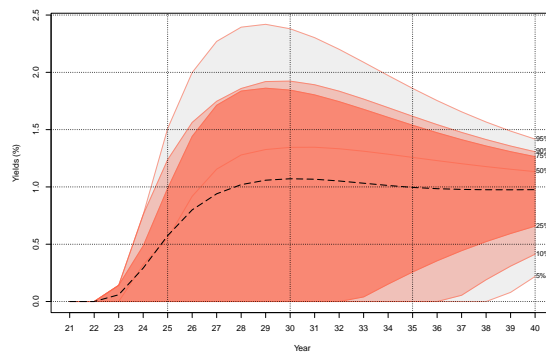
(c) Primary balance



(d) Inflation



(e) Nominal interest rates



our simulation assumes that the share of JBG holdings on total public debt remains constant. The mean value of the debt stock in the factual tracks closely the realised values of Japan’s debt-to-GDP ratio (as given by the IMF and shown by the triangles), attesting to the accuracy of our calibration.

The debt projection in the counterfactual is shown by the blue lines. We observe that the average debt levels are slightly higher in the counterfactual than the actual case and the difference widens with time. Most importantly, the 0.75 quantile of the no QQE case (blue line marked 75%) is clearly upward sloping whereas the factual 0.75 quantile is stable (and so is the 0.90 quantiles). Hence with probability at least 75% the sovereign debt stock dynamics would have exploded in the absence of the QQE. This analysis very strongly vindicates the role of the QQE in ensuring sustainable debt dynamics for Japan since its launch.

4.2 Forward looking analysis: Government debt post-QQE

We now look ahead by using the model to project future debt dynamics after a potential discontinuation of the QQE. We compare these debt dynamics with the dynamics under the actual projections when we assume that the QQE is continued (i.e., we repeat the factual analysis of Figure 4 starting from 2021 and looking forward to 2040.) We consider different strategies of unwinding the QQE. As we have argued, and demonstrated, in Alberola et al. (2022), different unwinding strategies of unconventional monetary policy affect debt sustainability through their impact on sovereign yields. We consider here the term spread reversion due to the shedding of the BoJ’s government debt holding by reducing the variable h_t in equations (14)–15).

We assess two different strategies for discontinuing QQE at t_s :

Unwinding. This is also known as passive quantitative tightening, whereby the BoJ reduces the holdings in its balance sheet as the debt bonds mature.

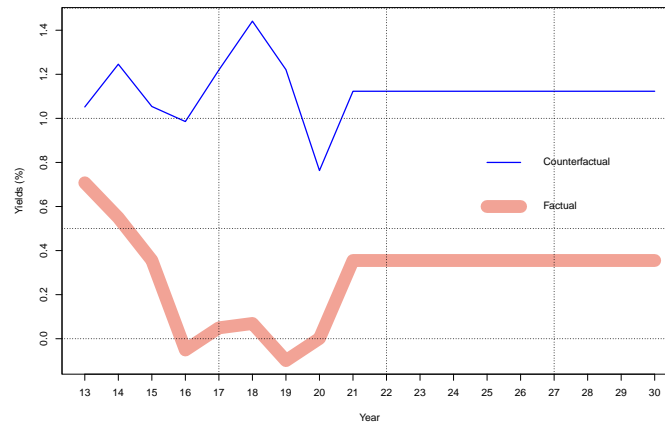
Rollover. This is the situation where the BoJ keeps its holdings constant $h_t = h_{t_s}$, for all $t \geq t_s$, implying a rollover of debt as it matures. Notwithstanding the rollover, the BoJ share of JGB holdings diminishes with time because of increasing debt level.

Figure 5 shows the results of the DSA analysis with both strategies, and compares them with the projection of the factual scenario with the QQE being a constant share of JGBs on the BoJ’s balance sheet. We use the red fan charts for the factual and the blue lines for the QQE exit strategies. The fan charts with the unwinding strategy shows that median debt deviates towards higher values from the case without unwinding. The debt dynamics are put on an upward trajectory that can be considered unsustainable with high

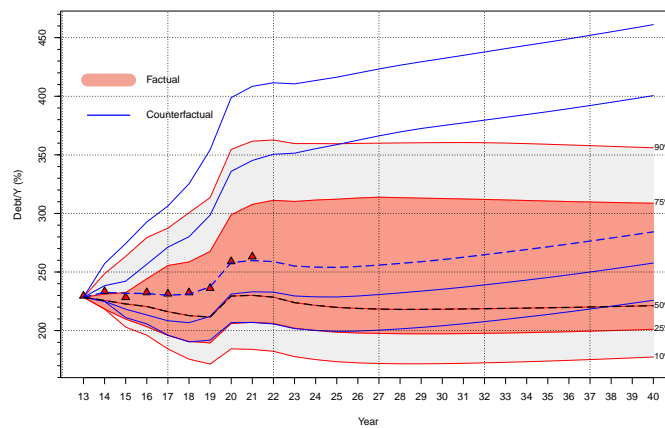
Figure 4 – Counterfactual exercise

This figure displays the results of the retrospective analysis under the counterfactual in the absence of the QQE. Panel A shows the factual yields of 10-year Japanese government bonds from 2013 to 2021 and projected to remain constant thereafter, together with counterfactual yield estimates in the absence of the BoJ asset purchase program from the study of Kawamoto et al. (2021). Panel B displays the fan chart of debt stock dynamics under the factual and counterfactual bond yields. The dashed lines denote the median values, and also shown are the 0.10, 0.25, 0.75, and 0.90 quantiles. Red triangles indicate the actual values from the IMF World Economic Outlook.

(a) 10-year JGB yields



(b) Debt-to-GDP dynamics



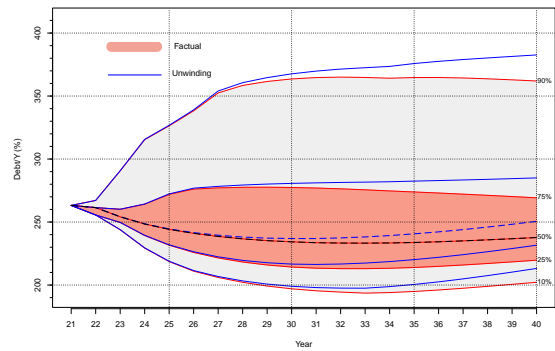
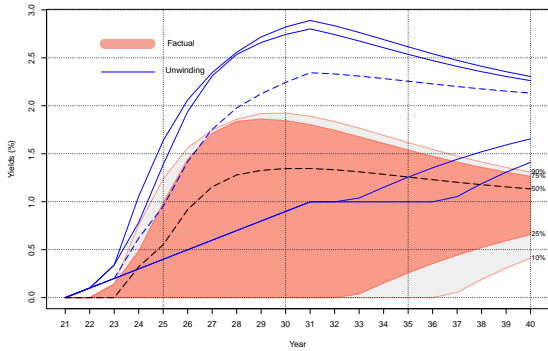
probability. On the contrary, if debt is rolled over, debt dynamics only slightly deteriorate over the factual benchmark and debt remains sustainable at the 75% confidence level.

Figure 5 – Debt sustainability under different QQE exit strategies

This figure displays the results of a forward-looking analysis under different strategies of the QQE exit. Panels A and B display, respectively, the 10-year interest rates and debt dynamics with the QQE unwinding (blue lines) and the benchmark of continuing QQE at its current level (red fan charts). The dashed lines denote the medians and the quantiles are marked at the 0.10, 0.25, 0.75, and 0.90 levels. Panels C and D likewise display the interest rates and debt dynamics of QQE rollover (blue lines) and the benchmark.

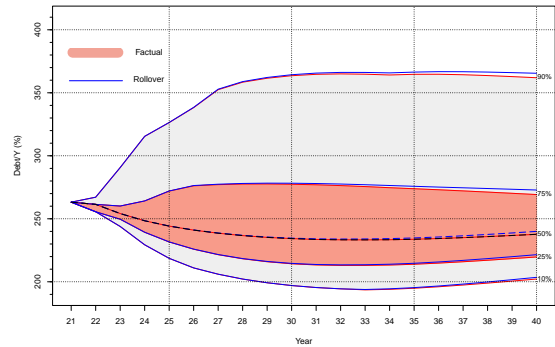
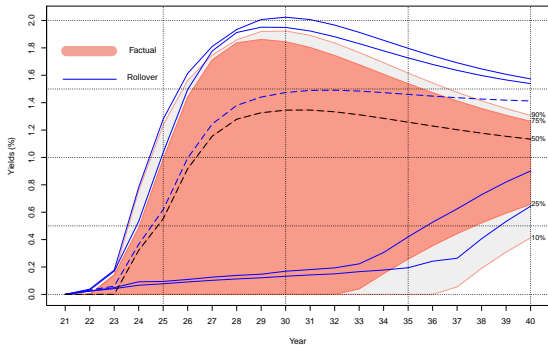
(a) Yields under QQE unwinding

(b) Debt-to-GDP under QQE unwinding



(c) Yields under QQE rollover

(d) Debt-to-GDP under QQE rollover



4.3 Global monetary tightening

Finally, we investigate the effect of an external shock. In the current context of rising inflation, the global tightening of monetary policy has implications for the Japanese debt sustainability, directly because of the correlations between the Fed rates and long-term JGB yields as predicted by Kawamoto et al. (2021), and indirectly through a potential change in the BoJ's monetary policy stance.

We perform a forward-looking simulation with a sudden and permanent increase in the 10-year US Treasury bond yields by 275 bps, which results in an increase in the

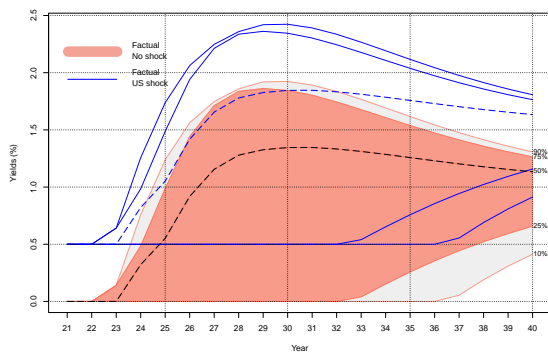
10-year JGB yield by 50 bps, using an elasticity of 0.18 estimated by Kawamoto et al. (2021) (equation 14).

Figure 6 compares the benchmark scenario with that of a global monetary tightening, while keeping the QQE unchanged in both cases. Debt dynamics worsen with the US tightening in a magnitude similar to the discontinuation of the QQE with the unwinding strategy. This is not surprising as the changes in the JGB yield are similar to what would happen should the BoJ unwind the QQE. Debt sustainability is consequently jeopardised, as now the debt path drifts slightly up with a probability of 75%. The higher the increase in the Fed rates, the more likely the Japanese government debt becomes less sustainable.

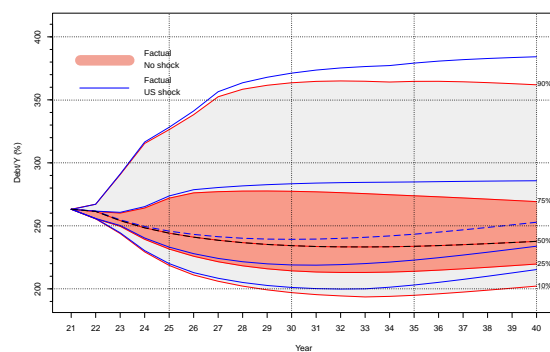
Figure 6 – US rate shock with different QQE exit strategies

This figure displays the results of a forward-looking analysis in response to a permanent surge of the US Fed rates by 275bps (blue lines) against the benchmark of continuing QQE (red fan charts). Panel A displays the 10-year interest rates and panel B the debt dynamics following the US Fed rate shock

(a) Yields without QQE exit



(b) Debt-to-GDP without QQE exit



But this might not be the end of the story. Higher interest rates in the United States could exert strong downward pressures on the yen, and the BoJ could be forced to drop the QQE to mitigate the plummeting of the currency.⁸

If the Bank of Japan abandons the QQE as a result of the global tightening, the two effects would add up. As noted above and in Figure 5, if the discontinuation of QQE implies the rollover of maturing debt, there would be no significant impact on debt dynamics. However, if it leads to the unwinding of the purchases, abandoning QQE could have a large additional negative impact on debt sustainability.

In conclusion, an increase in the Fed rates has an adverse effect on the Japanese debt dynamics, its impact depending on the size of the Fed hikers. The cumulative

⁸The BoJ in fact intervened in the foreign exchange market on 22 September 2022 to defend the yen, the first time since 1998. See <https://www.reuters.com/markets/asia/boj-keep-ultra-low-rate-s-remain-global-outlier-despite-weak-yen-2022-09-21/>

increases as the market currently foresees goes well beyond the 275bps we have used for the simulations, implying higher risks for the Japanese government debt to become unsustainable. If, on top of the global tightening, the BoJ is forced to exit from the QQE and unwind the purchases, debt dynamics would worsen further, raising significant debt sustainability concerns.

5 Conclusion

Using a stochastic DSA model with a macro framework, our work provides a useful tool to assess sovereign debt sustainability in the presence of unconventional monetary policy measures. The application of this model to the Japanese situation shows that the QQE and the YCC helped the Japanese government to ensure sovereign debt sustainability. A potential exit from the QQE could derail debt dynamics and create sustainability concerns under certain conditions. Specifically if the exit is followed by unwinding as debt matures and especially when the exit coincides with a monetary tightening in the United States, debt is put on an upward trending trajectory with high probability. Terminating the QQE but rolling over any maturing holdings puts much less pressure on the Japanese government financing conditions and debt dynamics remain stable, even in the presence of a US initiated shock.

The widening interest rate differential between Japan and the United States has already plunged the Japanese yen exchange rate to record low levels against the US dollar. The authorities have so far been lenient towards the yen depreciation as it helped exports and can reignite inflation. However, the BoJ may be forced to rethink unconventional monetary policies should the value of the Japanese yen falls below a tolerable level or if central banks in advanced economies are called once again to intervene in foreign exchange markets like in 1985 with the Plaza Accord. In this case, the sovereign funding cost will increase following domestic interest rate hikes.

In our current work, we do not model explicitly exchange rates. This choice is fit for purpose to analyse debt sustainability in Japan, given the predominance of domestic-currency denominated sovereign bonds. However, our model could be extended to include exchange rates as an additional (stochastic) parameter to formally control for the impact of exchange rates on sovereign debt sustainability. This would make the model suitable for emerging economies.

References

- K. Alberola, G. Cheng, A. Consiglio, and S.A. Zenios. Debt sustainability and monetary policy: The case of ecb asset purchases. BIS Working Papers No 1034, Bank for International Settlements, July 2022.
- G-M. Angeletos. Fiscal policy with noncontingent debt and the optimal maturity structure. *The Quarterly Journal of Economics*, 117:1105–1131, 2002.
- C. Arellano and A. Ramanarayanan. Default and the maturity structure in sovereign bonds. *Journal of Political Economy*, 120:187–232, 2012.
- Philippe Artzner, Freddy Delbaen, Jean Marc Eber, and David Heath. Coherent measures of risk. *Mathematical Finance*, 9(3):203–228, 1999.
- Naohiko Baba, Shinichi Nishioka, Nobuyuki Oda, Masaaki Shirakawa, Kazuo Ueda, and Hiroshi Ugai. Japan’s deflation, problems in the financial system and monetary policy. BIS Working Papers 188, Bank for International Settlements, November 2005.
- A. Bassanetti, C. Cottarelli, and A.F. Presbitero. Lost and found: market access and public debt dynamics. *Oxford Economic Papers*, 71:445–471, 2018.
- L. Bocola and A. Dovis. Self-fulfilling debt crises: A quantitative analysis. *American Economic Review*, 109:4343–77, 2019.
- Fructuoso Borrallo Egea and Pedro del Río. Monetary policy strategy and inflation in japan. Occasional Papers 2116, Banco de España, 2021. URL <https://EconPapers.repec.org/RePEc:bde:opaper:2116e>.
- O. Bouabdallah, C. Checherita-Westphal, T. Warmedinger, R. de Stefani, F. Drudi, R. Setzer, and A. Westphal. Debt sustainability analysis for euro area sovereigns: a methodological framework. Occasional Paper 185, European Central Banks, 2017.
- S. Chatterjee and B. Eyigungor. Maturity, indebtedness, and default risk. *American Economic Review*, 102:2674–2699, May 2012.
- Jérémie Cohen-Setton and Keita Oikawa. Japans public debt sustainability before and after COVID-19. In Benno Ferrarini, Marcelo M. Giugale, and Juan J. Pradelli, editors, *The Sustainability of Asia’s Debt*, Chapters, chapter 2, pages 66–86. Edward Elgar Publishing, 2022.
- J.C. Conesa and T.J. Kehoe. Gambling for redemption and self-fulfilling debt crises. *Economic Theory*, 64:707–740, 2017.

- A. Consiglio, A. Carollo, and S.A. Zenios. A parsimonious model for generating arbitrage-free scenario trees. *Quantitative Finance*, 16:201–212, 2016.
- P. D’Erasmus, E.G. Mendoza, and J. Zhang. What is a sustainable public debt? In J.B. Taylor and H. Uhlig, editors, *Handbook of Macroeconomics*, chapter 32, pages 2493 – 2597. Elsevier, Amsterdam, 2016.
- D.A. Dias, C. Richmond, and M.L. Wright. The stock of external sovereign debt: Can we take the data at face value? *Journal of International Economics*, 94:1–17, 2014.
- European Commission. Debt sustainability monitor. Institutional Paper 143, European Commission, Brussels, BE, 2020.
- Raquel Fernández and Alberto Martin. The long and the short of it: Sovereign debt crises and debt maturity. Working Paper 20786, National Bureau of Economic Research, December 2014.
- Jean-Marc Fournier, Takuma Hisanaga, and Anh D. M. Nguyen. The fiscal stance in japan: A model-based analysis. *IMF Working Papers*, 2022(164):A001, 2022. doi: 10.5089/9798400217135.001.A001. URL <https://www.elibrary.imf.org/view/journals/001/2022/164/article-A001-en.xml>.
- J.C. Hatchondo and L. Martinez. Long-duration bonds and sovereign defaults. *Journal of International Economics*, 79:117–125, 2009.
- IMF. Review of the debt sustainability framework for market access countries. Policy paper, International Monetary Fund, January 2021.
- IMF. Japan: 2022 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for Japan. IMF Country Report 2022/099, International Monetary Fund, April 2022. URL <https://www.imf.org/en/Publications/CR/Issues/2022/04/06/Japan-2022-Article-IV-Consultation-Press-Release-Staff-Report-and-Statement-by-the-516216>.
- T.C. Irwin. Defining the government’s debt and deficit. *Journal of Economic Surveys*, 29:711–732, 2015.
- Takuji Kawamoto, Takashi Nakazawa, Yui Kishaba, Kohei Matsumura, and Jouchi Nakajima. Estimating effects of expansionary monetary policy since the introduction of quantitative and qualitative monetary easing (QQE) using the macroeconomic model (Q-JEM). Bank of Japan Working Paper Series 21-E-4, Bank of Japan, April 2021.
- Junko Koeda. Macroeconomic effects of quantitative and qualitative monetary easing measures. *Journal of the Japanese and International Economies*, 52:121–141, 2019. ISSN 0889-1583.

- Junko Koeda and Yosuke Kimura. Government Debt Maturity and the Term Structure in Japan. Technical report, SSRN, January 2022. URL <https://ssrn.com/abstract=4015576> or <http://dx.doi.org/10.2139/ssrn.4015576>.
- Robert N. McCauley and Kazuo Ueda. Government Debt Management at Low Interest Rates. In *Taxation and the Financial Crisis*. Oxford University Press, 02 2012.
- Alessandro Missale. Sovereign debt management and fiscal vulnerabilities. In Bank for International Settlements, editor, *Threat of fiscal dominance?*, volume 65 of *BIS Papers*, pages 157–176. Bank for International Settlements, November 2012.
- Dirk Niepelt. Debt maturity without commitment. *Journal of Monetary Economics*, 68: S37–S54, 2014. ISSN 0304-3932.
- Nobuyuki Oda and Kazuo Ueda. The Effects Of The Bank Of Japan’S Zero Interest Rate Commitment And Quantitative Monetary Easing On The Yield Curve: A Macro-Finance Approach. *The Japanese Economic Review*, 58(3):303–328, September 2007.
- Alexis Stenfors, Ioannis Chatziantoniou, and David Gabauer. The evolution of monetary policy focal points. *Journal of Economic Issues*, 56(2):348–355, 2022.
- Kazuo Ueda. The Effectiveness Of Non-Traditional Monetary Policy Measures: The Case Of The Bank Of Japan. *The Japanese Economic Review*, 63(1):1–22, March 2012.
- Niklas J Westelius. Twenty Years of Unconventional Monetary Policies: Lessons and Way Forward for the Bank of Japan. IMF Working Papers 2020/226, International Monetary Fund, November 2020.
- S.A. Zenios, A. Consiglio, M. Athanasopoulou, E. Moshhammer, A. Gavilan, and A. Erce. Risk management for sustainable sovereign debt financing. *Operations Research*, 69: 755–773, 2021.