Issuing GDP-linked bonds: Supply and demand can match

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ISSUING GDP-LINKED BONDS: SUPPLY AND DEMAND CAN MATCH

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On 3 May 2018, the OECD Council invited Lithuania to become a Member. At the time of preparation, the deposit of Lithuania's instrument of accession to the OECD Convention was pending and therefore Lithuania does not appear in the list of OECD Members and is not included in the OECD zone aggregates.

On 25 May 2018, the OECD Council invited Colombia to become a Member. At the time of preparation, the deposit of Colombia's instrument of accession to the OECD Convention was pending and therefore Colombia does not appear in the list of OECD Members and is not included in the OECD zone aggregates.

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ABSTRACT/RÉSUMÉ

Issuing GDP-linked bonds: Supply and demand can match

This paper compares supply and demand to assess to what extent there can be a market for GDP-linked bonds (GLBs). For the government side, simulations illustrate the debt-stabilisation property of GLBs. These simulations consider shock persistence with a VAR structure and large events with shocks drawn from the residuals. Countries where shock persistence and the standard deviation of the interest rate – growth rate differential scaled with the debt level are higher reap more benefits from GLBs and hence can accept a larger risk premium on GLBs. For the investors' side, risk premia compensating for GDP volatility are calculated with a CAPM, considering not only the size of growth shocks and their correlation with market prices, but also their persistence. Calculations are made with simplifying assumptions going against the case of GLBs: in particular, the possible reduction in the default risk premium is ignored. Even so, both high-risk and low-risk countries can benefit from GLBs: the ones that have to pay a larger risk premium are those that need this insurance against debt crises the most.

JEL Classification: G12; H63
Keywords: GDP-linked bonds, public debt, euro area, asset pricing

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Émissions d'obligations indexées sur le PIB : l'offre peut rencontrer la demande

Le présent document propose une analyse comparative de l'offre et de la demande visant à déterminer s'il existe un marché pour les obligations indexées sur le PIB. Du côté de l'État, les simulations mettent en évidence l'effet positif de ces obligations sur la stabilisation de la dette. Ces simulations permettent d'apprécier la persistance des chocs au moyen d'un modèle VAR et les évènements de grande ampleur au moyen de chocs tirés à partir des résidus. Les pays où la persistance des chocs et l'écart-type du différentiel taux d'intérêt – taux de croissance multiplié par le niveau de l'endettement sont élevés tirent davantage profit des obligations indexées sur le PIB et peuvent donc accepter une prime de risque plus importante sur ces titres. Du côté des investisseurs, la prime de risque qui compense la volatilité du PIB est calculée au moyen d'un modèle d'équilibre des actifs financiers prenant en compte non seulement l'ampleur des chocs de croissance et leur corrélation avec les prix du marché, mais aussi leur persistance. Les calculs sont réalisés à partir d'hypothèses simplificatrices non favorables aux obligations indexées sur le PIB : en particulier, il est fait abstraction de la diminution possible de la prime de risque de défaut. Or, même dans ces conditions, les obligations indexées sur le PIB peuvent être bénéfiques aux pays à risque élevé comme aux pays à risque faible : ceux qui doivent s'acquitter d'une prime de risque plus élevée sont aussi ceux qui ont le plus besoin de cette couverture contre une crise de la dette.

Classification JEL : G12; H63
Mots clés : obligations indexées sur le PIB, dette publique, zone euro, tarification des actifs

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ISSUING GDP-LINKED BONDS: SUPPLY AND DEMAND CAN MATCH

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1. Introduction

1.   Government bonds indexed on the evolution of overall economic activity present attractive theoretical advantages. However, the take-up has been limited so far. This raises the question whether the low take-up can be explained by a mismatch between demand and supply: maybe governments never issue such bonds because the risk premium would be too high compared to the insurance against the effect of recessions that such bonds provide.

2.   This paper argues that supply and demand can match. From the government's point of view, debt simulations with and without GLBs are compared to gauge the acceptable increase in risk premia associated with these indexed bonds. This is defined as the GLB-specific premium that equates debt levels with and without GLBs at the 90th percentile. This means that GDP-linked bonds are effective in reducing extreme risks. In such a case, default risk is lowered, reducing the default component of the risk premium on all bonds. These simulations ignore this reduction and hence are likely to underestimate the gains. Even with this prudent simplification, estimates from a Capital Asset Pricing Model (CAPM) suggest that the risk premium investors will demand to compensate for growth risks is below this acceptable risk premium for governments. Hence there can be a market for GLBs.

3.   This shows that GLBs are a relevant debt instrument to be issued by governments in advanced economies in normal times, going beyond the practice observed so far: such instruments have usually been issued in emerging economies or as part of restructurings such as in Greece. Issuance during normal times in advanced economies can imply a lower premium, thanks to lower uncertainties and higher data reliability.

4.   Applications presented in this paper focus on the euro area because this instrument is particularly relevant in the absence of national-level monetary policy. The exchange rate cannot plunge in the case of a large negative shock, thereby increasing the difficulty to adjust debt stocks. Another interesting feature of GLBs is that they can be introduced by sovereign issuers within the existing EU treaties. As this paper suggests that each country reaps benefits from GLB issuance even if it acts individually, coordination is not necessary. And also, it is a cross-country risk sharing mechanism to the extent GLBs are held by foreigners, mitigating the effects of asymmetric shocks. In the euro area about one half of sovereign debt is held by foreigners (Arslanalp and Tsuda, 2012). If each euro area country issues GLBs, then a GDP-weighted portfolio of GLBs would replicate euro area GDP: asset managers may be interested in such portfolios with no exchange rate risk. GLB implementation can also be facilitated by the coherence of EU

statistics, as Eurostat ensures data are comparable, using a harmonised methodology. Last, within the existing fiscal rules, GLBs can provide additional fiscal space in times of stress.

5.   The remainder of this paper is structured as follows: Section (2) reviews the existing literature, (3) analysis how GLBs can stabilise the debt to GDP ratio i.e. it takes the government's perspective, (4) takes the investor perspective and estimates the risk premium that compensates for GDP volatility. Section (5) concludes.

2. Literature review

6.   State contingent debt instruments have a long history in the academic debate. The literature highlights different features of these instruments each catering to different objectives. Broadly speaking one could distinguish between the issuer and the investor perspective. Overall, this literature suggests that these instruments have attractive theoretical properties for governments and investors.

7.   Early contributions show the theoretical advantages of state contingent debt instruments, and GLBs specifically, both for investors and governments. For the government side, Bohn (1990) and Barro (1995) show that government liabilities should hedge against shocks that affect the government balance. Barro (1995) thus shows that letting aside moral hazard issues, in theory an optimal bond should be indexed on the tax base and government expenditure, and then mentions GDP as a more realistic indexation variable. They argue that the structure of public debt in general should be an instrument to smooth tax rates over states of nature. State-contingent bonds help in this respect as the government's budget is partly insulated from negative shocks with interest payments linked to economic performance. Hence, tax rates can be left unchanged. Borensztein and Mauro (2004) show that this shock absorption provides larger scope for counter-cyclical fiscal policy. Future tax revenues can be regarded as an asset that can be matched with GLBs: they could fit well into a sovereign asset and liability management framework (see Koc, 2014 for a discussion of the benefits and challenges of such frameworks). From the investors' side, Shiller (1993) proposed perpetual claims on GDP to follow aggregate income closely. Thus, purchasing power relative to GDP will be preserved and therefore insure investors against unforeseen macroeconomic events. These features might be particularly valuable for pension funds (Kamstra and Shiller, 2009). And in the case of debt overhang, Krugman (1988) highlights the benefits for investors that want to go beyond the trade-off between rolling over unsustainable debt and forgiveness as state-contingent bonds improve debt sustainability. In the context of a debt overhang, indexation payment was foreseen for upside scenarios only. These warrants are rather different from the GLBs discussed more recently which index payments on both upside and downside scenarios.

8.   GDP is a broad-based and generally accepted measure of a country's income, that is linked to repayment capacities with moderate adverse moral hazard problems (Borensztein and Mauro, 2004). There can be a trade-off between the absence of control and the need to choose a measure linked to the government balance (Barro, 1995). Because of moral hazard concerns, Krugman (1988) and Froot et al. (1989) discuss the advantages of indexation on truly exogenous variables, such as commodity prices, which can reflect debt repayment capacities in some countries. In a country with debt in foreign currencies or in the euro area, exports may also reflect to some extent the repayment capacity. At the same time, in the presence of such an instrument, ex-post, governments can prefer policies that reduce trade openness to reduce interest payments (Borensztein and Mauro, 2004). In the same vein, bonds indexed on consumption could affect the investment-consumption mix. With GLBs, the risk identified by Krugman (1988) that governments can be discouraged to make growth-friendly reforms that are costly to the policy maker is likely to be limited as governments can also reap political benefits of higher growth. And also, this would only be a short-sighted behaviour as this would make future GLB debt issuance costlier. Last, Borensztein and Mauro (2004) mention the role of official intervention to set statistical standards and verify the reliability of national accounts to avoid GDP misreporting.

9.   GLBs can decrease the probability of default as debt paths are less likely to become explosive (Borensztein and Mauro, 2004 among others). This has been emphasised recently in the light of high debt levels after the global financial crisis. For example, Barr et al. (2014) build on this reduction in default probability to show that GLBs increase the maximum sustainable debt level in a model with endogenous default and an explicit fiscal reaction function.

10.   Recent contributions focus on debt stabilization properties of GLBs, e.g. Blanchard (2016), Bank of England (2016), the International Monetary Fund (2017), Carnot and Sumners (2017) and Banque de France (2017). These studies use Monte Carlo simulations to illustrate the debt stabilisation properties of GLBs. This recent wave of papers was sparked by the G20 September Summit in 2016 which called upon the IMF to "explore the technicalities, opportunities, and challenges of state-contingent debt instruments, including GDP-linked bonds" (G20 communique, Hangzhou summit, 5 September 2016). Carnot and Sumners (2017) focus explicitly on euro area countries. Blanchard (2016) concludes that the current period would present a good starting point for the issuance of GLBs in advanced economies.

11.   This interest in GLBs has stimulated work on implementation. IMF (2017) and Bank of England (2016) discuss a wide range of practical questions, such as payment structure, GDP measurement and historical experiences with state contingent debt and GLB market development. Legal questions are addressed in the so called "London Term Sheet". In this document, potential issuers and investors outline key design features of GLBs and provide some form of blueprint for the contractual set-up (ICMA, 2017). In light of recent research, the G20 acknowledges that GLBs increase flexibility of economic policy in economically difficult times (G20, 2017). It highlights a yet insufficient understanding of the demand side and points to practical design choices that need to be made to issue GLBs.

12.   Four types of risk-premia are usually considered in the literature discussing the cost of GLBs (e.g. Blanchard et al., 2016). A default risk premium, similar to the one for vanilla bonds (the usual bonds with fixed nominal payments), can be lowered for all bonds in the presence of GLBs thanks to their debt stabilisation property: Chamon and Mauro (2005) estimate the reduction of the default probability associated with the rise of the share of indexed debt, assuming risk neutral investors. There can be a liquidity premium if the market is not sufficiently deep, and a novelty premium at the beginning, as investors lack historical data. Last, there is a risk premium that compensates investors for the risk associated with GDP volatility. The liquidity and novelty premium are temporary only and thus will not be crucial in the long run. Research on the introduction of inflation-linked bonds suggests that both declined significantly after a short transition period. The novelty premium for inflation linked bonds in advanced economies was estimated to be around 100 basis points (BOE, 2015). According to the IMF the novelty premium on GLBs in the specific case of Argentina halved within one year (Costa et al., 2008). The size of the novelty premium is difficult to anticipate, but the dispersion of the GDP volatility risk premium estimates across models may give some indication on the price uncertainty during an initial learning phase.

13.   The literature on GLB pricing remains fairly scarce, probably because of the limited GLB take-up so far. Some apply the standard and widely used capital asset pricing model (CAPM) introduced by Treynor (1961, 1962). In this approach, the risk premium increases with the size of GDP shocks and its correlation with the reference market. This premium compensates for systemic risk, i.e. the overall market risk that cannot be diversified. Applications by Borensztein and Mauro (2004) and Kamstra and Shiller (2009) suggest a risk premium of around 100 basis points for Argentina and 150 basis points for the United States, respectively. The relatively moderate GDP-volatility risk premium for Argentina reflects the low correlation between the reference US financial market and Argentina's growth. More broadly, Cabrillac et al. (2017) show that GLBs can be attractive compared to stock markets of the same country thanks to its moderate volatility and moderate correlation with the United State market used as a reference. Miyajima (2006) finds an even smaller risk premium with a similar CAPM approach, and confirms the magnitude with a Consumption Capital Asset Pricing Model. With a CAPM approach again, Bowman and Naylor

provide several estimates that reveal a larger risk premium that depends on the reference market choice (2016). With a different pricing approach based on the Black-Scholes formula, Kruse et al. (2005) find that the behaviour of the log-returns of GDP-linked bonds is very similar to that of vanilla bonds. With the certainty equivalent method that is conservative as it ignores the fact that the correlation between GDP growth and asset price changes is moderate, the IMF (2017) finds a higher volatility risk premium. Last, Consiglio and Zenios (2017) model the pay-offs with a stochastic linear programme on a state-space scenario tree to price GLBs. They also find a moderate risk premium.

3. The government side: Reduction of debt uncertainties

14.   From the government side, GLBs provide insurance against adverse economic conditions. A negative shock leads to an automatic decrease of interest payments. In extreme cases, it can prevent debt dynamics from becoming explosive and thus reduces the probability of default. This section explains why the debt to GDP ratio is less volatile with GLBs, presents debt path simulations and estimates the acceptable risk premium for governments.

3.1. Debt dynamics with and without GLBs

15.   Government debt evolves according to the formula below:

(1) $d_t = \frac{1+r_t}{1+g_t} d_{t-1} - pb_t$

where the debt to GDP ratio at time t is d_t, r is the nominal effective interest rate on government debt, g_t the nominal GDP growth rate and pb_t the primary balance as a fraction of GDP. In providing a stylised illustration of the effect of GLBs on the debt dynamic, it is helpful to consider the case in which the whole public debt stock consists of GLBs the return of which replicates the growth rate exactly. In practice, long-term GLBs can come quite close to this case. Then, the formula would reduce to:

(2) $d_t = d_{t-1} - pb_t$

The change in the debt to GDP ratio with conventional bonds is:

(3) $\Delta d_t = d_t - d_{t-1} = \frac{1+r_t}{1+g_t} d_{t-1} - pb_t - d_{t-1} = \frac{r_t - g_t}{1+g_t} d_{t-1} - pb_t \approx (r_t - g_t) d_{t-1} - pb_t$

The variance of the change in the debt to GDP ratio is then:

(4) $Var(\Delta d_t) = \underbrace{d_{t-1}^2 Var(r_t - g_t)}_{(1)} + \underbrace{Var(pb_t)}_{(2)} - \underbrace{2 d_{t-1} Cov((r_t - g_t), pb_t)}_{(3)}$

If the GLB links the interest rate directly to the growth rate such that $r - g$ becomes a constant, the expression for the variance collapses to:

(5) $Var(\Delta d_t) = Var(pb_t)$

16.   One can see from (4) and (5) the main benefits of GLBs for governments: it can reduce the uncertainty around the future debt path. For instance, if one assumes there is a critical threshold beyond which debt is unsustainable, GLBs can reduce the probability of default to the extent that they reduce the probability of crossing the threshold.

17.   From the two expressions above one can identify the conditions under which countries benefit the most from GLBs. The first part of equation (4) is the variance of the difference between the effective interest rate and the growth rate scaled by the square of the debt level. Consequently, the stabilising effect of GLBs is higher the higher the initial debt level. Moreover, $Var(r_t - g_t) = Var(r_t) + Var(g_t) - 2 * Cov(g_t, r_t)$ and therefore, the stabilising effect will be higher the more negative the covariance between growth and interest rates. This is intuitive as it means that refinancing conditions in the absence of GLBs tend to deteriorate in the event of a negative shock. The second term (2) is the variance of the primary balance which remains unaffected by the issuance of GLBs unless one assumes governments might alter their behaviour. The third term reflects the government's response to changes of $r - g$. The primary balance is under the discretion of the government. A negative covariance between $r - g$ and the primary balance reflects in most cases a counter-cyclical fiscal stance. With GLBs this behaviour does not come at the cost of a volatile debt to GDP ratio: they thus promote good policy.

18.   Addressing the risk of the toxic mix of rising interest rate with a decline in economic output is even more crucial in the euro area. This can be illustrated by the correlation between nominal growth and nominal interest rates (Figure 1). Figure 1 shows the change in this correlation after the global financial crisis, a common shock for euro area and non-euro-area countries. Under stress, this correlation decreased and even became negative in many euro area countries: the decline of economic activity could go together with low inflation and higher default risk premia. By contrast, in countries outside the euro area under stress such as Iceland, the rise of inflation and the presence of a lender of last resort helped to keep a positive correlation between nominal interest rates and nominal growth rates after 2007.

Figure 1. The growth-interest rate correlation turned negative in crisis euro area countries after the Global Financial Crisis

Correlation between annual nominal 10-year sovereign bond yields and lagged nominal growth
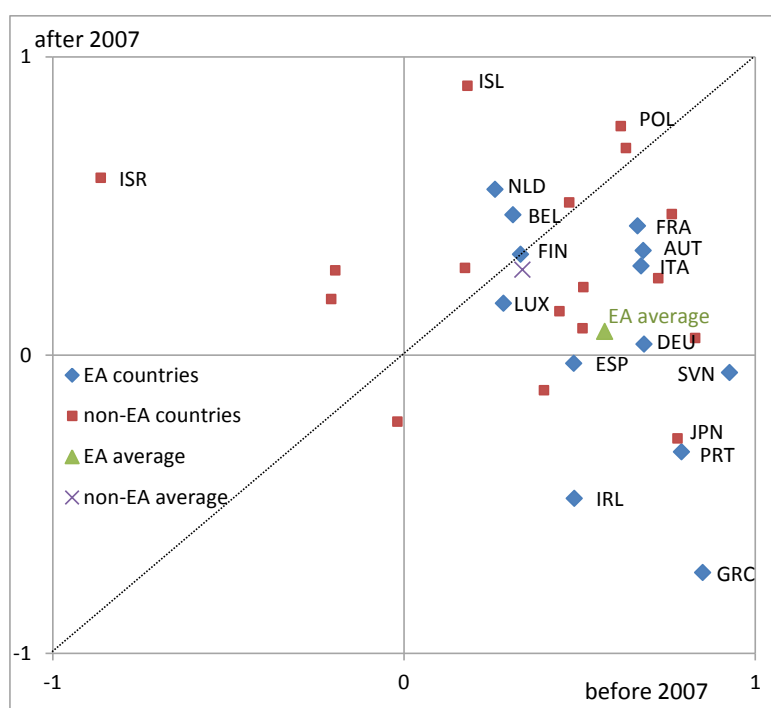
Note: The correlation between nominal 10-year sovereign bond yields and contemporaneous nominal growth shows a similar pattern.

Source: OECD Analytical Database.

3.2. Debt path simulations

19.   Debt to GDP ratio paths with and without GLBs are compared to gauge what is an acceptable risk premium. Similar comparisons were presented before by Blanchard et al. (2016), the Bank of England (2016) and Cabrillac et al. (2017). The acceptable risk premium depends critically on the country-specific stabilisation properties of GLBs which is the combination of the factors discussed in the previous sub-section. As the relevant determinants of the stabilisation effect vary a lot across countries, acceptable risk premia differ substantially.

3.2.1. Simulation framework

20.   The framework is similar to Bank of England (2016) and Blanchard et al. (2016). As in these papers, growth, the interest rate and the primary balance, all in nominal terms, are simulated in scenarios with and without GLBs to compare debt developments. There are two main differences with respect to the simulation technique. The first is that autocorrelation is captured with a vector autoregression (VAR) representation estimated with quarterly data from 1992 till 2016. The second one is that simulations are semi-parametric: shocks are not drawn from simulated residuals that follow a specific distribution but instead from the residuals of the VAR estimation. The semi-parametric approach replicates the whole distribution of past shocks and hence it includes large tail events as observed in historical data. By contrast, BOE (2016) and Blanchard et al. (2016) use past annual data to estimate the variance covariance matrix for growth, the effective interest rate and the primary balance. They simulate data assuming a multivariate normal distribution without autocorrelation. Here, alternative simulations with an assumption of normality and/or without the VAR structure are compared with the baseline approach to discuss the importance of shock persistence and of tail events.

21.   This paper follows Bank of England (2016) and Blanchard et al. (2016) in their assumption that primary balance and GDP developments are similar in the presence of GLBs. This is likely to be the case if the share of GLBs is moderate, assuming that governments' fiscal stance behaviour does not react to small structural changes. If the share of GLBs becomes large, the government may take advantage of the reduction in debt uncertainty to rely more on fiscal policy to mitigate shocks. As briefly discussed below, in some cases where governments usually run pro-cyclical fiscal policy that contain debt uncertainties, the main benefit of GLBs may indeed be a reduction in GDP volatility rather than a reduction in debt uncertainty. In the cost-benefit analysis discussed here, ignoring the possibility that governments run more counter-cyclical fiscal policies in the presence of GLBs can lead to overestimate the debt reduction uncertainty, to miss a benefit (lower GDP volatility) and to overestimate the market risk premium associated with GDP volatility.

22.   The following VAR is estimated:

$$(6) \qquad X_t = \vartheta + A_{t-1} X_{t-1} \dots + A_{t-p} X_{t-p} + \varepsilon_t$$

where $X = \begin{pmatrix} r-g \\ pb \end{pmatrix}$ and ϑ is a constant. Combining $r - g$ yields stationary time series over the period between 1992 and 2016 for most countries and such a bivariate VAR is parsimonious. It comes at the expense of losing some information, however. In theory, the primary balance cannot behave explosively. Still, augmented Dickey-Fuller tests do not confirm this: for most countries the null hypothesis of non-stationarity cannot be rejected. As a robustness check, results for simulations with the primary balance in first differences are reported and stabilisation effects are quite similar (Annex Figure A1.1). For the sake of parsimony, the lag order is the minimum of those selected by Akaike, Final Prediction Error, Hannan-Quinn and Schwarz criteria for each country. OECD data are used for the period between 1992 and 2016. For debt the Maastricht definition is used.

23.   In the baseline, $r - g$ and *pb* are simulated until 2030 starting in the first quarter of 2017. Shocks ε_t are drawn from the residuals of the estimation period. The unconditional mean is subtracted from the simulated data. The respective figures from the IMF's World Economic Outlook are then added to the demeaned data, i.e. the simulations are anchored to the IMF's long-term scenario. As the IMF's scenario projects only five years ahead subsequent years are an extrapolation of the last projection period.

3.2.2. Debt path simulation with GLBs

24.   The interest rate of the stylized GLB r_t^{GLB} is indexed on GDP:

(7) $r_t^{GLB} = coupon + rp + g_t$

where g_t is the GDP growth rate in period t which is stochastic. The *coupon* and the GLB-specific risk premium rp are fixed components determined when the GLB is issued. In the simulations the coupon is adjusted such that in expectations a GLB with rp equal to zero would yield the same return as a vanilla bond. rp is the difference between the risk premium for GLBs and the risk premium of a vanilla bond. This includes a GDP volatility premium, and temporary liquidity and novelty premia, and excludes the default risk premium that can exist for vanilla bonds. This GLB-specific risk premium captures the cost of replacing vanilla bonds by GLBs, holding the default risk premium constant. The coupon can be negative if the expected growth rate is higher than the expected interest rate paid on the respective countries' government bond. This is the case for many countries as the low interest rate environment is expected to prevail.

25.   The debt to GDP ratio with GLBs evolves as follows:

(8) $d_t^{GDP} = \frac{1+coupon+rp+g_t}{1+g_t} d_{t-1}^{GDP} - pb_t$

which can be written as

(9) $d_t^{GDP} = \left(1 + \frac{coupon+rp}{1+g_t}\right) d_{t-1}^{GDP} - pb_t$

The fraction in the brackets does not vary much and can be approximated by a constant:

(10) $\frac{coupon+rp}{1+g_t} \approx (1 - g_t) * (coupon + rp) \approx (1 - \bar{g}) * (coupon + rp)$

where g_t is replaced by $\bar{g}$ which is the average growth rate. Hence, the debt to GDP ratio evolves in the following manner:

(11) $d_t^{GDP} = (1 + (coupon + rp)(1 - \bar{g}))d_{t-1}^{GDP} - pb_t$

Only the primary balance remains stochastic. For the simulations, a share $\alpha = 50\%$ of conventional bonds is replaced by GLBs. Linearising the debt development under conventional bonds[2] one obtains the following expression for the debt to GDP ratio:

(12) $d_{i,t} \approx \alpha * \left((1 + (1 - \bar{g}) * (coupon + rp))d_{i,t-1}\right) + (1 - \alpha) * \left(1 + r_{i,t} - g_{i,t}\right)d_{i,t-1} - pb_{i,t}$

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2. $d_t = \frac{1+r_t}{1+g_t} d_{t-1} - pb_t \cong (1 + r_t - g_t)d_{t-1} - pb_t.$

3.2.3. Results

26.   Potential debt to GDP ratio realisations can be visualized with fan charts, as illustrated here with the cases of Germany and Spain (Figure 2). The decreased variance of the debt to GDP ratio with GLBs is reflected by a smaller width of the fan charts. Not surprisingly, magnitudes vary substantially as countries are heterogeneous with respect to the relevant determinants. In this example, debt uncertainty is larger in Spain because shocks are more persistent.

Figure 2. Debt-to-GDP ratio simulations
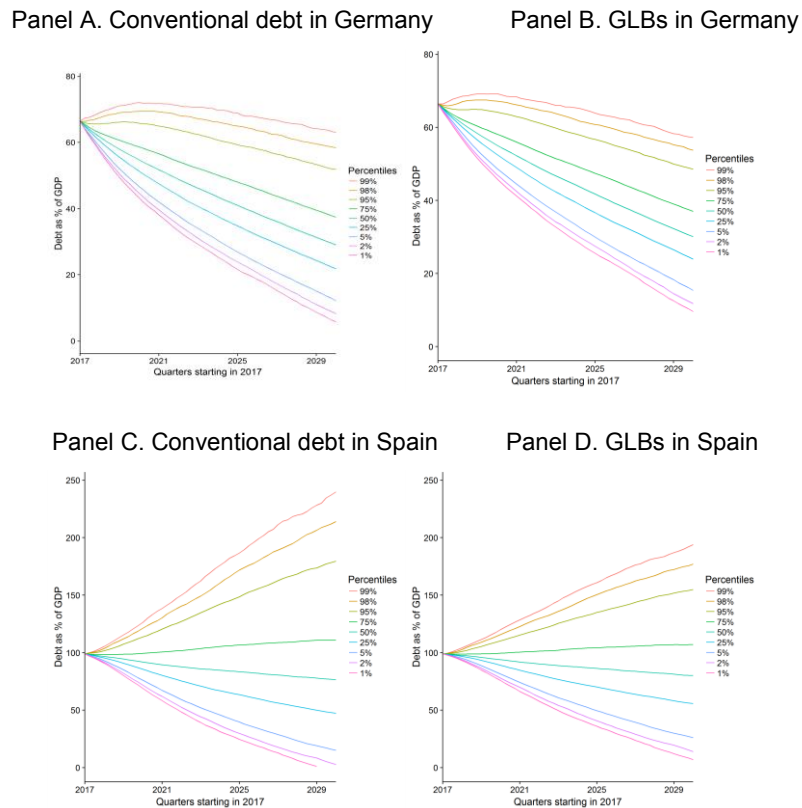
Panel A. Conventional debt in Germany   Panel B. GLBs in Germany

Panel C. Conventional debt in Spain   Panel D. GLBs in Spain

Note: Simulated debt to GDP ratios are built on a non-Gaussian quarterly bivariate VAR with the primary balance and the gap between the growth rate and the effective interest rate.

27.   The difference between the width of the fan-charts with and without GLB at the end of the simulation period reflects the stabilisation effect for each country (Table 1). This stabilisation effect is the largest in Greece, Ireland and Spain.

Table 1.   GLB debt stabilisation effect

Country	Conv bond: Fan-chart width	GLB: Fan-chart width	Stabilisation effect
AUT	34,4	27,5	6,9
BEL	83,8	88,4	-4,6
DEU	57,2	47,6	9,5
ESP	243,9	187,1	56,8
FIN	116,7	108,8	7,9
FRA	65,2	53,8	11,4
GRC	343,0	211,7	131,3
IRL	249,6	196,3	53,4
ITA	80,2	61,3	18,9
LUX	27,7	27,8	-0,1
NLD	95,0	86,0	9,0
PRT	150,3	96,8	53,5
SVK	73,2	67,1	6,2
SVN	152,4	119,7	32,7

Note: The width of the fan-charts is the difference between debt in the last period at the 99th percentile and at the first percentile. Simulated debt to GDP ratios are built on a non-Gaussian quarterly bivariate VAR of the primary balance and the gap between the growth rate and the effective interest rate.

28.   Belgium is a particular case in these simulations as GLBs do not reduce debt uncertainty. This is because its government has run a pro-cyclical fiscal stance to keep debt quite stable in the absence of GLBs. One benefit of GLBs is rather to give room for counter-cyclical fiscal policy. The third term of equation (4) indeed hints at a possibly adverse effect on the distribution of the debt to GDP ratio: from (4) one can show that if the following inequality holds, the variance of Δd_t increases as a result of the replacement of vanilla bonds by GLBs:

(13) $d_{t-1} sd(r_t - g_t) < 2\rho_{(r-g),pb} sd(pb)$

29.   For this inequality to hold, the correlation $\rho_{(r-g),pb}$ between $r - g$ and the primary balance needs to be positive: the primary balance is pro-cyclical. This inequality is more likely to hold if debt is low, the dispersion of the interest rate/growth rate gap is low and the dispersion of the primary balance is large. The effect on the debt to GDP ratio of a widening gap between $r - g$ is then offset by the primary balance.

30.   More broadly, these simulations reveal that GLBs provide additional fiscal space when growth slows down unexpectedly. This can help to conduct a more pronounced counter-cyclical stabilisation policy in all countries. This paper assumes that governments would still react in the same way to growth shocks (the matrix of variance-covariance of shocks is the same). This is likely to be realistic in the medium run as it can take time for GLBs to provide sizeable shock absorption, and hence it can also take time for policy makers to change their behaviour accordingly. Fall and Fournier (2015) illustrate the trade-off between a counter-cyclical fiscal stance and debt uncertainty reduction. If governments use the additional fiscal space to pursue a more counter-cyclical policy, then the reduction of debt-to-GDP uncertainty would be less pronounced. The gain would take the form of a lower GDP volatility. This would

reduce the GLB risk premium, and hence an assessment of the effect of GLBs with an endogenous fiscal stance should be made with a model that also takes into account this channel. This goes beyond the scope of this paper.

31.   The marginal effect of GLBs can vary with their share in the debt stock. This sensitivity is negligible for most but not all countries. Building on equation (12), one can show that the marginal stabilization effect decreases with the share of GLBs:

$$(14) \qquad Var(\Delta d_t) \approx d_{t-1}^2 (1-\alpha)^2 Var(r_t - g_t)) - 2(1-\alpha)d_{t-1}Cov((r_t - g_t), pb_t) + Var(pb_t)$$

$$(15) \qquad \frac{\partial Var(\Delta d_t)}{\partial \alpha} \approx \underbrace{-2d_{t-1}^2(1-\alpha)Var(r_t - g_t))}_{\text{Decreasing marginal reduction in debt uncertainty}} + \underbrace{2d_{t-1}Cov((r_t - g_t), pb_t)}_{\text{does not depend on the share } \alpha}$$

32.   This formula shows that the link between the GLB share and debt stabilisation depends on the debt ratio, on the variance of the interest rate/growth rate differential and on its covariance with the primary balance. In practice the relationship between the stabilisation effect and the share of GLBs is explored with simulations, and turns out to be roughly linear in most countries (Annex Table A1.1). Luxembourg is an exception, where the marginal gain of GLBs would peak at a low share. In Italy and Slovakia, decreasing marginal returns would materialise if the share of GLBs is very high.

3.3. The acceptable risk premium

33.   GLBs provide insurance against the budgetary effects of a negative shock: they transfer risk from the government to the holders of the GLB. A decrease in the probability of default or smoother tax rates over time can increase social welfare. The insurance perspective of GLBs is described in a first step without a GLB-specific risk premium. The distribution of the debt-to-GDP ratio at the end of the simulation period becomes narrower (Figure 3).

Figure 3. Density plots: The reduction of the debt tail risk by 2030 with GLBs
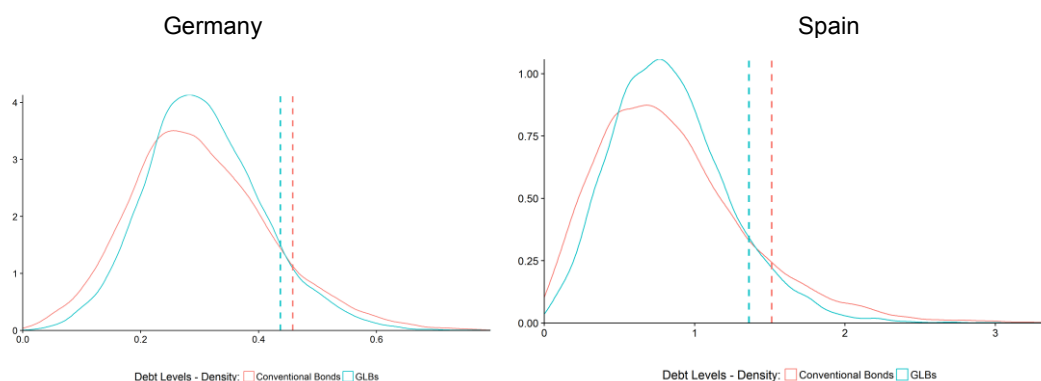
Note: The dashed lines are drawn at the 90th percentile of debt ratio distributions with and without GLBs. Simulated debt to GDP ratios are built on simulated non-Gaussian quarterly bivariate VAR of the primary balance and the gap between the growth rate and the effective interest rate.

34.   Investors will demand a risk/insurance premium that compensates them for the stochastic return. With the simplifying assumption that the default risk premium is not reduced, which goes against the GLB case, the median debt level, i.e. the debt level at the 50th percentile will be higher with GLBs as compared to vanilla bonds and the density plot for GLBs will be shifted to the right. As the distribution gets narrower with GLBs there can be a percentile at which the debt levels with and without GLBs coincide. Beyond that percentile the debt level with GLBs will be lower as compared to the debt level at the respective percentile without GLBs.

35.   The risk premia which equate the debt levels at the 90th percentile vary from 0 to 332 basis points (Table 2). This implies that in the worst 10% of realisations, the debt to GDP ratio is lower with GLBs. The objective here is debt stabilisation: the government insures itself but has to pay an insurance premium. That is costly in normal times in this simplified calculation that ignores the possible reduction in default risk premia. The premia for Belgium and Luxemburg are zero since the width of the fan charts does not become smaller with GLBs. As explained above the rational for GLBs is only to give room for more counter-cyclical policy in these countries, an outcome that is not captured by the estimate of the critical risk premium.

Table 2.   Critical risk premium

Country	Reduction in debt uncertainty, in GDP point	Critical risk premium – Baseline, in per cent	Debt level at the 90th percentile for GLBs with critical risk premium
AUT	6,9	0,36	67,0
BEL	-4,6	0	127,0
DEU	9,5	0,64	45,8
ESP	56,8	1,92	151,3
FIN	7,9	0,4	81,6
FRA	11,4	0,48	87,9
GRC	131,3	2,96	255,1
IRL	53,4	3,32	116,5
ITA	18,9	0,28	117,9
LUX	-0,1	0	33,3
NLD	9,0	0,76	60,7
PRT	53,5	1,12	149,4
SVK	6,2	0,68	45,9
SVN	32,7	1,72	111,8

Note: The reduction in debt uncertainty, critical risk premium and debt levels are those of the last year of the simulation period. Simulated debt to GDP ratios are built on simulated non-Gaussian quarterly bivariate VAR of the primary balance and the gap between the growth rate and the effective interest rate.

36.   For many countries, the debt level at the 90th percentile is typically not associated with sovereign crisis in advanced economies (Table 2, column 3). By contrast, for a few countries that are already deeply indebted a critical threshold for the debt to GDP ratio beyond which they are forced to default might still lie below the 90th percentile. Hence, if the risk premium is equal to those reported in the table above, the critical default level will be reached with a higher probability with GLBs. This is why GLBs appear as a promising instrument for those countries in which debt levels are high "but not catastrophically high" (Blanchard et al. 2016). In highly indebted countries, GLBs may still work if this instrument delivers a sizeable reduction in the default risk premium. This channel is difficult to model.

37.   There is a small discrepancy between median debt outcomes with the GLB and vanilla bonds before one introduces the GLB-specific risk premium. Among other things this might reflect non-linearities in the debt dynamic and a difference between median and mean outcomes. In sum, the simulated median debt ratios in the last period are typically higher with GLBs (Table 3). For instance, in the Austrian case, the median debt ratio with GLBs is 0.46 percent of GDP above the median with conventional bonds. Since for most countries the interquartile range of debt ratios is not very large, the percentile for which debt with and without GLBs is the same is often substantially greater than 0.5 (Table 3). Therefore, the

acceptable risk premium that equates debt levels at the 90th percentile may be higher than those reported in the table above.

Table 3. Median discrepancy between simulations with and without GLBs

Country	Percentage difference in median debt ratios in the last period (GLB – Conv)	Percentile for which debt with and without GLBs is the same	Interquartile range with vanilla bonds
AUT	0,46	0,63	9,83
BEL	4,28	0,00	24,50
DEU	1,11	0,69	15,85
ESP	3,62	0,64	63,78
FIN	1,17	0,73	33,69
FRA	0,99	0,66	18,48
GRC	2,22	0,54	92,16
IRL	1,83	0,58	70,94
ITA	4,48	0,81	23,57
NLD	0,70	0,62	26,5
LUX	0,56	0,00	7,93
PRT	5,89	0,70	41,16
SVK	0,06	0,53	19,4
SVN	0,21	0,52	42,11

3.4. What drives the results?

38.   The size of the acceptable risk premium and the stabilisation effect are closely linked. Section 3.1 described the conditions that render the issuance of GLBs most beneficial in terms of debt stabilisation. The analysis of the simulation results echoes the conclusions from these theoretical considerations.

39.   There is a negative link between the acceptable risk premium and the correlation between the interest and growth rate (Figure 4, Panel A).[3] This negative relationship is intuitive: the GLB creates a perfect correlation between growth and interest rates. Thus, the smaller the correlation ex ante the bigger the difference due to the introduction of GLBs. Still, the correlation between the interest and growth rate is part of the overall variance of $r - g$. If the standard deviation of $r - g$ is scaled with the respective debt levels the relationship is even stronger, as one would expect from equation 4 (Figure 4, Panel B). There are a couple of outliers, such as Belgium a little further away from the line. This is because the primary balance did not react counter-cyclically in the estimation period but rather off-set shocks to (r-g). As explained in Section 3.1 this can lead to a higher variability of the debt to GDP ratio with GLBs as compared to conventional bonds. On the contrary, the Spanish primary balance reacted particularly strongly to negative shocks. The correlation between the primary balance and $(r - g)$ amounted to -0.8 between 1992 and 2017. This form of active stabilization policy came at the expense of a volatile debt to GDP ratio.[4]

---

3.   For the correlation real growth and real interest rates are used as inflation as 'common factor' masks the relationship.

4.   Term (3) of equation (4) in 2.1 vanishes with GLBs. Spain benefits disproportionally from this effect.

**Figure 4. The reduction of debt uncertainty is larger
when the interest rate growth rate gap is more volatile and debt is higher**

Panel A.   Panel B.
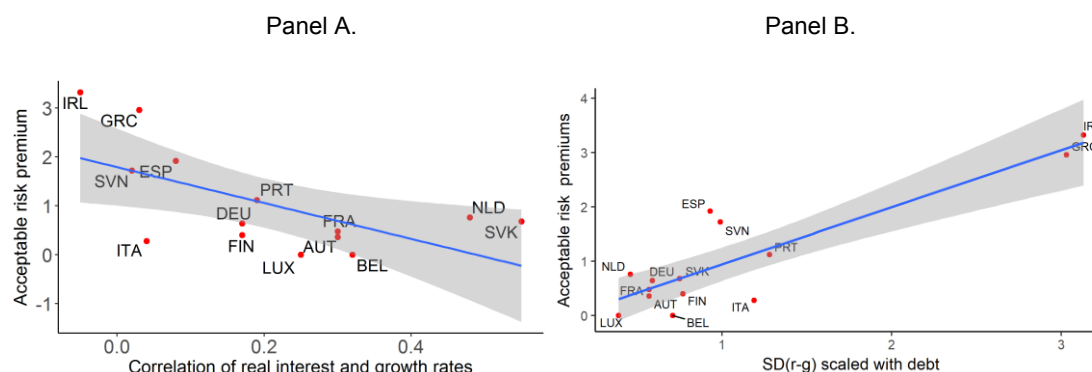
Note: The stabilisation effect is the reduction in the gap between the 99th and the first percentile at the last year of the simulation period. Simulated debt to GDP ratios are built on simulated non-Gaussian quarterly bivariate VAR of the primary balance and the gap between the growth rate and the effective interest rate.

40.   To identify the drivers of the results and to compare the baseline simulation with other papers such as Bank of England (2016) and Blanchard et al. (2016), the baseline is modified in two steps. First the semiparametric shocks are replaced by Gaussian shocks. The parameters of the Gaussian are estimated from the residuals. This modification of the baseline still accounts for autocorrelation as it still uses the same VAR. Fat tails however are no longer accounted for.

41.   The acceptable risk premium from the baseline is close to the one from the parametric VAR with Gaussian shocks: the stabilisation effect is very similar between the two methodologies (Figure 5, Panel A). The cross-country average stabilisation effect is 23.5 in the baseline approach and 24.1 in the Gaussian VAR. The correlation between the stabilisation effects is 0.99: the results are not driven by large shocks or "tail events". This is not surprising because the criterion focuses on the 90th percentile of the distribution, disregarding the size of those adverse scenarios beyond the 90th percentile. A close look at the tail of the distribution reveals a tiny difference (Figure 6). For each of these four panels, the tail risk is observed on the right side, while more moderate crises are observed on the left side. Under the non-Gaussian simulations, the tail risk is larger as expected. The reduction of this tail risk with GLBs is also larger under these non-Gaussian simulations. At the same time, the Gaussian simulations suggest a slightly larger risk reduction in the case of more moderate crises.

42.   By contrast, results are substantially different with a methodology that is similar to the one used by the Bank of England (2016) and Blanchard et al. (2016). The data are now simulated with annual data and without the VAR so that autocorrelation is no longer accounted for. The comparison between the acceptable risk premiums from the Gaussian VAR and the acceptable premia obtained from the methodology used by the Bank of England singles out the role of autocorrelation (Figure 5, Panel B). Numerous countries are significantly below the 45-degree line: autocorrelation does affect the results. The cross-country average stabilisation effect using the multivariate normal distribution without VAR is 16.5 compared to 23.1 in the Gaussian VAR and the correlation between the stabilisation effects is 0.92. Using annual data in the case of the multivariate normal distribution already accounts for part of the autocorrelation that can be found in the quarterly data. Using the same approach with quarterly data yields a significantly lower cross-country average stabilisation effect of a mere 11.35.

Figure 5. Sensitivity of acceptable risk premiums: Persistence matters more than tail events

Panel A. Comparing acceptable risk premia with the baseline and with Gaussian shocks:
Tail events do not matter much
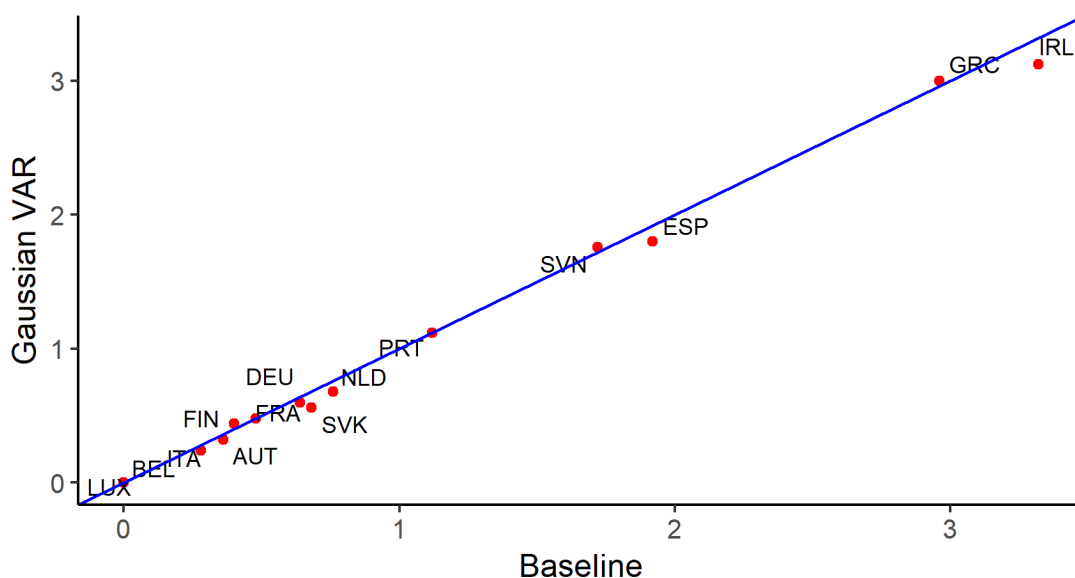
Panel B. Comparing acceptable risk premia with and without the VAR structure: Persistence matters
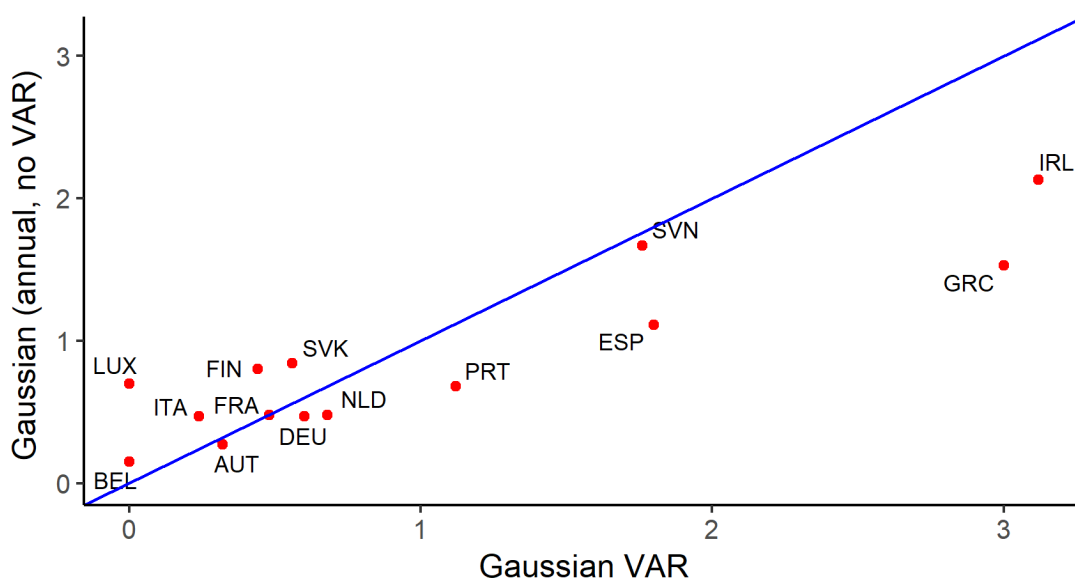
Note: For the Gaussian with annual data, with no VAR, the results in this paper differ slightly from the results presented by the Bank of England: different data are used and the covariance between interest rates, growth and the primary balance was estimated in this paper from data between 1992 and 2017 while the Bank of England used data from 2001 till 2016.

Figure 6. The tail of the debt-to-GDP ratio simulations without and with the Gaussian assumption

Panel A: non-Gaussian shocks, Germany

Panel B: Gaussian shocks, Germany

Panel C: non-Gaussian shocks, Spain

Panel D: Gaussian shocks, Spain
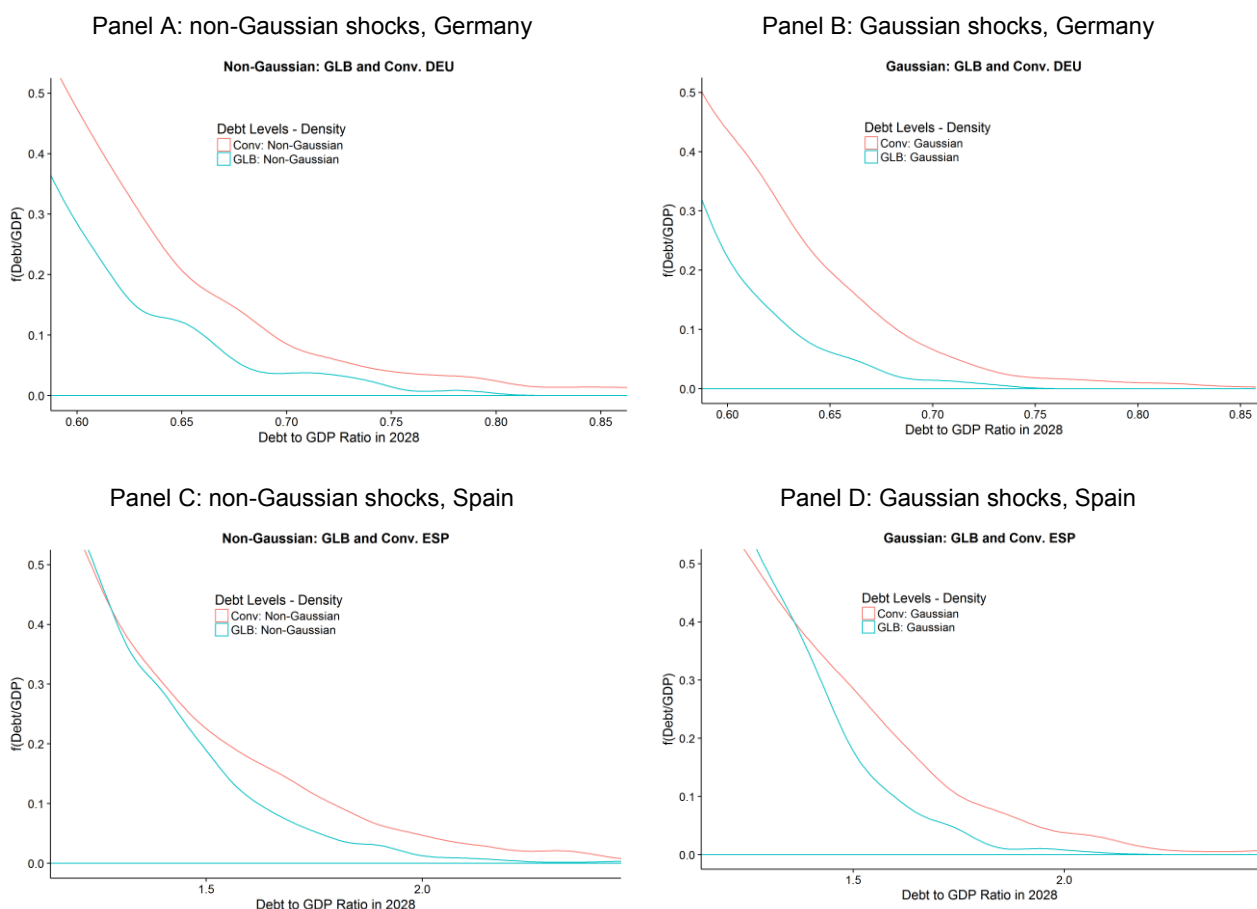
Note: Simulated debt to GDP ratios are built on a quarterly bivariate VAR with the primary balance and the gap between the growth rate and the effective interest rate.

3.5. Robustness checks

43.   This sub-section presents the stabilisation effects and the acceptable risk premia obtained from all three simulation methodologies. The stabilisation effect for both approaches that use the VAR is estimated with the primary balances in first differences as the unit root hypothesis could not be rejected for the primary balance in most countries. In addition, for those countries for which it is possible to find a subsample between 1972 and 2016 for which both *r-g* and primary balance are stationary, the longest one has been used to estimate an alternative VAR (Table 4). If there are several sub-samples with the same length, the most recent is chosen. Therefore, the stable series for Spain does not include the great recession and for Italy, it hardly includes the monetary union period (last column of Table 4). For these two countries, this renders this robustness check less relevant.

Table 4.   Reduction in debt uncertainty with different methodologies

GDP points

Country	Baseline (VAR, non-Gaussian)	VAR with Gaussian shocks	Gaussian with annual data, no VAR	First difference (VAR, non-Gaussian)	First difference (VAR, Gaussian)	Stabilisation with stationary window (VAR, non-Gaussian)	Stationary window
AUT	6.9	7.0	4.9	10.4	10.2	20.1	1970 Q4-2016
BEL	-4.6	-5.4	5.6	15.8	16.0	4.0	1981 Q4-2016
DEU	9.5	9.3	5.9	8.3	7.9	6.7	1970 Q1-2016
ESP	56.8	55.5	23.9	44.3	43.4	63.1	1991 Q2-2007
FIN	7.9	8.1	10.6	11.6	11.6	28.1	1975 Q4-2016
FRA	11.4	12.4	9.0	16.4	15.9	29.0	1978 Q2-2016
GRC	131.3	138.4	64.1	167.1	173.6	NA	NA
IRL	53.4	70.6	35.1	76.7	86.8	NA	NA
ITA	18.9	21.5	17.4	24.4	24.6	92.8	1979 Q1-2001
LUX	-0.1	0.1	3.7	7.3	7.4	0.1	1999 Q4-2016
NLD	9.0	9.6	5.2	6.9	6.5	11.5	1970 Q4-2016
PRT	53.5	52.1	24.2	49.7	51.5	52.1	1996 Q1-2011
SVK	6.2	5.5	7.3	13.1	12.1	11.3	2000 Q1-2016
SVN	32.7	35.2	29.4	31.9	31.3	23.3	2007 Q2-2015
Average	28.1	30.0	17.9	34.6	35.6	28.5	

Note: VAR refers to a quarterly bivariate VAR of the primary balance and the gap between the growth rate and the effective interest rate.

44.   Overall, the results from the robustness checks indicate that if anything, estimates in the baseline are conservative. Reduction in debt uncertainty is slightly larger with Gaussian shocks. With a VAR with the primary balance in first differences, the cross-country average stabilisation effect is about 35 against about 28 in the baseline. The higher averages are partly driven by the outliers Greece and Ireland. Without these two countries the baseline also provides lower average stabilisation effects than alternatives with Gaussian shocks or primary balance in first difference. Checks with the acceptable risk premium present similar results (Table 5 and scatterplots which show the difference between the results obtained from the level series and the first differenced series in appendix Figure A1.1).

Table 5.   Acceptable risk premium for governments

Country	Baseline (VAR, non-Gaussian)	VAR with Gaussian shocks	Gaussian with annual data, no VAR	First difference (VAR, non-Gaussian)	First difference (VAR, Gaussian)
AUT	0.36	0.32	0.27	0.52	0.52
BEL	0	0	0.15	0.68	0.64
DEU	0.64	0.6	0.47	0.64	0.64
ESP	1.92	1.8	1.11	1.52	1.56
FIN	0.4	0.44	0.8	0.76	0.76
FRA	0.48	0.48	0.48	0.68	0.68
GRC	2.96	3	1.53	3.68	3.76
IRL	3.32	3.12	2.13	5.04	5.08
ITA	0.28	0.24	0.47	0.64	0.64
LUX	0	0	0.7	1.8	1.8
NLD	0.76	0.68	0.48	0.48	0.52
PRT	1.12	1.12	0.68	1.56	1.52
SVK	0.68	0.56	0.84	1.48	1.44
SVN	1.72	1.76	1.67	2.12	2

4. The market side: A risk premium associated with growth uncertainties

45.   A major practical issue for GLBs to become reality is to be able to set a price that provides a fair compensation for their risk. In the presence of vanilla bonds, the pricing of GLBs can consist in estimating the risk premium difference between vanilla bonds and GLBs. The analysis from the investor side presented here thus focuses on this GLB-specific risk premium. As governments can choose between GLBs and vanilla bonds, it is useful to focus on this difference in returns. This is a prudent approach to assess whether supply and demand can match as this ignores the reduction in default premia that can be induced by GLBs (see Chamon and Mauro, 2005 for estimates of the reduction in the default probability).
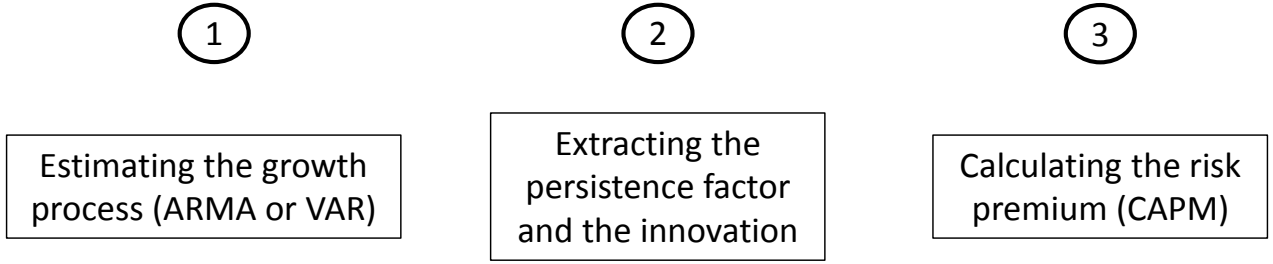
46.   This paper focuses on the risk premium associated with GDP volatility, the most important driver of the difference between GLBs and vanilla bonds in the medium to long run as the novelty premium is temporary by definition and the liquidity premium is also temporary if there is enough take-up. In the widely used capital asset pricing model (CAPM) introduced by Treynor (1961, 1962), risk premia are additive. In practice, the estimated risk premium associated with volatility can thus be added on top of the risk premia already embedded in vanilla bonds of similar maturity. The term premium is not considered here as it can be assumed to be similar for GLBs and vanilla bonds.

47.   The persistence of growth shocks is of crucial importance for GLB prices. When shocks are persistent, they have an impact on future pay-offs. If investors know this persistence, they will anticipate the consequences of shocks, and the market price of GLBs will adjust accordingly. In other words, if shocks are highly persistent, then the risk of a protracted recession is higher, and hence investors provide an insurance against a larger risk and want a higher risk premium.

48.   This paper uses a simple method to take into account the shock persistence information embedded in historical data in the calculation of the risk premium. GLB returns thus reflect growth innovations magnified by a persistence coefficient. These returns are used in the usual CAPM formula to find the risk premium. This is an improvement compared to most of the literature that typically assumes that returns would replicate growth directly. An application for the euro area countries suggests that this matters: persistence can be high and varies across countries. Even after considering this persistence, GLB risk premia remain moderate.

49.   The section implements the CAPM in a three-step method that takes into account GDP persistence to calculate risk premia (Figure 7). In a first step, one shall estimate an ARMA or a VAR process. Coefficients of such processes capture the effect of shocks in future periods: this gives the relevant information to extract the persistence factor in a second step. This also provides the innovation process, which is the new information that will drive market price changes. In the third step, this is combined with market developments to calculate the risk premium with the CAPM formula. In this third step, the risk premium is magnified by the persistence factor, and reflects the correlation between growth innovation and the reference market. Section 4.1 provides a general GLB price equation that converts growth into market price changes in GLBs. Sections 4.2 and 4.3 provide formula in the univariate and multivariate forecast cases respectively. Section 4.4 provides an application for euro area countries.

Figure 7. Pricing implementation

①	②	③
Estimating the growth process (ARMA or VAR)	Extracting the persistence factor and the innovation	Calculating the risk premium (CAPM)

4.1. General price equation with risk-adverse investors

50.   The GDP-linked bond (GLB) is defined as a bond that replicates GDP. Its nominal value is *V* and it matures at date *T* with the following pay-off rules: at each date *t* between *1* and *T-1*, the issuer pays a coupon *(g_t+p)V* where g_t is the observed growth rate at date *t* and at maturity, the principal is added to the coupon: the last payoff is *V+(g_T+p)V*, where *p* is a nominal risk premium. The issuer is assumed to auction bonds, and informed by the likely anticipations of the market, *p* is assumed to be set so that the market value of the bond remains fairly close to the nominal value. This is realistic if the volatility of GDP is moderate, which is plausible as GDP volatility is small compared to stock price or house price volatility. A perpetual GLB is a limit case, in which maturity tends to infinity and the pay-off is always *(g_t+p)V*.

51.   The value P_t of such a GLB is set by the market so that risk-adverse investors are indifferent between holding the GLB or selling it against cash. The utility of selling the bond is $\mathcal{U}(P_t)$ where $\mathcal{U}(.)$ is the utility function of the investor. The utility of holding the bond is the expected utility of the sum of pay-offs discounted with a reference rate of return *r*. The market price of GLBs is thus determined by the following relationship:

(16) $\mathcal{U}(P_t) = E\left(\mathcal{U}\left(\frac{1}{(1+r)^{T-t}}V + \sum_{k=t}^{T}\frac{1}{(1+r)^{k-t}}(g_{t+k}+p)V\right)\Big|I_t\right)$

52.   The second order approximation in the neighbourhood of the price P_t is:

(17) $\mathcal{U}(P_t) = E\left(\mathcal{U}\left(P_t + \frac{1}{(1+r)^{T-t}}V + \sum_{k=t}^{T}\frac{1}{(1+r)^{k-t}}(g_{t+k}+p)V - P_t\right)\Big|I_t\right)$

$$\mathcal{U}(P_t) \approx \mathcal{U}(P_t) + E\left(\left(\frac{1}{(1+r)^{T-t}}V + \sum_{k=t}^{T}\frac{1}{(1+r)^{k-t}}(g_k+p)V - P_t\right)\mathcal{U}'(P_t)\Big|I_t\right) + \cdots$$

$$\cdots + E\left(\frac{1}{2}\left(\frac{1}{(1+r)^{T-t}}V + \sum_{k=t}^{T}\frac{1}{(1+r)^{k-t}}(g_k+p)V - P_t\right)^2\mathcal{U}''(P_t)\Big|I_t\right)$$

(18)

$$P_t \approx \underbrace{\frac{1}{(1+r)^{T-t}}V + E\left(\sum_{k=t}^{T}\frac{1}{(1+r)^{k-t}}(g_k+p)V\Big|I_t\right)}_{EP_t} +$$

$$\underbrace{E\left(\frac{1}{2}\left((EP - P_t) + \sum_{k=t}^{T}\frac{1}{(1+r)^{k-t}}(g_k-\bar{g})V\right)^2\Big|I_t\right)\frac{\mathcal{U}''(P_t)}{\mathcal{U}'(P_t)}}_{RA_t}$$

22

53.   The GDP-linked bond market price has two components: the expected pay-off EP_t given the information revealed until the date t and a negative risk adjustment RA_t reflecting the risk premium.

The return of the GDP-linked bond between date t-1 and date t is the payment of the coupon and the change in the price, and it can be compared to the interest rate:

$$(19) \quad \frac{P_t - P_{t-1} + (g_{t-1}+p)V}{P_{t-1}} - r \approx \frac{P_t + (g_{t-1}+p)V - (1+r)P_{t-1}}{P_{t-1}}$$

$$\approx \frac{\sum_{k=t}^{T} \frac{1}{(1+r)^{k-t}} E(g_k|I_t)V + (g_{t-1}+p)V - \sum_{k=t-1}^{T} \frac{1}{(1+r)^{k-t}} E(g_k|I_{t-1})V}{P_{t-1}} + \frac{RA_t - (1+r)RA_{t-1}}{P_{t-1}}$$

$$\approx \frac{\sum_{k=t}^{T} \frac{1}{(1+r)^{k-t}} \left(E(g_k|I_t) - E(g_k|I_{t-1}) \right)V}{P_{t-1}} + \frac{RA_t - (1+r)RA_{t-1}}{P_{t-1}}$$

54.   This formula illustrates that the change in the expected pay-off reflects changes in GDP forecasts associated with new information for each future period k: $(E(g_k|I_t) - E(g_k|I_{t-1}))$. Changes in the risk adjustment term are less straightforward to compute with finite maturity bonds. This should decline as time passes because the uncertainty on future payments fades away. In the case of long-term GLBs, such changes are likely to be a second order issue, and investors willing to refine the GLB pricing can consider numerical approximations of this risk-adjustment term.

55.   These formulas can be simplified in the particular case of a perpetual GLB. This particular case is useful. It is quite close to long-term GLBs and it provides a higher bound estimate for the risk premium: perpetual GLBs bear more risk than any finite GLB. Assuming further that the GDP growth rate is stationary, it is reasonable to assume that the changes associated with the risk-adjustment term can be replaced by a constant C. Then, the return of GLBs can be approximated by:

$$(20) \quad \frac{P_t + (g_{t-1}+p)V - P_{t-1}}{P_{t-1}} - r \approx \frac{\sum_{k=t-1}^{+\infty} \frac{1}{(1+r)^{k-t}} \left(E(g_k|I_t) - E(g_k|I_{t-1}) \right)V}{P_{t-1}} + C$$

56.   As discussed above, the price change today is the discounted sum of forecast revisions and the implication of new available information on all future forecasts plus a constant. If there is persistence, the news of a growth shock will lead investors to adjust growth expectations accordingly. This price change can be included in the CAPM formula to calculate the risk premium:

$$(21) \quad RP = (r_m - r_f) \frac{Cov\left(r_m, \frac{\sum_{k=t-1}^{+\infty} \frac{1}{(1+r)^{k-t}} \left(E(g_k|I_t) - E(g_k|I_{t-1}) \right)V}{P_{t-1}} \right)}{Var(r_m)}$$

where r_m is the average return of the market and r_f is the risk-free return.

4.2. Univariate forecast

57.   One can make the general assumption that GDP growth g_t follows an ergodic covariance stationary process. The Wold (1954) representation theorem allows to write this process as the sum of past innovations:

$$(22) \quad g_t = \bar{g} + \Theta(L)\varepsilon_t = \bar{g} + \sum_{j=0}^{+\infty} \theta_j \varepsilon_{t-j}$$

where $\bar{g}$ is the average growth rate and ε_t is the innovation.

58.   In this case, the information revealed at date t leads to revise the GDP growth forecast for any date k after t as follows:

(23) $E(g_k|I_t) - E(g_k|I_{t-1}) = \theta_{k-t}\varepsilon_t$

59.   As any market price, the return of the GDP-linked bond reflects new information, which is an innovation at date t. The coefficients θ_k reflect shock persistence as they capture the effect of a shock on future outcomes. Innovation is thus rescaled with a persistence factor:

(24) $\dfrac{P_t+(g_{t-1}+p)V-P_{t-1}}{P_{t-1}} - r = \underbrace{\left(\dfrac{V}{P_{t-1}}\right)}_{Close\ to\ 1} \underbrace{\sum_{k=0}^{+\infty}\dfrac{\theta_k}{(1+r)^k}}_{persistence\ factor} \underbrace{\varepsilon_t}_{new\ info.} + C$

This result can be used to calculate the risk premium with the CAPM:

(25) $RP \approx E(r_m - r_f)\left(\sum_{k=0}^{+\infty}\dfrac{\theta_k}{(1+r)^k}\right)\left(\dfrac{cov(\varepsilon_t, r_m)}{V(r_m)}\right)$

60.   In practice, this can be implemented with an ARMA representation, such as an ARMA (1,2) for instance:

(26) $(1 - \rho L)g_t = \varepsilon_t + \vartheta_1\varepsilon_{t-1} + \vartheta_2\varepsilon_{t-2}$

The Wold representation is:

(27) $g_t = \left(\sum_{k=0}^{+\infty}\rho^k L^k\right)(\varepsilon_t + \vartheta_1\varepsilon_{t-1} + \vartheta_2\varepsilon_{t-2})$

(28) $g_t = \varepsilon_t + (\rho + \vartheta_1)\varepsilon_{t-1}\sum_{k=2}^{+\infty}(\rho^k + \vartheta_1\rho^{k-1} + \vartheta_2\rho^{k-2})\varepsilon_{t-k}$

The persistence factor can be calculated with the estimated coefficients of the ARMA process and a given discount factor:

(29)
$$\sum_{k=0}^{+\infty}\frac{\theta_k}{(1+r)^k} = 1 + \left(\frac{\rho}{1+r} + \frac{\vartheta_1}{1+r}\right) + \sum_{k=2}^{+\infty}\left(\left(\frac{\rho}{1+r}\right)^k + \frac{\vartheta_1}{1+r}\left(\frac{\rho}{1+r}\right)^{k-1} + \frac{\vartheta_2}{(1+r)^2}\left(\frac{\rho}{1+r}\right)^{k-2}\right)$$
$$= \frac{1 + \frac{\vartheta_1}{1+r} + \frac{\vartheta_2}{(1+r)^2}}{1 - \frac{\rho}{1+r}}$$

61.   This can be generalised to an ARMA(p,q) defined as follows:

(30) $\prod_{k=1}^{p}(1 - \rho_k L)\,g_t = \varepsilon_t + \vartheta_1\varepsilon_{t-1} + \cdots + \vartheta_q\varepsilon_{t-2}$

For which the scaling factor capturing persistence becomes:

(31) $\sum_{k=0}^{+\infty}\dfrac{\theta_k}{(1+r)^k} = \dfrac{1 + \frac{\vartheta_1}{1+r} + \cdots + \frac{\vartheta_q}{(1+r)^q}}{\prod_{k=1}^{p}\left(1 - \frac{\rho_k}{1+r}\right)}$

62.   This formula can be simplified in the frequent case of a fast decay of the coefficients in the Wold representation. In this case, only a few terms with a short horizon matter in practice, for which the discount factor $\frac{1}{(1+r)^k}$ is fairly close to one. The calculation with r=0 gives an upper bound of the persistence factor that is likely to be close to the true one. Further neglecting the discrepancy between P_t and V, the market return becomes:

$$(32) \qquad \boxed{\frac{P_t + (g_{t-1} + p)V - P_{t-1}}{P_{t-1}} \approx C + \Theta(1)\varepsilon_t}$$

where $|\Theta(1)|$ is the ratio between the long-run to short-run standard deviation of the growth rate and hence is a measure of growth persistence.

63.   This can be formulated with the parameters of the ARMA(p,q) representation:

$$(33) \qquad \frac{P_t + (g_{t-1} + p)V - P_{t-1}}{P_{t-1}} \approx r + C + \frac{1 + \vartheta_1 + \cdots + \vartheta_q}{\prod_{k=1}^{p}(1 - \rho_k)}\varepsilon_t$$

The risk premium in the CAPM formula becomes:

$$(34) \qquad RP = (r_m - r_f)\frac{1 + \vartheta_1 + \cdots + \vartheta_q}{\prod_{k=1}^{p}(1 - \rho_k)}\frac{Cov(r_m, \varepsilon_t)}{Var(r_m)}$$

4.3. Multivariate forecast

64.   In practice, practitioners forecast growth with additional information on top of past GDP data. This is formalised here with a multivariate ergodic covariance stationary process that includes the growth rate and additional time series $X_2,...,X_n$, such as business surveys . Such a process leads to the following Wold representation:

$$(35) \qquad \begin{pmatrix} g_t \\ X_2 \\ \vdots \\ X_n \end{pmatrix} = \begin{pmatrix} \bar{g} \\ \overline{X_2} \\ \vdots \\ \overline{X_n} \end{pmatrix} + \sum_{j=0}^{+\infty} \begin{pmatrix} A_{1,1,t-j} & A_{1,2,t-j} & \cdots & A_{1,n,t-j} \\ A_{2,1,t-j} & A_{2,2,t-j} & \cdots & A_{2,n,t-j} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n,1,t-j} & A_{n,2,t-j} & \cdots & A_{n,n,t-j} \end{pmatrix} \begin{pmatrix} \eta_{1,t-j} \\ \eta_{2,t-j} \\ \vdots \\ \eta_{n,t-j} \end{pmatrix}$$

65.   Price changes can thus be adjusted as follows.

$$(36) \qquad \frac{P_t + (g_{t-1} + p)V - P_{t-1}}{P_{t-1}} - r = \left(\frac{V}{P_{t-1}}\right)\left(\sum_{k=0}^{+\infty} \frac{A_{1,1,k}}{(1+r)^k}\eta_{1,t} + \sum_{k=0}^{+\infty} \frac{A_{1,2,k}}{(1+r)^k}\eta_{2,t} + \cdots + \sum_{k=0}^{+\infty} \frac{A_{1,n,k}}{(1+r)^k}\eta_{n,t}\right)$$

This embeds all new information available at date t, each component i of the innovation process being rescaled with a factor $\sum_{k=0}^{+\infty} \frac{A_{1,i,k}}{(1+r)^k}$ to reflect the extent to which the component contributes to current and future GDP forecasts.

66.   With this multivariate forecast, the CAPM risk premium becomes:

$$(37) \qquad E(r_m - r_f)\left(\frac{\sum_{k=0}^{+\infty} \frac{A_{1,1,k}}{(1+r)^k}cov(\eta_{1,t}, r_m) + \sum_{k=0}^{+\infty} \frac{A_{1,2,k}}{(1+r)^k}cov(\eta_{2,t}, r_m) + \cdots + \sum_{k=0}^{+\infty} \frac{A_{1,n,k}}{(1+r)^k}cov(\eta_{n,t}, r_m)}{V(r_m)}\right)$$

4.3. Application for euro area countries

67.   Risk premia adjusted for the persistence factor are reported for euro area countries in Table 6. First, an ARMA(p,q) process is estimated for each country. The orders of the autoregressive and moving average parts p and q, the persistence factor $\Theta(1)$ and the ratio between growth and innovation standard

deviations are reported in the table. For all countries but Ireland and Luxembourg, there is persistence. Persistence is largest in Greece and Spain. Risk premia are calculated with formula (33) for investors that consider the average for euro area stocks and euro area sovereign bonds' returns as a reference market, and the return on short-term German government bonds as the risk-free rate (column 1). Robustness checks with alternative reference markets suggest that GLBs could be even lower. Growth innovations are negatively correlated with changes in the sovereign bond market, so that the risk premium calculated with this particular reference market is even negative (column 3). CAPM calculated with growth rates directly are typically lower, especially for those countries with high persistence: there is a downward bias (column 5).

Table 6.   GDP-linked bond risk premia for euro area countries

Risk premium in per cent

Country	p	q	Persistence Factor Θ(1)	Sd ratio	(1) With the persistence factor EA stocks and bonds	(2) EA stocks	(3) EA bonds	(4) World equity	(5) B&M EA stocks and bonds	10-year CDS
AUT	1	0	1.42	1.06	0.077	0.033	-0.083	0.044	0.053	0.36
BEL	1	0	1.47	1.06	0.111	0.052	-0.270	0.130	0.076	0.40
DEU	1	0	1.61	1.08	0.078	0.037	-0.222	0.085	0.056	0.19
ESP	1	2	11.23	2.66	0.521	0.204	0.306	0.470	0.041	0.96
EST	1	2	2.93	1.27	0.824	0.360	-1.025	0.763	0.236	NA
FIN	2	0	1.80	1.07	0.176	0.084	-0.527	0.183	0.056	0.47
FRA	1	0	3.02	1.35	0.131	0.056	-0.112	0.127	0.042	0.46
GRC	1	2	6.69	1.37	0.530	0.241	-1.058	0.543	0.066	NA
ITA	2	1	2.13	1.17	0.160	0.069	-0.171	0.124	0.066	1.80
LUX	0	0	1.00	1.00	0.168	0.087	-0.750	0.211	0.168	NA
LVA	1	2	4.50	1.64	0.981	0.431	-1.328	0.988	0.179	NA
NLD	1	0	2.49	1.27	0.033	0.015	-0.045	0.012	-0.019	0.47
PRT	1	2	2.91	1.28	0.364	0.146	0.103	0.318	0.105	2.64
SVK	2	0	2.12	1.12	0.443	0.179	0.063	0.364	0.153	0.72
SVN	2	0	3.92	1.44	0.416	0.193	-0.988	0.426	0.031	1.31
Mean			3.14	1.30	0.323	0.140	-0.353	0.300	0.091	0.88

Note: p and q are the orders of the ARMA representation of quarterly GDP growth rate selected on the basis of an information criterion. Sd ratio is the ratio of the growth rate standard deviation to its innovation standard deviation. Risk premia reported in columns 1 to 5 are calculated with a CAPM, considering the reference market indicated in the column. EA stocks and bonds are a simple average of euro area equity returns and the Bloomberg Barclays Euro Treasury Index (fixed-rate, investment grade public bonds). B&M is a risk premium provided by the CAPM with GDP growth rates, as in Borensztein and Mauro (2004). 10-year CDS are observed in mid-November 2017.

68.   An alternative VAR forecast with the OECD composite leading indicator (CLI) is also used to compute risk premia, reflecting in a stylised way the additional information used by practitioners to forecast GDP (Table 7). Aggregating a large set of information in a common factor is a widespread approach in the GDP forecasting literature to address the curse of dimensionality (see for instance the seminal papers of Stock and Watson, 1989 or Forni et al., 2000). With this VAR approach, the risk premium can be lower than with the univariate approach because surprises are smaller (better forecast). It could also be larger as these surprises may have a stronger positive correlation with the market. In practice, risk premia are typically lower with this VAR approach, suggesting that the first effect dominates. All this suggests that the rather naïve ARIMA forecast is quite a prudent approach that may overestimate risk premia. Risk premia with the VAR and ARIMA approaches are also positively correlated (in the case of the EA stock and bond market, the cross-country correlation is about 0.85), suggesting that the univariate approach, despite its limitation, can suffice to identify which countries are more likely to pay a larger risk premium.

Table 7.   Multivariate using the CLI: GDP-linked bond risk premia for euro area countries

Risk premium in percent

Country	Lag order	Persistence factor CLI $\sum_{k=0}^{+\infty} A_{1,CLI,k}$	Persistence factor g $\sum_{k=0}^{+\infty} A_{1,g,k}$	SD ratio	(1) Reference market EA stocks and bonds	(2) EA stocks and bond (univariate)	(3) EA stocks	(4) World equity
AUT	3	2.77	0.48	0.91	0.084	0.077	0.036	0.025
BEL	3	2.83	0.26	0.88	0.075	0.111	0.034	0.100
DEU	5	2.19	0.66	0.69	0.040	0.078	0.010	0.035
ESP	4	45.40	3.54	0.30	0.252	0.521	0.068	-0.068
EST	3	3.91	0.11	0.69	0.335	0.824	0.127	0.128
FIN	3	2.58	0.95	0.79	0.103	0.176	0.045	0.103
FRA	3	4.32	0.48	0.65	0.115	0.131	0.045	0.012
ITA	3	5.04	-0.19	0.73	0.041	0.160	0.020	-0.005
NLD	3	5.03	1.17	0.57	0.035	0.033	0.019	0.072
PRT	2	1.90	2.73	0.92	0.317	0.364	0.131	0.255
SVK	2	1.49	1.71	0.95	0.416	0.443	0.164	0.169
SVN	3	5.78	0.84	0.76	0.291	0.416	0.119	0.222
Mean		6.94	1.06	0.74	0.18	0.28	0.068	0.087

Note: The lag order of the VAR is selected on the basis of information criteria. The scaling factors are the sum of the respective first 80 coefficients from the MA-representation of the VAR. SD ratio is the ratio of the sum of the standard deviations from the CLI innovation and growth innovation to the standard deviation of the growth rate. Risk premia reported in columns 1 to 4 are calculated with a CAPM, considering the reference market indicated in the column. EA stocks and bonds are a simple average of euro area equity returns and the Bloomberg Barclays Euro Treasury Index (fixed-rate, investment grade public bonds). For comparability, the results from the univariate approach with a restriction to the sample for which the CLI is available are reported as well.

69.   Whatever the methodology that is considered here, the risk premia are much lower than the default premium suggested by CDS prices reported in the last column of Table 6. On average, if GDP-linked bonds were associated with a decline in the perceived default probability by 40%, then the decline in default risk premium would offset the GDP-volatility risk premium. This holds after the large decline of default risk premia observed between 2011 and 2017: the comparison with CDS observed a few years ago would have suggested even more favourable results. If GLBs are a credible instrument to decrease the perception of default risk, then the overall effect on risk premia may even be negative, and they can be appropriate for highly indebted countries.

5. Conclusion

70.   In sum, the GLB risk premia that governments may accept to be insured against the debt risk seem to be above the one that investors may require as a compensation for GDP volatility. Countries where the standard deviation of $(r - g)$ scaled with the debt level and shock persistence are higher reap more benefits from the issuance of GLBs and hence can accept a larger risk premium. Those countries where growth shocks are large and persistent would have to pay a larger risk premium. The drivers from the demand and supply side share common features: those that benefit more tend also to be those that would have to pay a higher risk premium. Overall, both high-risk and low-risk countries can benefit from GLBs: the ones that have to pay a larger risk premium are those that need this insurance against debt crises the most. As discussed in the OECD Committee on Financial Markets, the premium associated to GDP volatility is perceived by policy makers as a major issue (OECD, 2018). The moderate GDP volatility and its low correlation with other assets suggest that this concern can be overcome.

71.   Further research could make the case even sharper in models that consider a reduction in the default risk premium reflecting reduced debt uncertainties with GLBs. This would require assumptions on how markets should price the reduction in default risks. Credit events are rare, especially in advanced economies, and CDS developments suggest that default risk premia may present regime switches, such as a switch triggered by the global financial crisis. Inferring the effect of debt uncertainty reduction on default risk premium reduction from historical data is thus likely to be much more delicate than inferring the risk premium compensating for GDP volatility from past GDP volatility. That said, the magnitude of risk premia suggested by CDS prices is typically above GLB risk premia compensating for GDP volatility: one could expect thus a first order effect of a default risk premium channel in the cost-benefit analysis of GLBs.

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APPENDIX

Figure A1.1 Robustness check with the first difference of the primary balance used in the VAR estimation
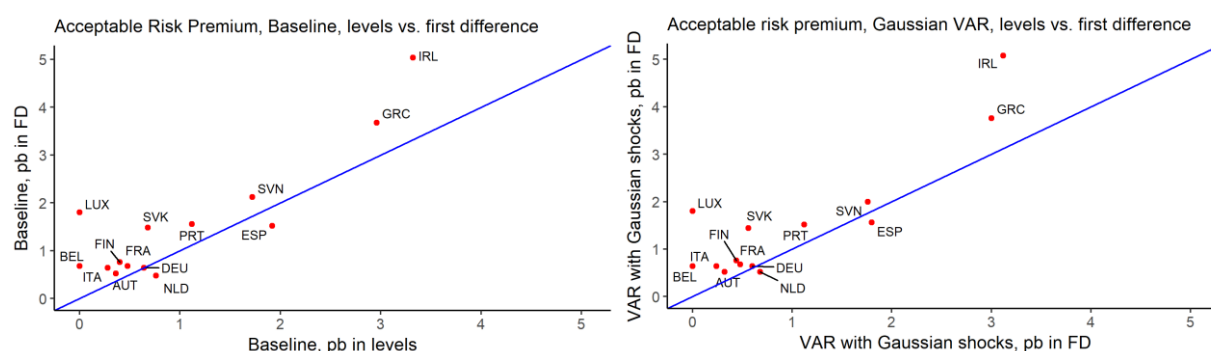

Table A1.1. The stabilisation effect and the share of GLBs

Share	AUT	BEL	DEU	ESP	FIN	FRA	GRC	IRL	ITA	LUX	NLD	PRT	SVK	SVN
0.1	1.4	-0.3	1.9	9.4	1.5	2.3	20.8	10.9	4.5	0.1	1.7	9.1	1.5	6.2
0.2	2.7	-0.9	3.6	18.3	2.9	4.6	40.4	21.9	8.5	0.4	3.3	18.2	2.4	12.5
0.3	3.8	-1.2	5.4	28.4	4.4	7	59.8	31.1	12.4	0.3	4.9	26.5	3.6	17.8
0.4	5.1	-1.6	7.4	37.4	6	9.2	78	40.3	16.2	0.3	7	35.2	4.6	23.1
0.5	6.3	-2.2	9.3	46.2	7.5	11.2	95.8	48.9	19.8	0.2	8.6	44.2	5.7	28.1
0.6	7.2	-3.1	11.2	55.1	8.8	13.3	114.4	56.9	22.7	0	10.4	52.8	6.7	33.4
0.7	8.2	-3.8	12.8	64	10.2	15.2	131.8	64.1	25	-0.2	12.1	61.2	7.1	38.8
0.8	9.1	-4.9	14.4	72.3	11.5	16.9	148	71.4	26.7	-0.4	13.4	69.7	7.6	43.3
0.9	10.2	-6.1	15.7	81.1	12.9	18.8	162.7	78.4	27.5	-0.7	14.9	78.2	7.9	47.7
1	11	-7.4	17.4	89.3	14.4	20.8	176.1	84.4	28	-1	16.3	86	8.5	51.9