

PUBLIC DEBT DYNAMICS: A STOCHASTIC
APPROACH APPLIED TO SPAIN

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Abstract

This paper presents a methodology for analysing public debt sustainability that incorporates factors that enable uncertainty in the macro-financial environment to be quantified. The aim is to identify risks, not only under specific assumptions, but also considering a complete characterisation of potential developments in the real economy and in financing costs, based on the historical evidence available. To this end, stochastic shocks are included in the equations for a standard debt sustainability analysis (DSA) model, using recent evidence to gauge their scale and recurrence. When applied to Spain, the results suggest that uncertainty over the macro-financial environment and the growing pressure of the costs of ageing pose a challenge for the sustainability of our public finances. Specifically, in the absence of new fiscal consolidation measures, it is estimated that the probability of public debt in Spain being above 100% of GDP in 2040 is 80%. However, in a scenario characterised by a consolidation policy consistent with the new European economic governance framework, that probability would drop to 20%.

Keywords: public debt sustainability, public finances, stochastic model.

JEL classification: H62, H63, H68, C32, C63.

Resumen

Este documento presenta una metodología para analizar la sostenibilidad de la deuda pública, que incorpora elementos que permiten cuantificar la incertidumbre del entorno macrofinanciero. El objetivo es identificar los riesgos, no solo bajo supuestos concretos, sino también teniendo en cuenta una completa caracterización de los posibles desarrollos en la economía real y en los costes de financiación, de acuerdo con la evidencia histórica disponible. Para ello, se incorporan perturbaciones estocásticas a las ecuaciones de un modelo de análisis de sostenibilidad de la deuda (DSA, por sus siglas en inglés) estándar, utilizando evidencia del pasado reciente para calibrar su magnitud y recurrencia. Aplicado al caso particular de España, los resultados sugieren que la incertidumbre sobre el entorno macrofinanciero y la creciente presión de los costes del envejecimiento suponen un desafío para la sostenibilidad de nuestras finanzas públicas. En concreto, en ausencia de nuevas medidas de consolidación fiscal, se estima una probabilidad del 80 % de que la deuda pública en España se sitúe por encima del 100 % del PIB en 2040. Sin embargo, en un escenario caracterizado por una política de consolidación coherente con el nuevo marco europeo de gobernanza económica, dicha probabilidad se reduciría al 20%.

Palabras clave: sostenibilidad de la deuda pública, finanzas públicas, modelo estocástico.

Códigos JEL: H62, H63, H68, C32, C63.

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1 Introduction

The recent crises prompted by COVID-19 and by the surge in energy prices have left developed countries with soaring public debt (over 110% of GDP).¹ Furthermore, they face the challenge of managing those high debt levels amid uncertain macroeconomic and financial conditions, characterised by monetary policy tightening, while also contending with other medium and long-term challenges such as population ageing and climate-related physical and transition risks.

Against this adverse backdrop, public debt sustainability analysis is all the more relevant, with a view to identifying and quantifying the risks to public finances and the sovereign's debt-servicing capacity. This is typically done using debt sustainability analysis (DSA) tools.² Indeed, the use of such tools has attracted particular attention recently, for instance in the context of assessing compliance with the public debt sustainability requirement for activation of the European Central Bank's (ECB) Transmission Protection Instrument (TPI), or their role in the new European fiscal rules framework.³

The standard DSA approach centres on a deterministic projection of future public debt using a reduced-form dynamic model that considers the relationships between the real, monetary and fiscal variables that determine public debt developments, incorporating assumptions about the primary surplus, growth, inflation and interest rates.⁴ In particular, the conceptual framework inherent in DSA models consists in several equations capturing developments in the real economy (GDP growth), the nominal economy (inflation) and the financial economy (interest rates), together with an accounting identity that determines the public debt dynamics based on the budget balance and the aforementioned variables. Potentially unsustainable dynamics can be identified based on the projected level and path of debt over a specific time frame and the country's historical capacity to generate primary surpluses.

The adverse shocks that have affected the advanced economies in recent years have underscored the limitations of analysing public debt sustainability based primarily on deterministic projections (i.e. imposing a specific future path for the relevant variables). This has raised the question of whether the uncertainty surrounding the macro-financial variables included in those public debt sustainability models should be given far greater

1 IMF (2023).

2 IMF (2013) offers the following definition of public debt sustainability: "In general terms, public debt can be regarded as sustainable when the primary balance needed to at least stabilize debt under both the baseline and realistic shock scenarios is economically and politically feasible, such that the level of debt is consistent with an acceptably low rollover risk and with preserving potential growth at a satisfactory level." Accordingly, public debt sustainability is primarily analysed based on the identification and quantification of liquidity and solvency risk (Pamies, Carnot and Pătăraș, 2021).

3 See the [ECB](#) press release on the establishment of the TPI and the [European Commission](#) communication on the new European economic governance framework.

4 See, for example, Hernández de Cos, López Rodríguez and Pérez García (2018) and Burriel, Kataryniuk and Pérez (2023).

prominence.⁵ Including a stochastic dimension in DSA models is particularly significant in highly indebted countries, where debt dynamics are particularly sensitive to small shocks that could shift those dynamics onto an exponential growth trajectory.⁶ The accommodative monetary policy stance of the last decade would have helped to mitigate this risk by holding sovereign yields close to or below the economy's nominal growth rates. However, there is still no consensus over how the interaction between future financing conditions and the macroeconomic environment may impact public debt dynamics.⁷

This paper presents a methodology for analysing public debt sustainability that incorporates elements to quantify uncertainty in the macro-financial environment.⁸ The aim is to identify the risks to public debt sustainability not only under certain specific assumptions, but also considering a complete characterisation of potential developments in the real economy and in financing costs. To this end, stochastic shocks are included in the equations making up a DSA model, using recent evidence to gauge their scale and recurrence. These shocks are obtained through the non-parametric estimation of the distribution function of the residuals of the Spanish economy, drawn from an empirical specification consistent with the DSA model representation and applied to a panel of European countries between 1999 and 2021.

In addition to introducing the stochastic dimension, this new DSA framework includes two material characteristics for the Spanish economy in particular. First, it includes a detailed description of the costs of ageing, along with the mechanisms envisaged in the recent pension system reform. Second, the model includes an estimation of gross financing needs based on an interest burden projections framework that takes into account the different types of liabilities issued along with the differences in their maturity.⁹

For Spain, the model results suggest risks to sustainability towards the end of the simulation horizon (up to 2040). In a no-policy-change scenario, with no fiscal consolidation plan, in 2040 public debt would exceed 100% in four out of every five possible trajectories for real GDP and financing costs. This owes to the starting point for public finances (characterised by relatively high indebtedness), the steady increase in the costs of ageing and the uncertainty stemming from the macro-financial environment. Conversely, under a scenario of compliance with the new European economic governance framework, the probability of the public debt ratio exceeding 100% in 2040 would be around 20%, while that of a ratio below 60% would turn positive.

5 Blanchard (2023).

6 Recent studies suggest a non-linear relationship between the level of indebtedness and market risk perception. In particular, some models predict that, in highly indebted countries, small shocks to economic fundamentals could prompt self-fuelling investor pessimism over the country's solvency, reflected in the sovereign yield, that might jeopardise debt sustainability. Conesa and Kehoe (2017), Lorenzoni and Werning (2019) and Bocola and Dovis (2019).

7 Blanchard (2023) and Cochrane (2021).

8 See Bouabdallah et al. (2017) or Alloza, Andrés, Pérez and Rojas (2020) for alternative methodologies that address stochasticity based on a vector autoregression applied to a no-policy-change scenario, or the inclusion of innovations with a pre-established distribution (Berti, 2013).

9 Martínez (2018).

The rest of this paper is structured as follows. Section 2 identifies some of the approaches proposed in the economic literature to analyse public debt sustainability, with particular emphasis on the DSA models currently used by the main international organisations. Seeking to frame the relevance, from the practical standpoint, of the different elements of the general model and their practical application, Section 3 reviews the recent developments in Spanish public debt, noting the key characteristics, dynamics and challenges in terms of analysing its sustainability. Based on this, Section 4 puts forward a general conceptual framework for identifying risks to public debt sustainability, with particular emphasis on the inclusion of the aforementioned stochastic dimension and on the Spanish economy in particular. Section 5 sets out the main results and insights drawn from that model, considering different fiscal conduct scenarios. Section 6 concludes the paper by exploring some possible future avenues for analysis.

2 Assessing the risks to sovereign debt sustainability

This section identifies some of the most relevant analysis frameworks proposed by the academic literature for assessing the risks to debt sustainability and the related impact on economic activity.

First, research has focused on how running a high level of public debt can affect a country's economic growth. The underlying assumption is that high government debt absorbs private resources that might otherwise be used more productively, thus constraining a country's economic growth. Reinhart and Rogoff (2010) prompted lively debate over the potential existence of a threshold (90%) above which public debt was particularly detrimental. However, although numerous subsequent studies have found a negative and strong relationship between the level of public debt and economic growth, there is still no clear consensus that such thresholds exist or even over the causal relationship between the two variables (Heimberger, 2023b).¹⁰

Another branch of the literature has focused on analysing public debt sustainability in advanced economies using empirical estimations. In particular, this non-structural literature had its genesis in the seminal papers by Bohn (1998 and 2007), which aimed to estimate the "fiscal space" in an economy, defined as the gap between a country's current level of debt and its "debt limit", i.e. the level beyond which solvency and public debt servicing capacity cannot be assured. In particular, this approach infers the degree of debt sustainability by analysing the stationarity of the public debt time series based on the estimation of reaction functions that describe the primary balance dynamics on the basis of changes in the debt level.¹¹ This empirical approach is relatively quick and transparent in its implementation. However, its non-structural nature precludes the analysis of counterfactual policies aimed at mitigating the sustainability risks.

To address such problems, the economic literature has also analysed public debt sustainability using structural general equilibrium models. For instance, one line of work has focused on identifying the most effective fiscal policy combination to restore public debt sustainability, based on the concept of dynamic Laffer curves and their relationship with the fiscal limit.¹² Further, adopting a structural framework allows in-depth analysis of the relationship between fiscal policy and public debt sustainability from the sovereign risk standpoint. Corsetti, Kuester, Meier and Mueller (2013) illustrate how, when monetary policy is tight, certain fiscal policies may exacerbate or attenuate a sovereign debt crisis through their effect on the cost of public debt financing (the sovereign risk premium) and how this feeds through to financing costs in the private sector. A further line of research focuses on

¹⁰ See also Panizza and Presbitero (2013) and Hernández de Cos, López Rodríguez and Pérez García (2018) for a review of the literature on the relationship between public debt and economic growth. Also, see Leeper (2010) for an example of the interaction between government indebtedness and monetary policy.

¹¹ Other examples of this avenue of research are Mendoza and Ostry (2008) and Ghosh, Kim, Mendoza, Ostry and Qureshi (2013).

¹² Trabandt and Uhlig (2011), Davig, Leeper and Walker (2011), Mendoza, Tesar and Zhang (2014) and Bi (2012).

strategic decisions to restructure a portion of public debt (domestic and/or foreign), an issue that tends to apply more to emerging countries.¹³

Beyond the academic literature, the public debt dynamics of the last two decades have also prompted different international organisations, such as the European Commission, the ECB and the International Monetary Fund (IMF), to work on identifying the risks to fiscal sustainability using the group of tools known as DSA. The aim is to evaluate the risks in the short term (liquidity), medium term (solvency) and long term (population ageing, climate change, etc.).¹⁴ In their most traditional form these tools model the behaviour of the determinants of public debt and the relationships between those variables using a set of dynamic equations (see Section 4.1 for an example). Through this stylised representation of the economy, DSA models can be used to construct scenarios that help to identify the different sources of risk to public debt sustainability. This analysis is often supplemented by a set of indicators that examine the risks to solvency from a different standpoint (e.g. including liquidity risk-related indicators). When applied to a group of countries, as is often the practice at international organisations, this set of tools and indicators is typically distilled into a numerical value for the purposes of comparing sustainability risks over time and across countries. The rest of this section provides an overview of how DSA tools are used at the main international organisations.

In Europe, the European Commission operates a DSA model and publishes the results annually, either in the Fiscal Sustainability Report (every three years) or in the Debt Sustainability Monitor (in the interim years). The European Commission's use of the DSA tool is particularly relevant in the context of the proposed reform of the European fiscal rules framework, in which this tool plays a prominent role.¹⁵ In particular, the European Commission's DSA comprises deterministic ten-year projections and a stochastic simulation of the debt path. The deterministic block considers a baseline scenario (which assumes no changes to fiscal regulations) and various alternative scenarios for the structural primary balance and/or some of the variables that shape debt dynamics (the interest rate-economic growth rate differential, sovereign yields and exchange rates).¹⁶ The stochastic block is based on numerous debt path simulations over a five-year horizon, obtained by incorporating shocks to the GDP growth rate and to interest and exchange rates.¹⁷

Similarly, the ECB uses a DSA tool to assess the sustainability of public debt in euro area countries.¹⁸ The analysis breaks down into a deterministic block, a stochastic

13 For examples of such research, see Aguiar and Gopinath (2006), Arellano (2008), D'Erasmus, Mendoza and Zhang (2016) and D'Erasmus and Mendoza (2021), Dervis, Golosov and Shourideh (2014) and more recently Arellano, Mateos-Planas and Ríos-Rull (2023).

14 IMF (2013) offers the following definition of public debt sustainability: "In general terms, public debt can be regarded as sustainable when the primary balance needed to at least stabilize debt under both the baseline and realistic shock scenarios is economically and politically feasible, such that the level of debt is consistent with an acceptably low rollover risk and with preserving potential growth at a satisfactory level." Accordingly, public debt sustainability is primarily analysed based on the identification and quantification of liquidity risk and solvency (Pamies, Carnot and Pătărău, 2021).

15 Heimberger (2023a).

16 For a more detailed description, see the European Commission's Fiscal Sustainability Report 2021.

17 In contrast with this methodology, the framework set out in Section 4.2 estimates the shocks non-parametrically through a specification consistent with the representation of the DSA model as a restricted vector autoregression.

18 See Bouabdallah et al. (2017) for a detailed description of the methodology used.

block and a battery of additional liquidity risk and solvency indicators. For the deterministic block, the analysis is based on a ten-year projection of the debt path under a baseline scenario, which assumes compliance with the minimum requirements under the new European economic governance framework, together with other public debt projections under alternative scenarios built around the baseline scenario. The latter consider aspects such as the increase in the costs of ageing, the implications of real GDP growth and the primary balance converging towards their historical averages and the effects of adverse impacts on inflation and potential growth, along with a stressed scenario in line with the assumptions used in the European banking stress tests. The stochastic block is based on the simulation of numerous debt paths, incorporating shocks extracted from a reduced-form vector autoregressive (VAR) model that includes short and long-term interest rates, real GDP growth and inflation. Lastly, the additional indicators capture, first, liquidity risk (with short-term net financing needs) and, second, solvency risk in the medium-to-long term related to the debt structure, contingent liabilities, governance risk and other institutional factors.

For its part, in its public debt sustainability assessment the IMF explicitly differentiates between liquidity risk and solvency risk. In particular, the analysis is conducted in three parts at three different horizons: near term (1-2 years), medium term (up to 5 years) and long term (beyond 5 years).¹⁹ To assess the risk of a debt crisis in the near term, a logit model is used, which includes variables related to institutional quality, the position in the financial cycle and fiscal variables. The medium-term risks are analysed using three different tools. First, a probability distribution of future debt paths, calculated based on the IMF projections baseline scenario and an analysis of the country's historical debt developments, in line with the stochastic DSAs. The second considers rollover risks, taking into account the IMF's projections for gross financing needs and an analysis of the agents' ability to absorb them. The third tool consists of a battery of stress tests related to specific factors of particular relevance to the country in question. Lastly, long-term risks are measured using deterministic ten-year projections for public debt and gross financing needs, both under the baseline scenario and under the scenario which considers the impact of aspects such as population ageing and natural resource depletion.

The Independent Authority for Fiscal Responsibility (AIReF) regularly publishes its analysis of the sustainability of Spanish public finances based on two pillars. The first is a deterministic ten-year debt projection under a baseline scenario and also based on different alternative scenarios relating to the GDP growth rate, inflation and the primary deficit. The second incorporates a five-year stochastic analysis to measure the uncertainty surrounding the deterministic path. In particular, that analysis is based on the simulation of structural shocks extracted from a VAR model with macroeconomic, financial and fiscal variables, together with a dynamic debt equation. Further, the AIReF has published an analysis of fiscal sustainability over the very long term, with a horizon that currently extends to 2070.²⁰

¹⁹ IMF (2021).

²⁰ AIReF (2023).

Despite the continuous refinements and improvements, DSA tools have several limitations. Corsetti (2018) points out the need for headway in four different aspects. First, a longer forecasting horizon to include long-term trends that could affect debt dynamics, such as fiscal consolidation plans or population ageing. Second, improving the predictive power of DSA. Indeed, although these tools consider numerous indicators, the difficulty of incorporating agents' expectations (potential catalysts of self-fulfilling crises) limits their capacity to anticipate sovereign debt crises. Three, the need to use sufficiently realistic assumptions when projecting the DSA variables, avoiding optimism bias. Lastly, in the same paper Corsetti also stresses the need to improve the aggregation methods used for the various components comprising the DSA, for instance attaching greater weight to the stochastic analysis.

Other critics include Heimberger (2023a), who, in addition to noting the self-fulfilling prophecy problem (if investors' actions are influenced by the forecasts of international organisations, any assessment pointing to risks to debt sustainability could drive up sovereign yields and thus de facto put debt on an unsustainable growth trajectory), also points to the need to separate public spending into capital investment and government consumption. Indeed, fiscal consolidation that focuses on cutting productive expenditure could weaken the economy's growth and thus jeopardise the country's fiscal equilibrium. Meanwhile, Alcidi and Gros (2018) flag the difficulties inherent in calibrating the sensitivity parameters for the different variables (e.g. the relationship between the sovereign yield and debt dynamics) using historical averages. Strauch (2020) suggests shifting the focus of the analysis from debt levels to debt servicing flows, placing greater emphasis on the country's political and economic capacity to meet its debt servicing costs. In the same vein, Pamies and Reut (2020) identify DSA's difficulty in distinguishing liquidity crises from solvency problems as one of its main shortcomings.

Against this background, this paper sets out the results of a new DSA tool that uses the deterministic model to identify historical macro-financial shocks, through estimations of the model equations. The distribution functions of the corresponding innovations allow the subsequent simulation of public debt paths that are consistent with those innovations in the macro-financial environment. Thus, the uncertainty surrounding public debt trend dynamics can be objectively quantified (and in a manner consistent with the deterministic model). The theoretical framework used in this paper is a general one, but the empirical application is to Spain, which stands as an illustrative example of the challenges facing other euro area countries.

3 Recent developments in Spanish public debt

This section examines the recent dynamics of Spanish public debt, including the characteristics of the government liabilities in which it has been incurred. It also sets out the challenges facing Spain's general government in the years ahead.

3.1 Recent public debt dynamics

Spain's overall general government debt is currently soaring at over 107% of GDP. This ratio is high both by historical standards and compared with peer countries, standing 34 percentage points (pp) above the euro area arithmetic mean (see Chart 1.1). The public debt ratio was at very moderate levels at end-2007 (around 36%), but grew rapidly in the periods 2008-2014 and 2020-2021, resulting in a cumulative increase of 72 pp in the last 16 years.

One helpful tool to explain this marked growth is the accounting identity that breaks down the change in the public debt ratio (d_t) into its determinants: the primary balance (sp_t), costs stemming from the implied interest rate (i_t), nominal GDP growth (γ_t) and stock-flow adjustments (add_t):

$$\Delta d_t = \left(\frac{i_t}{1 + \gamma_t} \right) d_{t-1} - \left(\frac{\gamma_t}{1 + \gamma_t} \right) d_{t-1} - sp_t + add_t \quad (1)$$

Considering the cumulative change in the public debt ratio since 2007, Chart 1.2 shows how the main determinant is the build-up of primary deficits: as a result of the fiscal policy response to the economic fluctuations of 2008-2014 and to the COVID-19 crisis, the primary deficit has accounted for around 64 pp of the 72 pp change recorded since 2007. For its part, interest expenditure, which is shaped by changes both in financing costs and in the level of public debt, also contributed significantly to the increase in the public debt ratio during this period (around 40 pp). However, that rise was tempered by nominal GDP growth, which, through the denominator, has reduced the debt-to-GDP ratio by nearly 35 pp since 2007.

Indeed, although fiscal policy has served as a macroeconomic stabiliser, efforts to achieve such stabilisation tend to cause an increase in public debt that could end up limiting the authorities' scope for action, should it be needed. For instance, during the recessions that have taken place in the last three decades, public indebtedness has increased by as much as 20 pp on average one year after the onset of the shock and by up to 35 pp after two years (see Chart 1.3).

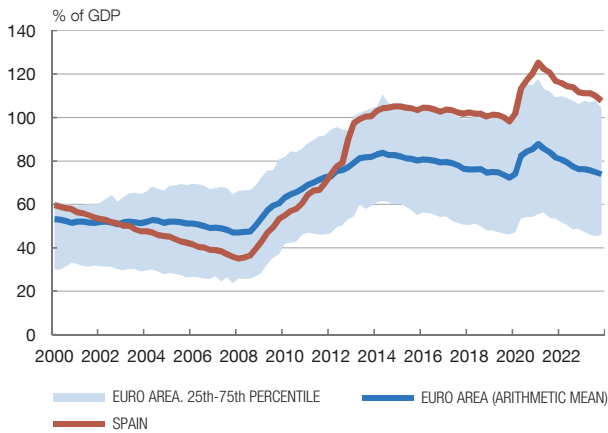
Furthermore, a country that fails to capitalise on economic upswings to reduce its public debt levels may struggle to make progress towards the reference values set out in the European fiscal rules (60% of GDP).²¹ A simple means of visualising this point in terms of the fiscal effort required is to substitute the variables in equation (1) for their average historical

²¹ See Alloza, Andrés, Burriel, Kataryniuk, Pérez and Vega (2021) for a discussion of the relevance of the rules agreed in the Maastricht Treaty in the current macroeconomic context.

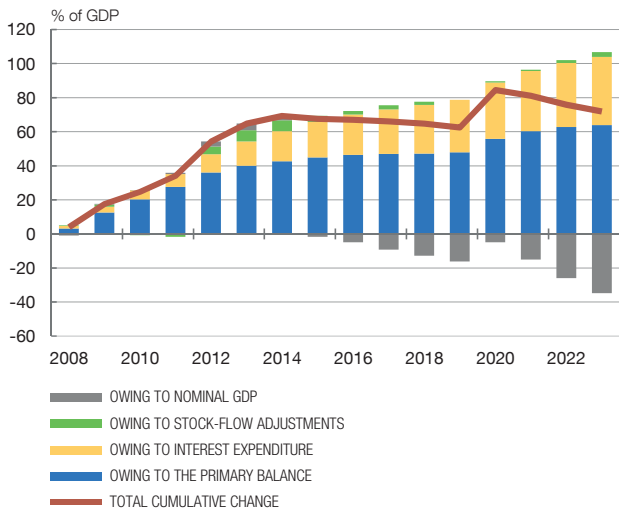
Chart 1

SPANISH PUBLIC DEBT: RECENT DYNAMICS

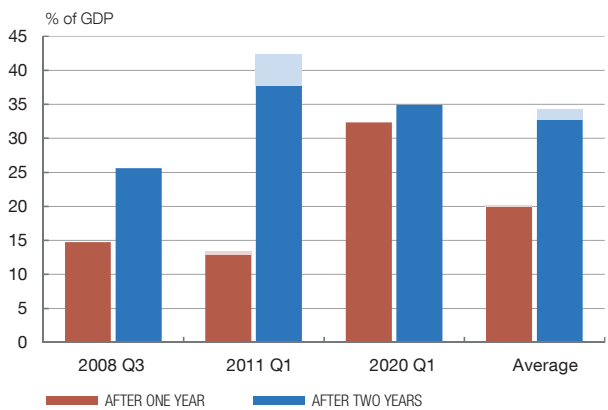
1 GENERAL GOVERNMENT DEBT



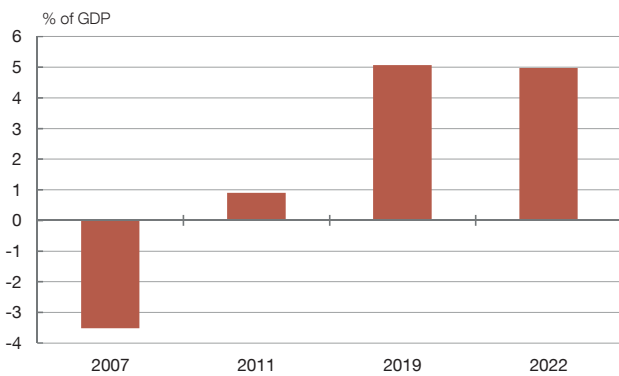
2 CUMULATIVE CHANGE IN THE PUBLIC DEBT RATIO



3 MAXIMUM DEBT RATIO INCREASE AFTER A RECESSION (a)



4 PRIMARY BALANCE NEEDED FOR THE PUBLIC DEBT RATIO TO STAND AT 60% IN TEN YEARS TIME (b)



SOURCES: INE, Eurostat, Intervención General de la Administración del Estado and Banco de España.

a Recessions are deemed to start in the first quarter of a period in which negative quarterly growth in real GDP (adjusted for seasonal and calendar effects) is recorded for two consecutive quarters. In the bars, the lighter shaded areas indicate the increase in debt directly related to the support provided to financial institutions.

b The constant primary balance required to attain a given debt-to-GDP ratio is defined as sp^* and is obtained from the expression $sp^* = \left(\frac{\lambda}{(1+\lambda)^N - 1} \right) \left[(1+\lambda)^N d_{t+N}^* - d_t \right]$, where $\lambda = \frac{i - \gamma}{1 + \lambda}$. This expression derives from equation (1) in the main text, assuming a stationary state in which the variables grow at a constant rate. i is calculated as the average implied interest rate in the last 5 years and γ as the average nominal GDP growth rate in the last 10 years. N is set at 10 years and $d_{t+N}^* = 60\%$.

values, ignoring the relationships between them. Based on this exercise, in 2011 Spain would have only needed to run a constant primary surplus of 0.9% of GDP for ten years to bring the debt-to-GDP ratio down to 60%. At end-2022, when debt stood nearly 50 pp higher, to achieve that same level of 60% of GDP Spain would have needed to run a constant primary surplus of about 5% of GDP for ten years. Despite its shortcomings, this simple exercise helps to illustrate the scale of the fiscal consolidation challenge facing Spain's general government. However,

addressing this consolidation process and its effect on the sustainability of public finances requires an understanding not only of the level and recent dynamics of general government debt, but also of its characteristics and composition.

First, it should be noted that the bulk of the general government liabilities incurred stem, in consolidated terms, from the central government, which accounts for 70% of current public debt (see Chart 2.1). This owes to institutional factors, given that the central government is the main player in raising funds on the financial markets and then reallocates part of these funds to the other tiers of government. Although regional governments have progressively increased their indebtedness since the great financial crisis of 2008, they currently account for one-fifth of total general government debt (some 22 pp of GDP). Meanwhile, social security funds and local governments make up around 8% and 1.6%, respectively, of that total.

Second, government funds are essentially raised through securities issuance (Treasury bonds, notes and bills), which accounts for around 90% of the liabilities incurred, according to the Excessive Deficit Protocol notification (see Chart 2.2). Turning to maturity, there has been a notable increase in the share of long-term debt since 2012, reaching 94% of total debt at present. This change in the financing strategy has also been reflected in longer-dated maturities: the average life of long-term central government debt has risen from 6.3 years in 2013 to more than 8 years in 2022. This means that, in average terms, just 12.5% of long-term debt needs to be refinanced each year.

Third, it is also helpful to characterise the sectors of public debt counterparties. The academic literature has underlined the effect that non-resident holdings of public debt can have on the fiscal multiplier, reducing the crowding-out effect on domestic investment.²² At present, 42% of Spanish debt is held by non-residents, in line with the average for this century so far (see Chart 2.3). Furthermore, since 2014 there has been a marked increase in the percentage of debt held by the Banco de España as a result of the Eurosystem's asset purchase operations. The fact that the percentage of debt held by other resident sectors (other than the Banco de España) has declined also has implications in terms of the stresses that arise when a high volume of sovereign debt is held on the balance sheets of domestic financial institutions. This can trigger doom loops between sovereign risk and bank risk.²³

Lastly, the role played by government variable-rate debt issuance is worth noting. As a percentage of total long-term securities issued by Spain's general government, such debt has increased from less than 3% before 2012 to over 7% in 2023 (see Chart 2.4). It largely comprises central government-issued bonds whose coupon and principal are indexed to the euro area Harmonised Index of Consumer Prices excluding tobacco. This is all the more important in inflationary environments, such as those witnessed recently.

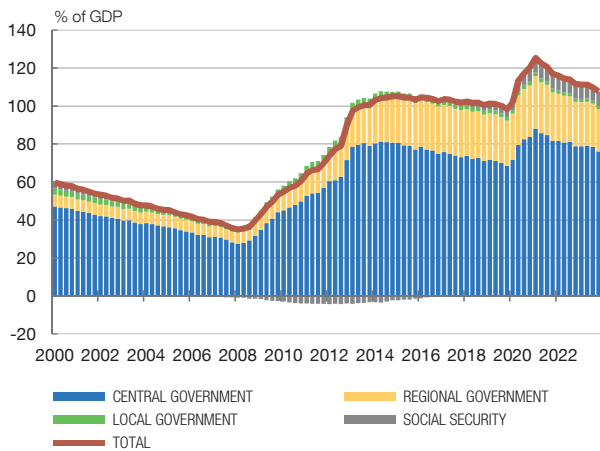
²² Broner, Clancy, Erce and Martin (2022).

²³ See Mitchener and Trebesch (2023) for a review of the recent literature on this sovereign-bank nexus.

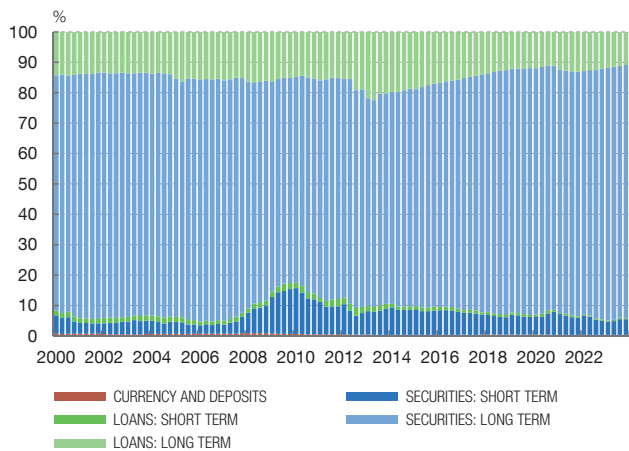
Chart 2

STOCK OF SPANISH PUBLIC DEBT: CHARACTERISTICS

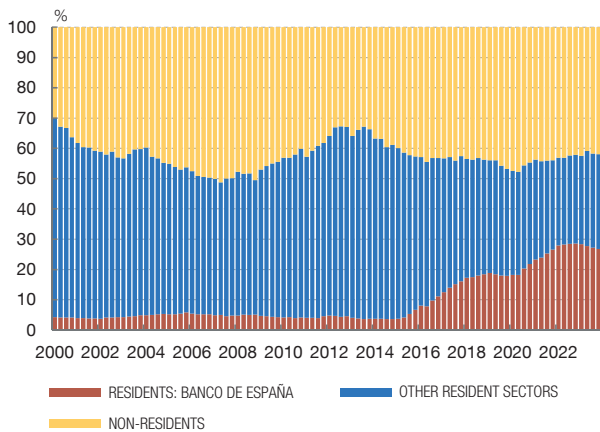
1 GENERAL GOVERNMENT DEBT



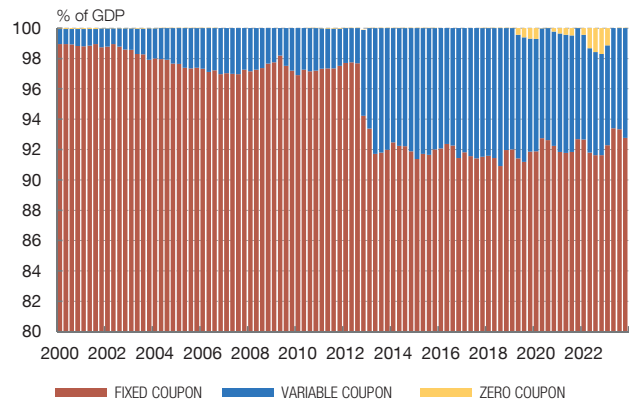
2 DBY INSTRUMENT AND MATURITY



3 BY HOLDERS



4 LONG-TERM SECURITIES, BY TYPE



SOURCES: INE and Banco de España.

For instance, in 2022 soaring inflation drove up the coupons and principal at maturity of such bonds, so much so that they accounted for 26% of the total cost of public debt in that year.

3.2 Public debt sustainability challenges

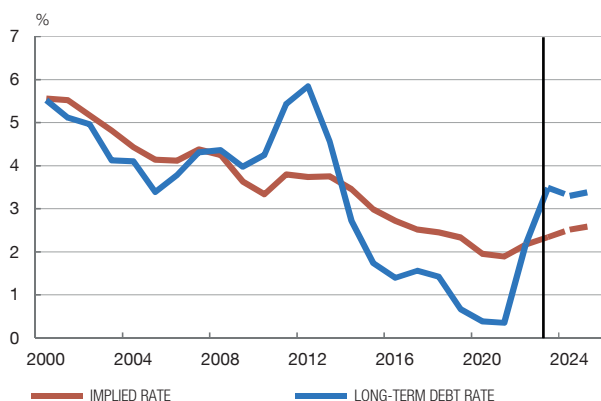
In addition to analysing the dynamics and characteristics of Spanish debt, it is also particularly useful to identify some of the public debt sustainability challenges facing Spain's general government. Two factors should be noted in particular.

First, the change in the macro-financial environment. Government borrowing costs stem from the implied interest rate on public debt (i.e. interest payments divided by the stock of public debt in the previous period). This variable is, in turn, determined by the cost

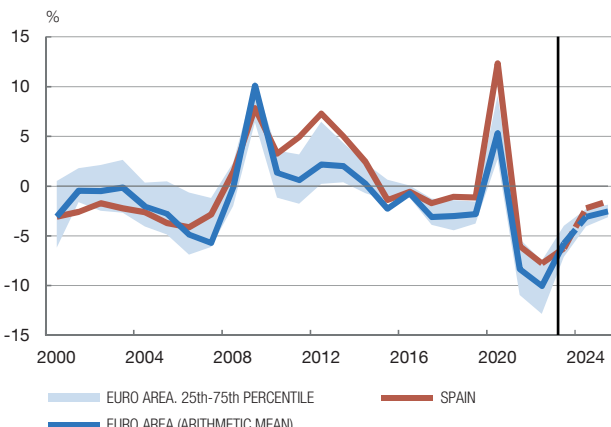
Chart 3

SOME CHALLENGES FACING SPANISH PUBLIC FINANCES

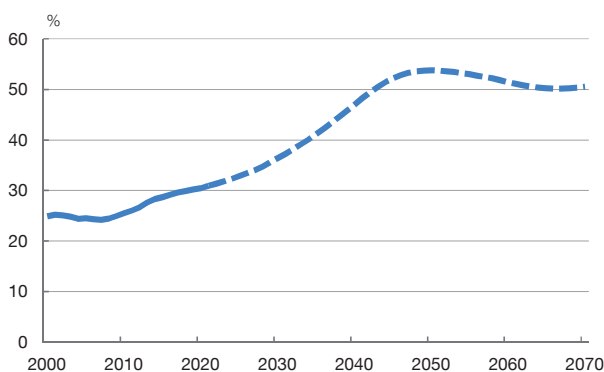
1 INTEREST RATES ON SPANISH PUBLIC DEBT (a)



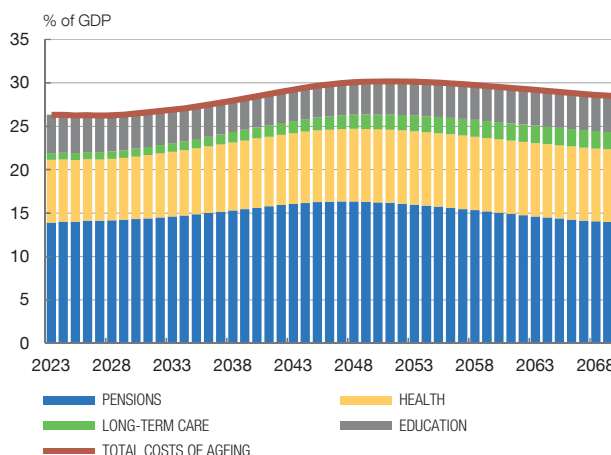
2 INTEREST RATE-NOMINAL GROWTH RATE DIFFERENTIAL (b)



3 DEPENDENCY RATIO (POPULATION 65+ / POPULATION 16-64)



4 PROJECTED COSTS OF AGEING



SOURCES: INE, Eurostat, Autoridad Independiente de Responsabilidad Fiscal and Banco de España.

- a The implied interest rate is calculated as the ratio between the interest burden and the stock of public debt in the previous period. The long-term interest rate refers to the secondary market rate for 10-year sovereign bonds. The dotted lines represent the Banco de España's March 2024 projections for Spain, and the November 2023 European Commission Forecast for the Euro Area.
- b This differential is calculated using the implied interest rate on public debt and the nominal GDP growth rate. The dotted lines represent the Banco de España's September 2023 projections.

at which general government raises financing on the markets in each period. However, not all debt is refinanced in each period. Therefore, changes in market rates are only passed through to the implied rate progressively, depending on the average life of outstanding public debt. In the case of Spanish general government, the implied cost of public debt has been in steady decline since the country joined the euro area, sliding from 5.5% in 2000 to below 2% at end-2021 (see Chart 3.1). However, the monetary tightening prompted by the energy crisis and subsequent inflation has resulted in a substantial increase in market rates for Spanish public debt, which has started to progressively be passed through to the implied rates. Going forward, should these financing conditions prove persistent, high market rates

will gradually pass through to the implied cost of debt as new refinancing needs arise. The above-mentioned lengthening of the average life of public liabilities is an opportunity to reduce the stock of debt before financing costs spread to the wider public debt portfolio.

However, while the implied rate is an important variable in its own right, the more relevant statistic for determining the effect of the macro-financial context on the outstanding stock of public debt is in fact the differential between the interest rate and nominal GDP growth, as described in equation (1). A negative differential (nominal GDP growth higher than the implied cost of debt) means, for a balanced budget, a decreasing debt trend. This differential is currently negative both for Spain and for the euro area (see Chart 3.2). However, the above-mentioned recent changes in monetary policy and a progressive convergence of nominal GDP growth towards its potential value could see the differential turn positive. In the euro area, the historical average has been negative since 2000 (-1.4 pp). However, in Spain that average has been higher (-0.2 pp since 2000 and 1.2 pp in 2008-2023). A possible reversal of the interest rate-growth rate differential towards positive values would mean additional strain in terms of public debt sustainability. Therefore, it is important that any fiscal consolidation process also consider those items that are more conducive to economic growth.

Other factors affecting medium and long-term debt dynamics are demographic trends and their implications for public finances. The latest projections by the National Statistics Institute (INE) suggest a substantial increase in the dependency ratio (population aged 65+ relative to those aged 16-64), rising from 31% in 2021 to nearly 54% in 2050 (see Chart 3.3). This substantial demographic shift entails an increase in ageing-related fiscal costs: higher expenditure on transfers to the elderly and on health and long-term care (partially offset by lower education expenditure). According to AIReF projections, annual ageing-related spending could increase by 3.9 pp of GDP to 2050 (see Chart 3.4). This very substantial amount would have a direct impact on public finances, which makes the case for debt sustainability analysis to take into account demographic considerations.

In sum, this section has shown how the level of public debt and its recent dynamics have strained Spanish public finances, with very little fiscal policy space available at present. Against this background, any fiscal consolidation must be guided by a conceptual framework that identifies the key relationships between the determinants of public debt and the uncertainty stemming from the macro-financial environment, along with the medium and long-term challenges associated with demographic change. The following section sets out a general conceptual framework that takes into account these aspects.

4 A debt sustainability analysis framework

The main components of the proposed tool are presented below. Section 4.1 presents the equations of the deterministic DSA model and its parameters' values. Section 4.2 then expands on the deterministic model by incorporating stochastic shocks calibrated for the Spanish economy that capture the uncertainty surrounding the future course of debt.

4.1 The deterministic DSA model

The DSA model is a tool whose main aim is to project the path of public debt under certain assumptions. The starting point for such a model must be the equation that determines public debt dynamics:

$$\Delta d_t = \frac{(1+i_t)}{(1+\pi_t)*(1+g_t)} d_{t-1} - sp_t + add_t \quad (2)$$

Where d is the public debt-to-GDP ratio, i is the average government bond yield, π is the rate of inflation measured as growth of the GDP deflator and g is the real economic growth rate. sp and add are, respectively, the general government primary balance and the stock-flow adjustment, both as a percentage of nominal GDP. The stock-flow adjustment includes changes in public debt that are not attributable to imbalances in the general government balance.²⁴

To determine the future course of debt from a given starting level, we need to know the changes in the different variables included in the equation and also factor in the interactions between them. To this end, the DSA tool incorporates, in addition to the dynamic debt equation, four main blocks of equations that model: 1) real output growth; 2) inflation dynamics; 3) the behaviour of interest rates; and 4) the course of the primary budget balance and of stock-flow adjustments. Each block influences and is affected by the others, via the standard interactions between the different economic variables.

Thus, firstly, the real growth equation (g) uses the specification in Hernández de Cos, López Rodríguez and Pérez (2018), incorporating trend potential growth (\bar{g}) and cyclical deviations from such potential growth, which maintain some inertia and are influenced by fiscal policy and interest rates. Changes in the fiscal policy stance, measured by the change in the primary structural balance (as a percentage of nominal potential GDP, sp^E) impact real economic growth via the fiscal multiplier β_1 . Similarly, there is a standard inverse relationship between changes in the interest rate and the output growth rate determined by the parameter β_3 . Meanwhile, the parameter ρ captures the persistence of real output growth, while the long-term output level is determined by potential growth, with a fraction β_2 of the difference between the two (i.e. the output gap) (O_t) being corrected in each period.

²⁴ E.g. as a result of general government purchases of financial assets or due to valuation changes and other effects. Such changes have no impact on the budget balance, but do alter the volume of public debt.

$$g_t = \rho g_{t-1} + (1 - \rho) \bar{g}_{t-1} - \beta_1 \Delta \text{sp}_t^E - \beta_2 O_t - \beta_3 (\dot{i}_t - i_{t-1}) \quad (3)$$

Where the output gap is determined by:

$$O_t \equiv (Y_t - \bar{Y}_t) Y_t \quad (4)$$

and the real and potential output levels would be, respectively, $Y_t = (1 + g_t) Y_{t-1}$ and $\bar{Y}_t = (1 + \bar{g}_t) \bar{Y}_{t-1}$ with exogenous \bar{g}_t .

The model's second behavioural equation also follows Hernández de Cos, López Rodríguez and Pérez (2018) and represents the Phillips curve. It links changes in the inflation rate to the degree of economic slack, measured by the output gap, and to inflation expectations, which weight the recent past and the ECB's medium-term target (π^0).

$$\pi_t = \vartheta_0 \pi^0 + (1 - \vartheta_0) \frac{1}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} \pi_{t-4}) + \vartheta_1 O_t \quad (5)$$

Thirdly, the DSA incorporates a block of equations that determine the average government bond yield using market rates and bond terms at issue. Although the model is explained in detail in Annex 1, one key aspect that should be highlighted here is that, unlike with other institution's DSAs, the market rates at which new sovereign debt is issued are calculated using their theoretical determinants, rather than being obtained from agents' expectations at a given point in time. This has the important advantage of making the scenarios projected and the issuance interest rates assumed more consistent, because the latter are not fixed, but rather vary across the scenarios as a result, for example, of changes in the sovereign risk premium in response to different behaviour in the public debt-to-GDP ratio.

Thus, the short and long-term sovereign bond yields are calculated drawing on the market expectations for the euro short-term rate (€STR) over the corresponding term²⁵ and a series of premia. Specifically, the yield on Spanish 10-year government bonds is obtained as:

$$i_t^p = \sum_{i=0}^9 i_{t+i}^{lr} / 10 + \theta_{\text{repo}} + \theta_{\text{plazo}}^p + \theta_t^{\text{sob10a}} \quad (6)$$

Where i_{t+i}^{lr} is the average €STR expected for year $t+i$, θ_{repo} is the average spread between yields on very short-term AAA-rated sovereign bonds and interbank rates, θ_{plazo}^p is the term premium on a 10-year bond and θ_t^{sob10a} is the Spanish 10-year risk premium against an equivalent AAA-rated bond.

Analogously, we represent the 1-year Spanish bond yield as:

$$i_t^{\text{cp}} = i_t^{lr} + \theta_{\text{repo}} + \theta_{\text{plazo}}^{\text{cp}} + \varphi \theta_t^{\text{sob10a}} \quad (7)$$

²⁵ Taken from the ECB's [Survey of Monetary Analysts](#).

Where $\theta_{\text{plazo}}^{\text{CP}}$ is the corresponding one-year term premium and the sovereign risk premium is a fraction φ of the corresponding 10-year premium.

The set of financial equations is completed with the equation that captures the dynamics of the 10-year sovereign risk premium according to the debt-to-GDP ratio:

$$\theta_t^{\text{sob10a}} = \beta_1^0 + \beta_2^0(d_{t-1} - 0.6) \quad (8)$$

The higher that ratio at the end of the period $t-1$, the greater the market's perception of the risks to its sustainability and, consequently, the higher the premium required. By expressing debt in differences from the 60% threshold, we capture the non-linearity of the response of sovereign risk premia to increases in debt, as detailed in multiple studies.²⁶

Lastly, the fourth block includes the general government primary balance and stock-flow adjustment variables. The latter is generally assumed to be zero. The former is defined as the sum of the structural primary balance and the cyclical balance, where the latter is determined on the basis of an output gap elasticity.²⁷

$$\text{sp}_t \equiv \text{sp}_t^E \left(\bar{Y}_t / Y_t \right) + \text{sp}_t^C \quad (9)$$

$$\text{sp}_t^C \equiv \varepsilon O_t \quad (10)$$

Meanwhile, the structural primary balance is assumed to be constant, from the last year of the horizon of the Banco de España's quarterly projections, except for the impact of ageing-related costs. Given how significant the ageing process is set to be in Spain, the DSA simulations always incorporate an estimation of its impact, via changes in the structural primary balance: the future path of this balance includes (i) the estimated effect of ageing on government spending on pensions, health, long-term care and education and (ii) the revenue-raising measures included in the latest reforms of the pension system (higher maximum bases, the intergenerational equity mechanism (IEM), the "solidarity quota" and revised social security contributions for the self-employed). In the first case and beyond the horizon of the Banco de España's macroeconomic projections, such spending is based on the AIReF's estimates.²⁸ As for revenue, we use the Banco de España's estimates, which are very similar to the AIReF's.

As a result, in the deterministic model the future course of debt is established by a series of variables exogenous to the model and by the equations presented above. The main exogenous variables are: real potential economic growth (\bar{g}_t), the ECB's inflation target (π^0), the expected path of very short-term risk-free interest rates (i_t^f), which for the farthest

²⁶ See, for example, Pamies, Carnot and Pătărău (2021).

²⁷ The structural primary balance is multiplied by (\bar{Y}_t / Y_t) to express it in nominal GDP terms, rather than in potential nominal GDP terms, which is how it is defined in equation (2) above.

²⁸ AIReF (2023).

horizons would be equal to the natural nominal interest rate, and the future path of fiscal policy (sp_t^E).

Sections 4.2 and 4.3 explain how we incorporate stochasticity into the deterministic model and how we calibrate the parameters, obtain the distributions of the stochastic shocks and determine the variables exogenous to the model, respectively.

4.2 The stochastic DSA model

The stochastic DSA model builds on the set of equations presented above by incorporating some temporary shocks, which seek to quantify the uncertainty of the macro-financial environment. The aim is to be able to analyse the risks to public debt sustainability, not only under certain baseline scenarios linked to specific assumptions, but also by factoring in the uncertainty surrounding macro-financial developments. To this end, innovations are included in the deterministic DSA model equations, using recent evidence to gauge their scale and recurrence.

It is important to highlight that these shocks affect behaviour over short and medium-term horizons and not the economy's structural variables (such as potential growth and the natural rate of interest), as extrapolating from historical behaviour is far more credible over such horizons than in longer-term projections.²⁹

Specifically, we incorporate into the deterministic DSA model two temporary shocks related to the dynamics of the real and financial economy. Thus, equation (3) – real growth – becomes:

$$g_t = \rho g_{t-1} + (1-\rho) \bar{g}_{t-1} - \beta_1 \Delta sp_t^E - \beta_2 O_t - \beta_3 (i_t^p - i_{t-1}^p) + \varepsilon_t^{\text{shock IS}} \quad (3b)$$

where $\varepsilon_t^{\text{shock IS}}$ is a zero mean random variable. This means that $\varepsilon_t^{\text{shock IS}}$ would thus capture the deviations in real growth that are not explained by the other determinants included in the equation (fiscal policy, interest rates and potential growth).

The 10-year sovereign risk premium equation (8) is modified as follows:

$$\theta_t^{\text{sob10a}} = \beta_1^0 + \beta_2^0 (d_{t-1} - 0.6) + \varepsilon_{1,t}^{\text{shock Spread}} \quad (8b)$$

Where, in turn, $\varepsilon_{1,t}^{\text{shock Spread}}$ is determined by the following equation:

$$\varepsilon_{1,t}^{\text{shock Spread}} = \beta_3^0 \varepsilon_{1,t-1}^{\text{shock Spread}} + \varepsilon_{2,t}^{\text{shock Spread}} \quad (11)$$

²⁹ Obviously, this does not mean that there is no uncertainty surrounding the variables that determine the trend behaviour of the economy, but that such uncertainty is more difficult to estimate and incorporate into the models. This is therefore left for future papers. Nor does it mean that differences in short and medium-term macro-financial developments have no impact on the longer-term path of public debt (see Section 5).

with $\varepsilon_{2,t}^{\text{shock Spread}}$ being a non-serially correlated zero mean variable.

The shock $\varepsilon_{1,t}^{\text{shock Spread}}$ aims to capture the deviations in the sovereign risk premium unexplained by the volume of public debt (e.g. a change in investor risk aversion). Modelling such shock as per equation (11) aims to replicate the observed historical persistence of changes in sovereign spread levels in the euro area. For instance, sovereign spread levels remained very high throughout the sovereign debt crisis, to subsequently correct over the last nine years to a level consistent with their fundamentals.³⁰

Incorporating these two shocks means that, unlike the deterministic model, this model does not generate just one path for the future course of debt, but multiple equally probably paths, which depend not only on the assumptions about the exogenous variables, but also on the specific materialisation of the shocks related to the real and financial economy.³¹

4.3 Calibration of the parameters, distributions and exogenous variables

The parameters of equations (3), (5) and (10) are calibrated following the estimations in Laubach (2009), Baldacci and Kumar (2010), Álvarez and Urtasun (2013), Warmedinger, Checherita-Westphal and Hernández de Cos (2015), Bouabdallah et al. (2017) and Hernández de Cos, López Rodríguez and Pérez García (2018): the value of the autoregressive coefficient of real output (ρ) is 0.5; the value of the net government spending multiplier (β_1) is 0.55; the closure of the output gap (β_2) is equal to 0.20; the coefficient of the elasticity of output to the change in the long-term interest rate (β_3) is equal to 1%; a value of 0.54 is assigned to the elasticity of the cyclical balance to the output gap (ϵ); the parameter governing the anchoring of inflation to its medium-term target (ϑ_0) is calibrated with a value of 0.3; and the parameter governing the effect of the output gap on inflation (ϑ_1) is assigned the value of 0.1.

The parameters of the interest rate equations – (6), (7) and (8) – are our own calculations. Thus, the interbank market AAA-rated government bond premium, θ_{repo} , is obtained as the difference between the implied instantaneous spot rate of the AAA sovereign yield curve

³⁰ There is ample literature that aims to estimate sovereign spreads on the basis of not only the public debt position, but also on that of other macroeconomic and financial fundamentals. However, Pamies, Carnot and Pătărău (2021) and Burriel, Delgado Téllez, Figueroa, Kataryniuk and Pérez (2024), for example, show that such estimations are highly sensitive to the sample period selected. The modelling chosen in this paper allows us to pragmatically incorporate relatively persistent deviations in the levels of the yields on Spanish debt, which would be consistent with their historical behaviour. Note that capturing the uncertainty surrounding the cost of public debt is particularly important in the current context of high debt levels. Further, in this modelling the unexplained changes in the sovereign spread are always temporary. Therefore, extreme cases of “self-fulfilling prophecies” – where the mere suspicion of insolvency risk leads agents to demand higher yields, to the point of worsening the sovereign’s financial position and causing such insolvency – are not included. This perhaps extreme risk may be present, but it is not included in the model. Burriel, Delgado Téllez, Figueroa, Kataryniuk and Pérez (2024) analyse in greater detail euro area sovereign bond spreads relative to their fundamentals.

³¹ The model also incorporates stochasticity into the risk-free rate that replicates the uncertainty surrounding the future paths of the risk-free rate reflected in the Survey of Monetary Analysts (SMA). Specifically, in each simulation, given the dispersion of the SMA median forecast, we draw the risk-free rate from a normal distribution for 2025 and construct a path that converges linearly to the SMA median by 2032. Such shock does not significantly affect the dispersion of the public debt-to-GDP ratio due to the limited dispersion of the SMA forecast and the long-term structure of the debt.

(estimated daily by the ECB)³² and the €STR. The 10-year term premium, θ_{plazo}^{lp} , is calculated on the basis of the difference between the 10-year spot rate of the ECB's AAA sovereign yield curve and the €STR expected over the next ten years, as per the ECB's Survey of Monetary Analysts.³³ The 1-year term premium, θ_{plazo}^{cp} , is assumed to be zero. The ratio of the 1-year sovereign spread to the 10-year sovereign spread, φ , is obtained from the respective spreads, calculated as the average yield on Spanish debt issuance less the spot rate at the corresponding term of the AAA sovereign yield curve. Lastly, the parameters of the equation that determines the 10-year sovereign risk premium, β_1^0 and β_2^0 , are obtained by estimating such equation, using monthly data, for the 11 countries that have belonged to the euro area since 2001.³⁴ In general, we take the estimated average value for each parameter for the longest available period after the euro area sovereign debt crisis. However, in those cases in which sizeable changes over time take place, such as in the term premium and in the sovereign spread parameters, we use only the most recent period (since the ECB began to raise its key interest rates in 2022). As a result, the interbank market AAA-rated government bond premium (θ_{repo}) is equal to -0.17; the 10-year term premium (θ_{plazo}^{lp}) takes the value 0.2; the 1-year term premium (θ_{plazo}^{cp}) takes the value 0; the ratio of the 1-year sovereign spread to the 10-year sovereign spread (φ) takes the value 0.33; and the parameters β_1^0 and β_2^0 take the values 0.32 and 1.37, respectively.

To obtain the distributions of the shocks added to the deterministic model, we estimate the corresponding equations using historical data and obtain the residuals, starting from the observation that the model described by equations (3b)-(8b) and (11) can be represented as a restricted VAR.³⁵ In the case of the growth equation (3b), an incomplete panel is constructed using annual data for all the euro area countries except for Croatia, for the period 1999-2021, and we estimate the following regression:

$$g_{i,t} = \beta_0^{is} + \beta_1^{is} g_{i,t-1} + \beta_2^{is} \Delta d_{i,t}^E + \beta_3^{is} O_{i,t} - \beta_4^{is} (i_{i,t} - i_{i,t-1}) + \lambda_t + \lambda_i + \varepsilon_{i,t}^{shock IS}$$

Similarly, the innovations $\varepsilon_{2,t}^{shock Spread}$ are derived from the estimation of a panel regression that considers the six largest euro area economies – excluding Germany, which is used as the benchmark for the 10-year sovereign bond spreads – and the same time sample. The specification estimated is as follows:

$$spread_{i,t} = \beta_0^{spr} + \beta_1^{spr} (dtot_{i,t-1} - 0.6) + \lambda_t + \lambda_i + \varepsilon_{i,t}^{shock Spread}$$

$$\varepsilon_{i,1,t}^{shock Spread} = \beta_1^{spr} \varepsilon_{i,1,t-1}^{shock Spread} + \varepsilon_{i,2,t}^{shock Spread}$$

In both cases, λ_t and λ_i are the year and country fixed effects, respectively.

32 Euro area yield curves.

33 Survey of Monetary Analysts.

34 11 countries because Germany, the benchmark for calculating sovereign bond spreads, is excluded. The countries that joined the euro area after 2001 (Baltic States and eastern European countries) are not considered since their particularities would add noise into the estimation.

35 Note that the procedure followed would be equivalent to estimating the distribution of the model's innovations by estimating a restricted VAR, resulting from reformulating the DSA equations in that format.

Once we have obtained the time series of $\varepsilon_{i,t}^{\text{shock IS}}$ and $\varepsilon_{i,2,t}^{\text{shock Spread}}$, we are left with the innovations specific to Spain for estimating the non-parametric density functions that are used to extract the innovations during the simulation of the DSA model.

Lastly, for the exogenous variables we make a series of assumptions, which can vary, by generating alternative scenarios. For instance, by default the Spanish economy's potential growth (\bar{g}_t) is 1.3% over the long term. The ECB's inflation target (π^0) is always 2%. The path of the risk-free interest rates (i_t^f) is taken from the ECB's [Survey of Monetary Analysts](#), such that the natural rate of interest will be the €STR expected over the long term in that survey. Lastly, the future fiscal policy stance is decided on a discretionary basis to illustrate the results of alternative scenarios.

5 Results

Section 5.1 presents the results of using the model described above to generate future paths of Spain's public debt, over the horizon 2025-2040.³⁶ This is done for different fiscal policy and long-term economic growth scenarios. For each scenario the shocks to the real economy and to the financial economy are simulated 100,000 times, generating 100,000 possible future paths under that scenario. There are four scenarios. Scenario 1 assumes no fiscal policy change over the simulation horizon and, further, that the pension system's automatic adjustment mechanism (approved in March 2023) will not be activated.³⁷ Scenario 2 likewise assumes no fiscal policy change, but does envisage the activation of the automatic adjustment to social security contributions, from 2026, as a result of a social security revenue shortfall. Scenario 3 incorporates a fiscal consolidation policy, in line with the new European economic governance framework, which entails an annual average adjustment to the primary structural balance of about 0.5 pp of potential GDP over a seven-year period, starting in 2024.³⁸ Lastly, Scenario 4 is identical to Scenario 3, but with long-term potential GDP growth 0.8 pp higher than the other scenarios.

Section 5.2 presents other measures or ways of exploiting the information contained in the model's results and Section 5.3 contains the results of a general government liquidity risk analysis.

5.1 The future path of public finances in an uncertain environment

Chart 4.1 shows the course of public debt under the assumptions of Scenario 1. The lack of fiscal consolidation and the non-implementation of the automatic mechanism included in the pension reform would put the public debt-to-GDP ratio on a generally upward path from 2030 onwards, to stand, on average, above 120% at the end of the projection horizon. However, depending on the specific shocks observed throughout this period, the range of possible results is very wide. For instance, in 20% of the most favourable simulations of those shocks, under this scenario, debt could stand below 100% of GDP in 2040. Furthermore, the probability of debt rising above 130% of GDP is around 40%, **while there is an 80% probability that debt will exceed 100% of GDP in that year**. To understand the mechanisms that explain the dynamics of these paths, it is useful to observe the course of the two principal components that determine the change in public debt in equation

³⁶ For the years 2023-2024 the values included in the [March 2024 Banco de España projections](#) are taken as given.

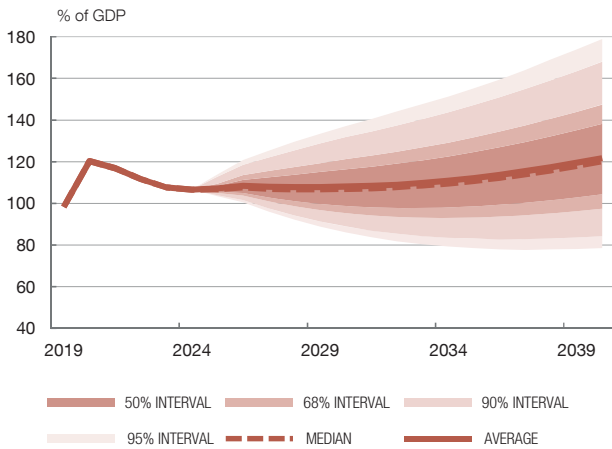
³⁷ Royal Decree-Law 2/2023 of 16 March 2023, which ushered in new revenue-raising measures to fund pension expenditure, also incorporates an automatic adjustment mechanism that is expected to enter into force in 2026. Under this Royal Decree-Law, on average in the period 2022-2050 and given an increase in revenue stemming from the new measures of 1.7 pp of GDP, pension expenditure should not exceed 15% of GDP. A greater (lesser) impact of the revenue-raising measures raises (reduces) the limit on spending by a similar amount. From 2025 onwards, the AIReF will assess the rule every three years taking into account the forecasts of the European Commission's latest Ageing Report. If the projected average spending exceeds the threshold and no offsetting revenue or expenditure measures are implemented, the rule establishes an automatic and gradual increase in the IEM. On the current projections, it is estimated that the automatic adjustment mechanism would need to be activated, with the projected level of revenue raised via the IEM increasing by up to three times if it is not. However, its future application is uncertain, as was the case with the sustainability factor in the 2013 reform.

³⁸ For more details, see Chapter 2 in Banco de España (2024).

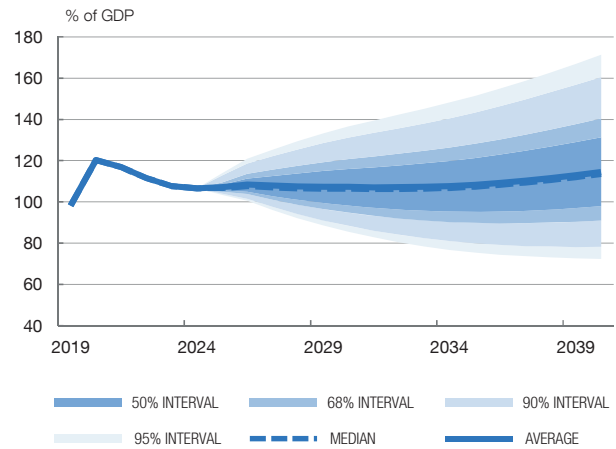
Chart 4

CHANGE IN THE PUBLIC DEBT RATIO UNDER DIFFERENT SCENARIOS (a)

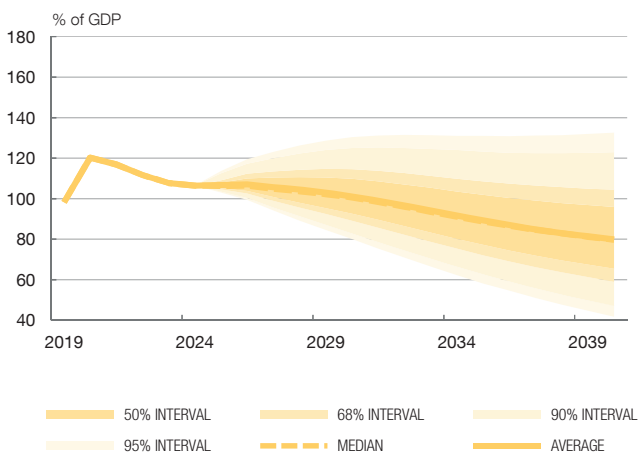
1 SCENARIO 1



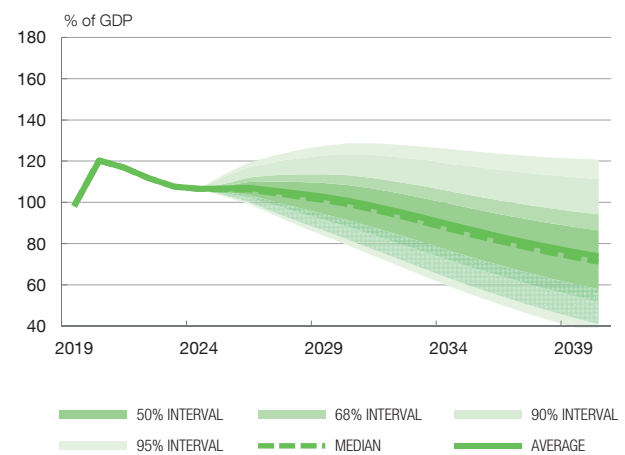
2 SCENARIO 2



3 SCENARIO 3



4 SCENARIO 4



SOURCES: INE, AIREF and Banco de España.

a All of the scenarios envisage a deterioration in the primary structural balance to 2040 owing to the costs of ageing (pensions, health and long-term care). Scenario 1 refers to a fiscal policy effort consistent with the new measures envisaged in the 2023 pension system reform, but does not envisage activation of the automatic adjustment mechanism to increase the revenue raised from social security contributions in order to correct deviations in pension expenditure. Scenario 2 is the same as Scenario 1 but includes activation of the automatic adjustment mechanism. Alternatively, Scenario 3 assumes a fiscal policy that aligns with the new European economic governance framework. Scenario 4 is the same as Scenario 3 but with long-term potential GDP growth of 1.9% (instead of the 1.1% assumed in the other scenarios).

(1): the differential between the implied interest rate and nominal growth; and the primary balance. With regard to the former, the assumptions about the convergence of the interest rates and nominal growth towards their long-term reference values yield, on average, a slightly negative differential (see Chart A.1.1 in Annex 2).³⁹ However, despite this favourable

³⁹ In approximately 70% of the paths simulated, nominal GDP growth exceeds public debt's implied interest rate, taking into account the current assumptions about real trend growth and the natural or long-term rate of interest.

Chart 5

CHANGE IN THE PUBLIC PRIMARY BALANCE UNDER DIFFERENT SCENARIOS (a)



SOURCES: INE, AIREF and Banco de España.

a All of the scenarios envisage a deterioration in the primary structural balance to 2040 owing to the costs of ageing (pensions, health and long-term care). Scenario 1 refers to a fiscal policy effort consistent with the new measures envisaged in the 2023 pension system reform, but does not envisage activation of the automatic adjustment mechanism to increase the revenue raised from social security contributions in order to correct deviations in pension expenditure. Scenario 2 is the same as Scenario 1 but includes activation of the automatic adjustment mechanism. Alternatively, Scenario 3 assumes a fiscal policy that aligns with the new European economic governance framework. Scenario 4 is the same as Scenario 3 but with long-term potential GDP growth of 1.9% (instead of the 1.1% assumed in the other scenarios).

differential, the public debt ratio would tend to rise as a result of the gradual deterioration in the primary balance over the projection horizon (see Chart 5.1). This is due to the ageing-related expenditure, which tends to worsen the existing primary deficit at the start of the simulations, such that, in 2040, in less than 10% of the macro-financial simulations, the strength of economic developments would improve the cyclical balance enough to raise the total primary balance to positive values that help reduce public debt.

Meanwhile, in the event that the automatic adjustment mechanism incorporated into the pension system reform were activated, as assumed in Scenario 2, the debt dynamics would tend to be slightly more favourable until the start of the 2030s, gradually increasing again thereafter to reach, on average, values of around 115% in 2040 (see Chart 4.2). As in Scenario 1 above, debt dynamics are explained mainly by the primary balance: thanks to the provisions in the reform of the public pension system, the high ageing-related spending would trigger a further temporary increase in government revenue that would help slightly improve the behaviour of the primary balance up to 2030 (see Chart 5.2). However, over the rest of the simulation horizon, the primary balance would tend to gradually deteriorate again. Overall, there is a **72% probability (9 pp less than under Scenario 1) that the public debt-to-GDP ratio will stand above 100% at the end of the simulation horizon (2040).**

The implementation of a sustained fiscal consolidation plan would have a considerable effect on the above-mentioned debt dynamics. Should such plan materialise as per the assumptions considered in Scenario 3 (i.e. a fiscal adjustment consistent with the new European economic governance framework), the primary balance would generally turn positive before the end of the 2020s (see Chart 5.3). At the end of the projection horizon, in approximately 75% of the cases the primary balance would contribute positively to reducing the debt ratio. This fiscal policy, together with nominal economic growth, would result in a debt ratio that stands on average at around 80% of GDP in 2040 (see Chart 4.3). **For comparison purposes with earlier scenarios, in this case, the probability of observing levels of debt in excess of 100% at the end of the projection horizon would decrease considerably, to 20%.** Thus, public finances would recover some room for manoeuvre and only in 6% of the most extreme macro-financial paths would debt reach levels similar to or higher than those recorded during the COVID-19 crisis (120%).

The effects of implementing such fiscal adjustment plan would be boosted were it accompanied by structural reforms conducive to raising potential GDP growth, as envisaged in Scenario 4. This would drive down the public debt ratio further (6 pp further on average) at the end of the projection horizon (see Chart 4.4). This would be due to the more favourable differential between the interest rate and nominal growth, which, on average, could reach -1.2% in 2040 (see Chart A.1.4) and **would trigger a further reduction, to 11% that year, in the probability of the public debt-to-GDP ratio standing above 100%.**

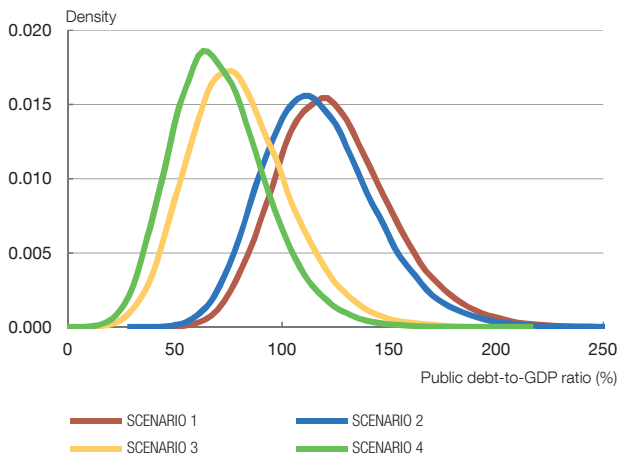
5.2 Other ways of characterising public debt sustainability

In addition to analysis of the time profile of public debt, the results of the stochastic model can be represented by the probability distributions that the model generates for the long-term debt-to-GDP ratio (see Chart 6.1). As expected, the scenarios including fiscal consolidation show probability distributions in 2040 centred around lower public debt ratios. However, in addition, those scenarios have a distribution of the debt ratio that is concentrated more around the median values. This means that the fiscal consolidation processes would not only enable a reduction in the debt ratio, but would also reduce the effect that the uncertainty inherent in the macro-financial environment has on this variable.

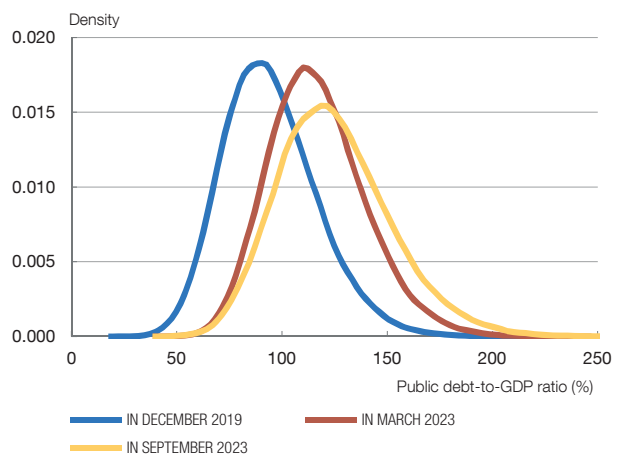
Chart 6

THE IMPORTANCE OF STOCHASTICITY IN PUBLIC DEBT SUSTAINABILITY ANALYSIS (a)

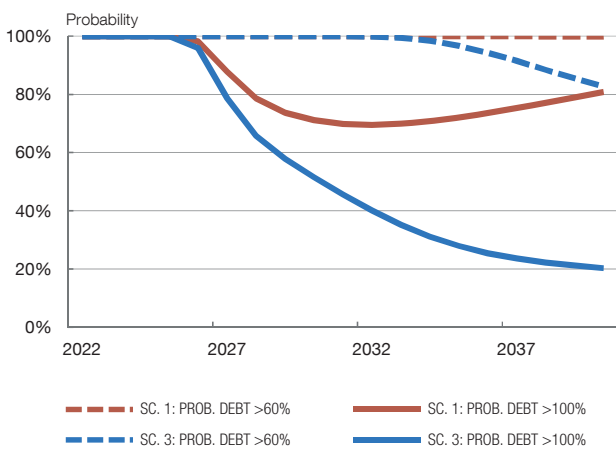
1 DISTRIBUTION OF DEBT-TO-GDP RATIOS IN 2040 UNDER DIFFERENT SCENARIOS (a)



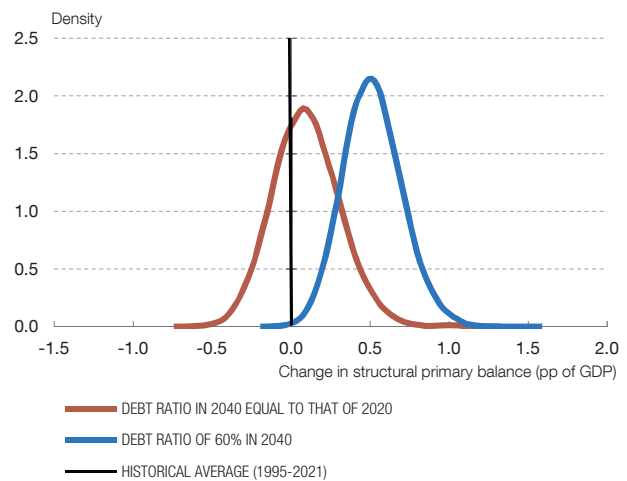
2 DISTRIBUTION OF DEBT-TO-GDP RATIOS IN 2040 UNDER SCENARIO 1, CALCULATED AT DIFFERENT MOMENTS IN TIME



3 PROBABILITY OF THE DEBT-TO-GDP RATIO EXCEEDING A PARTICULAR THRESHOLD



4 CONSTANT FISCAL EFFORT NEEDED TO ATTAIN A TARGET (b)



SOURCE: Banco de España.

- a All of the scenarios envisage a deterioration in the primary structural balance to 2040 owing to the costs of ageing (pensions, health and long-term care). Scenario 1 refers to a fiscal policy effort consistent with the new measures envisaged in the 2023 pension system reform, but does not envisage activation of the automatic adjustment mechanism to increase the revenue raised from social security contributions in order to correct deviations in pension expenditure. Scenario 2 is the same as Scenario 1 but includes activation of the automatic adjustment mechanism. Alternatively, Scenario 3 assumes a fiscal policy that aligns with the new European economic governance framework. Scenario 4 is the same as Scenario 3 but with long-term potential GDP growth of 1.9% (instead of the 1.1% assumed in the other scenarios).
- b Fiscal effort is defined as the change in the structural primary balance between two years and remains constant throughout the simulation horizon.

Furthermore, expanding the framework of the DSA with a stochastic dimension allows us to analyse changes in the distribution of future public debt ratios for the same scenario as new information becomes available. As an example, Chart 6.2 shows how the long-term debt ratio shifted towards higher values between December 2019 and March 2023. This was the result of various factors that exerted upward pressure on public debt,

such as the increased fiscal deterioration stemming from the response to the COVID-19 crisis and the energy crisis, the tightening of monetary policy and the pension system reform, which, although it also increases revenues, would raise expenses to a greater extent. Subsequently, changes to fiscal and long-run assumptions incorporated into the Banco de España's March 2024 projections would have nudged the distribution of long-term debt towards higher values.

Incorporating uncertainty into the DSA model framework also enables us to analyse public debt in terms of probabilities and make direct comparisons between different fiscal assumptions. Thus, Chart 6.3 depicts how, in a no-policy-change scenario – with no fiscal policy aimed at normalising public finances – there is about an 80% probability that the public debt-to-GDP ratio will exceed 100% in 2040. In addition, under this no-fiscal-consolidation scenario, the analysis suggests that, even considering the most optimistic macro-financial environments, the probability of reducing debt to 60% of GDP in 2040 is zero. Conversely, under tighter fiscal policy scenarios, the probability of the public debt ratio exceeding 100% in 2040 decreases to 20%, while that of a ratio below 60% turns positive.

Lastly, public debt sustainability can also be analysed in terms of the plausibility of the fiscal effort needed to attain a specific public debt goal. We define fiscal effort as the continued annual improvement (to 2040) in the primary structural balance required to attain the desired goal. Such effort will of course depend on macro-financial developments. Thus, in more favourable scenarios the effort will be lower and vice versa. The stochastic DSA model allows us to derive the probability distribution of the required effort, taking into account the historical evidence on possible macro-financial scenarios. For instance, the red line in Chart 6.4 shows that in one of every three simulations a positive fiscal effort would not be required to place the public debt-to-GDP ratio in 2040 at the same level as in 2022 (112%).⁴⁰ However, there is an almost 70% probability that a fiscal effort would be required, which could be considerable under the most adverse scenarios. When the goal is to reduce debt to 60% of GDP (the reference criterion established in the current European fiscal rules framework), even under the most favourable scenarios a not inconsiderable fiscal effort would be required on a continuous basis up to 2040 (blue line in Chart 6.4). In this case, if no fiscal effort is implemented, the possibility of attaining such goal would require extremely positive macro-financial scenarios whose probability of arising is virtually zero (0.5%). In average terms, converging to ratios of 60% in 2040 would require an average annual fiscal effort exceeding 0.5 pp. This figure is far higher than the historical average recorded in Spain (negative fiscal effort of 0.05 pp on average in the period 1995-2021) and would be even larger in adverse macro-financial scenarios.

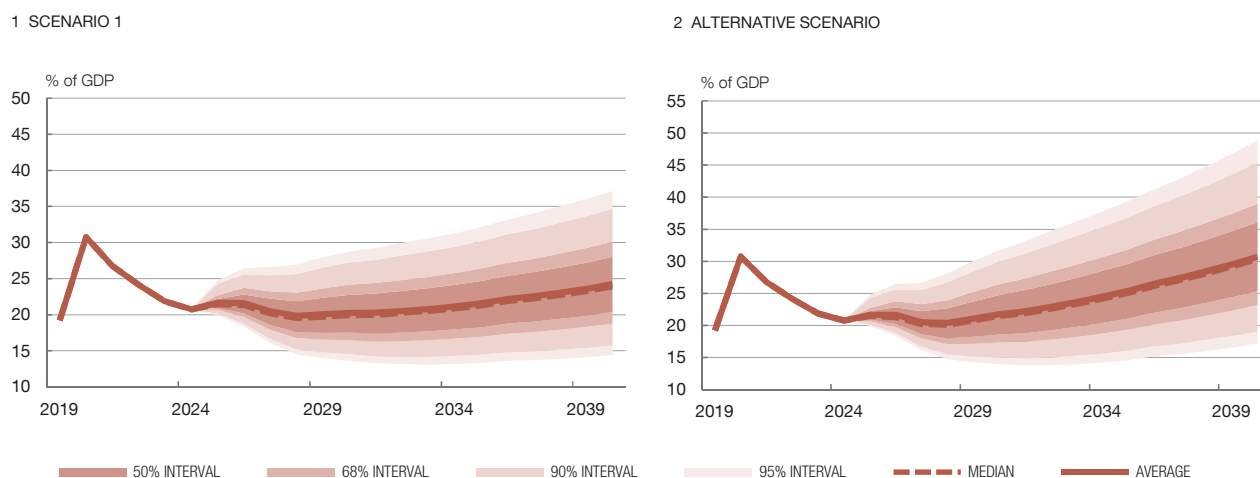
5.3 Liquidity risk analysis

The model also allows us to analyse other debt sustainability-related matters, such as liquidity risk. Such risk arises from the general government's need to raise a specific volume

⁴⁰ This is not equivalent to stabilising long-term public debt, as the 112% figure would be reached, in most cases, with an upward trajectory.

Chart 7

CHANGE IN GROSS FINANCING NEEDS (a)



SOURCE: Banco de España.

a Both scenarios envisage a deterioration in the primary structural balance to 2040 owing to the costs of ageing (pensions, health and long-term care). Scenario 1 assumes a fiscal policy that does not correct said deterioration, in the context prior to the pension reform. The alternative scenario is the same as Scenario 1 but assumes that, from 2026, 20% of each year's gross financing needs are covered with short-term debt.

of funds (gross financing needs) on the financial markets each year. This variable is important, as doubts surrounding the sovereign's solvency are more likely to trigger a crisis when its annual financing needs are very high than when they are small.⁴¹ Financing needs can be high either because of new needs stemming from a budget imbalance or because of large maturities from past debt issuance. Therefore, for given levels of budget deficit and public debt, liquidity risk is reduced if debt is issued at longer term. By contrast, the higher the debt issued at short term, the larger the annual repayments and, therefore, the yearly gross financing needs. As a result, the sovereign would be more exposed to unexpected changes in the financial market.

Chart 7 illustrates this using two scenarios. The first is the above-mentioned Scenario 1, in which short-term debt as a percentage of the total is always fixed at the 4.3% expected for 2025. The alternative scenario is exactly the same except for the assumption that, from 2026, 20% of the annual gross financing needs are covered by short-term debt. As a result, in 2040 short-term debt would account for 11.3% of the total. The volume of total debt is virtually unaffected by the change, as it only depends on the primary balance and interest variables. As a percentage of GDP and on average, in 2040 the public debt ratio would be 0.5 pp lower under the alternative scenario as compared with Scenario 1. This is because the short-term interest rates are slightly lower than the long-term rates. Accordingly, an issuance strategy based more on short-term instruments lowers the interest paid. However, conversely, the annual gross financing needs rise considerably, and with them the liquidity

⁴¹ Corsetti (2018).

risks, since recourse to shorter-term financing leaves the sovereign more exposed to risk premium shocks triggered, for example, by a change in investor risk aversion. This can be observed in the alternative scenario, where the distribution of the gross financing needs to the end of the simulated horizon is more dispersed than in Scenario 1 (see Chart 7.2). Therefore, the uncertainty around the macro-financial environment could be particularly adverse in a scenario in which short-term debt accounts for a larger share of financing.

6 Conclusions

In recent years, there has been a considerable increase in the public debt ratio in several countries, including Spain, prompting renewed interest in fiscal sustainability analysis. Meanwhile, there is a growing awareness of the importance of fiscal sustainability analysis in terms of risks and probabilities. Higher public debt has laid bare the need to launch fiscal normalisation policies that free up enough space for fiscal policy to act in response to possible negative shocks without jeopardising fiscal sustainability.

Such fiscal consolidation must be guided by tools to identify the risks to sustainability stemming from the different assumptions. In turn, these tools must also consider factors that have a particular impact on debt dynamics, such as ageing-related spending, the tightening of financing conditions and, above all, the uncertainty surrounding the macro-financial environment.

This paper proposes a general conceptual framework that includes some of the components required to guide this consolidation process in an uncertain environment. While this general framework can be applied to any euro area economy, our analysis of the Spanish economy in particular shows how a lack of fiscal consolidation poses a considerable risk of public debt in 2040 standing at higher levels than in the pre-COVID-19 period. Specifically, in a no-policy-change scenario with no fiscal consolidation, it is estimated that the probability of public debt being above 100% of GDP is 80%. Clearly, such risk would be lower were a fiscal consolidation plan consistent with the new European economic governance framework to be implemented. In this case, the probability of such event would only be around 20%.

The model proposed in this paper is a first step towards preparing a tool that enables the future path of public debt to be projected, by consistently including the framework of a deterministic theoretical model and the track record of the main cyclical and financial shocks that influence such future path. There are other ways this framework can be extended. First, the possible public debt reduction strategies should take into account the heterogeneity existing across the different instruments that characterise fiscal policy. For instance, possible future extensions of the DSA framework could distinguish between productive spending, with effects on potential GDP growth, and unproductive spending. Considering the possible impact of fiscal policy on long-term growth would yield more complex debt dynamics, consistent with the framework described in Mian, Straub and Sufi (2022).

Second, the economic effects of climate change, with a growing impact on public finances, in addition to the transition costs required to achieve greener economies, pose a challenge to fiscal conduct, which should be reflected in public debt sustainability analysis models.

Third, the structural changes in demographics, robotisation and the digitalisation of the economy generate further uncertainty over both the cost of debt financing and the

long-term rate of economic growth. Reflecting these additional sources of uncertainty is a challenge to be addressed in future iterations of the DSA framework.

Lastly, the possibility of incorporating other sources of uncertainty into the future path of the risk-free interest rate should be explored. Since the risk-free interest rate is a key determinant of the public debt ratio, stochastic shocks could likewise be introduced into that variable in the long run to assess debt sustainability amid uncertainty.

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Annex 1 The calculation of interest paid, debt and financing needs

The interest payable in a given year depends not only on the outstanding debt at the start of the period but also on the debt issued over the course of that year. In turn, the latter depends on how much interest is paid in the year, meaning that the two variables (interest and debt) are determined jointly. Moreover, the interest payable depends on the interest rate at which each unit of debt is issued, which varies over time and depending on the maturity of the debt. The latter also determines the volume of repayments in a given year and, by extension, gross financing needs, which are the sum of the debt maturing in the year and the net financing needs determined by the general government balance and stock-flow adjustments.

This Annex proposes a model for forecasting interest burden and debt drawing on the general government balance, market rates and a series of simplifying assumptions, in line with Martínez (2018).

The model is based on the following equations:⁴²

$$d = d^{\text{ant}} + d^{\text{nue}} \quad (\text{A1})$$

$$\text{int} = \left(d^{\text{ant}} + \frac{\text{amort}}{2} \right) i^{\text{ant}} + \frac{d^{\text{nue}}}{2} i^{\text{nue}} \quad (\text{A2})$$

$$d^{\text{ant}} = d_{t-1} - \text{amort} \quad (\text{A3})$$

$$d^{\text{nue}} = \text{amort} + n \quad (\text{A4})$$

$$n = -\text{sp} + \text{add} + \text{int} \quad (\text{A5})$$

Where total debt at the end of the period (d) is broken down into existing debt (d^{ant}) and new debt (d^{nue}). The difference lies in their respective yields. New debt refers to debt issued over the course of the period and, therefore, is remunerated at the market rates prevailing at that time (i^{nue}). In particular, i^{nue} will be a combination of short and long-term market rates, depending on the assumptions about the new debt's maturity at issuance. Conversely, the yields on existing debt (i^{ant}) depend on past rates at issuance and are therefore calculated based on the implied interest rate in year $t-1$.⁴³

Not all of the debt maturing in the period will do so at the start of the period, meaning a portion will also incur interest during the year. The simplifying assumption is that the debt matures uniformly over the period, and therefore its average balance in the year will be half the volume repayable and its yield is assumed to be equal that of the debt not repaid (existing debt). Similarly, not all new debt is issued at the beginning of the period

⁴² For simplicity, the time sub-index t is ignored, except where referring to variables relating to the previous period $t-1$.

⁴³ For more details, see Martínez (2018).

and therefore not all of it will incur interest over the full year. Applying the same simplifying assumption as above, the interest incurred on new debt would be only half the amount corresponding to a full year (equation A2).

The existing debt at the end of the period is the existing debt at the end of the previous period less the existing debt that matures during the period (equation A3). Therefore, a series of assumptions are required regarding the volume of debt that is repaid each year. In some cases, such as currency and deposits, we can assume that said debt does not mature and therefore its repayments are zero. Conversely, in the case of short-term debt (up to 1 year), all of the debt matures over the course of the year. In the case of some special debts, such as debt raised from the European Stability Mechanism (ESM) or the instrument for temporary Support to mitigate Unemployment Risks in an Emergency (SURE), the annual maturities are known. Lastly, for long-term debt, it is assumed that the proportion maturing in a given year is the inverse of the average life of that debt.

Meanwhile, the new debt at the end of the period will be equal to the financing needs in the year, which comprise the maturing debt (amort) and the net financing needs (n). In turn, the latter will be equal to the sum of the general government deficit (negative primary balance plus interest) plus the stock-flow adjustments (add).

Different types of debt ($i = 1, 2, \dots, J + L$) can exist in the model. Each debt type has its own interest rates (i_i^{ant} , i_i^{nue}) and amounts (d_i , $amort_i$, n_i , int_i).

For the debt types from $i = 1$ to $i = J$, the net (and gross) issuance is determined exogenously. Cases in point are currency and deposits and ESM and SURE debt.

For the debts types $i = J + 1$ to $i = J + L$, assumptions are made about their respective shares of total net issuance. This allows, for instance, the weight of a certain type of debt relative to the total to remain constant.⁴⁴ In these cases, the net issuance is determined simultaneously with total interest. Given that the sum of all debts must be equal to the total, it would suffice to perform $L-1$ assumption to determine the L debt types. Specifically, the following is assumed:

$$n_i = k_i * n, \text{ for } i = J + 1, J + 2, \dots, J + L - 1 \quad (A6)$$

Which, given also the exogenous assumptions about the debt types from $i = 1$ to $i = J$, entails:

$$n_{J+L} = n - \sum_{i=1}^{J+L-1} n_i \quad (A7)$$

Therefore, considering the equation (A2):

⁴⁴ Or increase (decrease) based on an assumed path.

$$\text{int} = \sum_{i=1}^{J+L} \text{int}_i = \sum_{i=1}^{J+L} \left(\left(d_i^{\text{ant}} + \frac{\text{amort}_i}{2} \right) i_i^{\text{ant}} + \frac{d_i^{\text{nue}}}{2} i_i^{\text{nue}} \right) \quad (\text{A8})$$

Using the equation (A4):

$$\text{int} = \sum_{i=1}^{J+L} \left(\left(d_i^{\text{ant}} + \frac{\text{amort}_i}{2} \right) i_i^{\text{ant}} + \frac{(\text{amort}_i + n_i)}{2} i_i^{\text{nue}} \right) \quad (\text{A9})$$

And solving the equations, we arrive at:

$$\text{int} = \sum_{i=1}^{J+L} d_i^{\text{ant}} i_i^{\text{ant}} + \sum_{i=1}^{J+L} \text{amort}_i \frac{(i_i^{\text{ant}} + i_i^{\text{nue}})}{2} + \sum_{i=1}^{J+L} \frac{n_i}{2} i_i^{\text{nue}} \quad (\text{A10})$$

The first two summations are pre-determined, i.e. they do not depend on the net issuance or on the interest payable. We then define:

$$A = \sum_{i=1}^{J+L} d_i^{\text{ant}} i_i^{\text{ant}} + \sum_{i=1}^{J+L} \text{amort}_i * \frac{(i_i^{\text{ant}} + i_i^{\text{nue}})}{2} \quad (\text{A11})$$

Such that:

$$\text{int} = A + \sum_{i=1}^{J+L} \frac{n_i}{2} i_i^{\text{nue}} \quad (\text{A12})$$

We separate the resulting summation into, first, debts whose net issuance is exogenously determined and, second, other debts.

$$\text{int} = A + \sum_{i=1}^J \frac{n_i}{2} i_i^{\text{nue}} + \sum_{i=J+1}^{J+L} \frac{n_i}{2} i_i^{\text{nue}} \quad (\text{A13})$$

And we separate $i = J + L$:

$$A + \sum_{i=1}^J \frac{n_i}{2} i_i^{\text{nue}} + \sum_{i=J+1}^{J+L-1} \frac{n_i}{2} i_i^{\text{nue}} + \frac{n_{J+L}}{2} i_{J+L}^{\text{nue}} \quad (\text{A14})$$

For $i = J + L$, we use:

$$n_{J+L} = n - \sum_{i=1}^J n_i - \sum_{i=J+1}^{J+L-1} n_i \quad (\text{A15})$$

Where we have separated the exogenous debts from the endogenous debts.

Replacing (A15) in (A14), we arrive at:

$$\text{int} = A + \sum_{i=1}^J \frac{n_i}{2} i_i^{\text{nue}} + \sum_{i=J+1}^{J+L-1} \frac{n_i}{2} i_i^{\text{nue}} + \frac{(n - \sum_{i=1}^J n_i - \sum_{i=J+1}^{J+L-1} n_i)}{2} i_{J+L}^{\text{nue}} \quad (\text{A16})$$

We separate the exogenous debts from the endogenous debts in the last term:

$$\text{int} = A + \sum_{i=1}^J \frac{n_i}{2} i_i^{\text{nue}} + \sum_{i=J+1}^{J+L-1} \frac{n_i}{2} i_i^{\text{nue}} - \frac{\sum_{i=1}^J n_i}{2} i_{J+L}^{\text{nue}} + \frac{(n - \sum_{i=J+1}^{J+L-1} n_i)}{2} i_{J+L}^{\text{nue}} \quad (\text{A17})$$

And we regroup the terms that affect the exogenous debts:

$$\text{int} = A + \sum_{i=1}^J \frac{n_i}{2} (i_i^{\text{nue}} - i_{J+L}^{\text{nue}}) + \sum_{i=J+1}^{J+L-1} \frac{n_i}{2} i_i^{\text{nue}} + \frac{(n - \sum_{i=J+1}^{J+L-1} n_i)}{2} i_{J+L}^{\text{nue}} \quad (\text{A18})$$

The second term of this equation is also pre-determined (meaning it does not depend on the amount of interest in the year) and therefore we call it B:

$$B = \sum_{i=1}^J \frac{n_i}{2} (i_i^{\text{nue}} - i_{J+L}^{\text{nue}}) \quad (\text{A19})$$

And the resulting equation is:

$$\text{int} = A + B + \sum_{i=J+1}^{J+L-1} \frac{n_i}{2} i_i^{\text{nue}} + \frac{(n - \sum_{i=J+1}^{J+L-1} n_i)}{2} i_{J+L}^{\text{nue}} \quad (\text{A20})$$

Now we incorporate the assumptions of equation (A6):

$$\text{int} = A + B + \sum_{i=J+1}^{J+L-1} \frac{k_i * n}{2} i_i^{\text{nue}} + \frac{(n - \sum_{i=J+1}^{J+L-1} k_i * n)}{2} i_{J+L}^{\text{nue}} \quad (\text{A21})$$

And we factor out the common factor from the last two terms:

$$\text{int} = A + B + \frac{n}{2} \left(\sum_{i=J+1}^{J+L-1} k_i i_i^{\text{nue}} + \left(1 - \sum_{i=J+1}^{J+L-1} k_i\right) i_{J+L}^{\text{nue}} \right) \quad (\text{A22})$$

Where the term in brackets is a weighted average of the rates at issue of the debt types from $i = J + 1$ to $i = J + L$, i.e. of the endogenous debts. Note that the weight of debt $J + L$ includes the weights of the exogenous debt. We call this weighted interest rate \widehat{i}^{nue} .

$$\widehat{i}^{\text{nue}} = \sum_{i=J+1}^{J+L-1} k_i i_i^{\text{nue}} + \left(1 - \sum_{i=J+1}^{J+L-1} k_i\right) i_{J+L}^{\text{nue}} \quad (\text{A23})$$

And the interest equation is:

$$\text{int} = A + B + \frac{n}{2} \widehat{i}^{\text{nue}} \quad (\text{A24})$$

Using equation (A5):

$$\text{int} = A + B - \frac{\text{sp} - \text{add}}{2} \widehat{i}^{\text{nue}} + \frac{\text{int}}{2} \widehat{i}^{\text{nue}} \quad (\text{A25})$$

And solving out for int, we obtain the interest based exclusively on the pre-determined or exogenous variables.

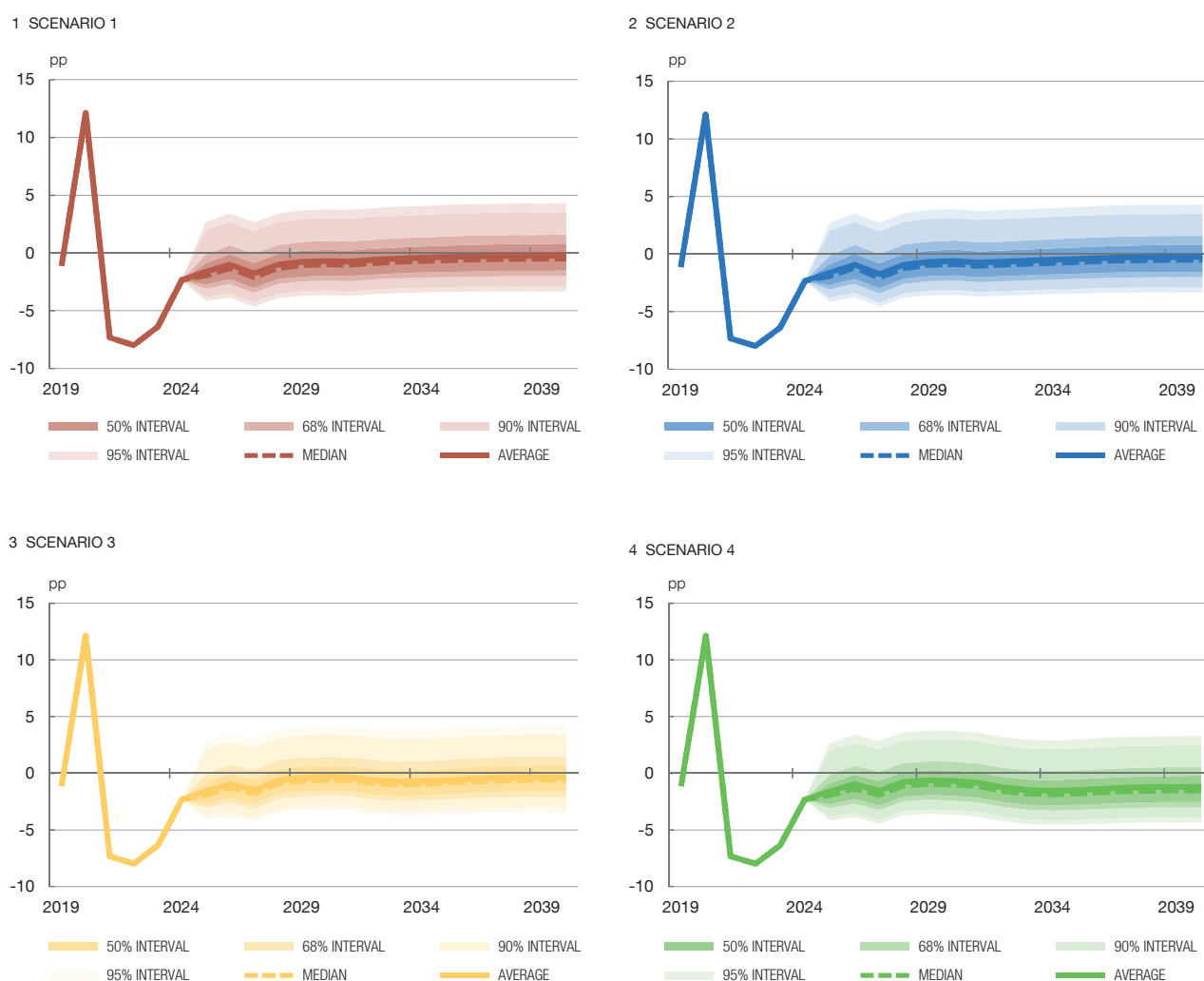
$$\text{int} = \frac{A + B - (\text{sp} - \text{add}) / 2 * \widehat{i}^{\text{nue}}}{(1 - \widehat{i}^{\text{nue}} / 2)} \quad (\text{A26})$$

Once int is known, the net financing needs (n), gross financing needs (d^{nue}) and total debt (d) can be calculated with equations (A1), (A4) and (A5).

Annex 2 Additional charts

Chart A.1

CHANGE IN THE INTEREST RATE-GROWTH DIFFERENTIAL UNDER DIFFERENT SCENARIOS (a)



SOURCES: INE, AIReF and Banco de España.

a The interest rate-growth rate differential is calculated using the implied interest rate on public debt and the nominal GDP growth rate. All of the scenarios envisage a deterioration in the primary structural balance to 2040 owing to the costs of ageing (pensions, health and long-term care). Scenario 1 refers to a fiscal policy effort consistent with the new measures envisaged in the 2023 pension system reform, but does not envisage activation of the automatic adjustment mechanism to increase the revenue raised from social security contributions in order to correct deviations in pension expenditure. Scenario 2 is the same as Scenario 1 but includes activation of the automatic adjustment mechanism. Alternatively, Scenario 3 assumes a fiscal policy that aligns with the new European economic governance framework. Scenario 4 is the same as Scenario 3 but with long-term potential GDP growth of 1.9% (instead of the 1.1% assumed in the other scenarios).

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