The effect of Treasury debt on bank lending and the economy

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Abstract

What are the long-term effects of an increase in the supply of Treasury securities on the financial sector and the economy? We assemble a dataset spanning 140 years with data about banks, firms' investments, fiscal policy, and other macroeconomic and financial variables. We then employ a VAR analysis to show that a higher supply of Treasury securities relative to GDP (i) reduces bank liabilities and the supply of bank loans, (ii) reduces firms' investments, and (iii) has negative impact on workers and the labor market. We then present a model that rationalizes these findings and allows us to derive policy implications. The current scenario in which the government can borrow at low or negative real rates does not necessarily imply that higher government debt is beneficial. We are working to provide a full quantitative policy analysis to determine the optimal supply of Treasury securities.

1 Introduction

The COVID crisis and its response have accelerated the growth of government debt both in the US and around the world. In the US, federal government debt was 54% of GDP in 2001, 108% in early 2020, and 129% at the end of 2020—a significant part of this increase is likely to be long-lasting.

Motivated by these events, the first objective of this paper is to identify the effects of an increase in the supply of Treasury securities on the financial sector and the macroeconomy. A recent and growing literature has shown that a higher supply of Treasury securities crowds out banks' liabilities (Krishnamurthy and Vissing-Jorgensen, 2015; Greenwood, Hanson, and Stein, 2015; Li, 2019;

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Li, Ma, and Zhao, 2020). We review and extend this result using a novel approach that allows us to push the analysis further by asking whether and how the reduction in liabilities is transmitted to bank lending, firms' investments, and a large array of financial and macroeconomic variables.

Our focus is on the long-term impact of an increase in Treasury debt. We find that an increase in debt to GDP not only crowds out of bank liabilities but also reduces the *supply* of loans to firms and, ultimately, leads to a contraction in firms' investments. Workers bear most of the negative consequences, as we document a reduction in employment and in the labor share of income, and an increase in the unemployment rate.

The second objective is to construct a model that replicates the key quantitative results derived in the empirical analysis and can be used to perform policy analysis—in particular, to determine the optimal supply of Treasury securities. A higher supply of Treasury securities reduces investments and produces negative effects on the labor market—in line with our empirical analysis. However, this effect is traded off against the provision of valuable liquidity services (Krishnamurthy and Vissing-Jorgensen, 2012). The current draft includes only a simple qualitative model that can be used for broad policy analyses, but we plan to extend it to produce a full quantitative policy analysis.

The empirical analysis uses a structural vector autoregression (VAR) to estimate the impact of an increase in the supply of Treasury debt relative to GDP. We assemble a dataset with banking, fiscal policy, financial, and macroeconomic data spanning 140 years, and we take a long-run perspective by focusing on changes in the supply of Treasury debt that are long-lasting and studying their long-term impact. The approach is novel—in the context of public debt and macro-finance outcomes—and complementary to those used in the classic macro literature (e.g., Elmendorf and Mankiw, 1999), international economics and cross-country comparisons (e.g., Rogoff and Reinhart, 2010) and banking (e.g., Greenwood, Hanson, and Stein, 2015; Li, Ma, and Zhao, 2020).

We document that a higher supply of Treasury securities (relative to GDP) crowds out bank liabilities (similar to Li, Ma, and Zhao, 2020) and leads to a reduction in bank lending. Crucially, firms replace bank loans with other sources of (nonbank) financing, showing that the drop in bank lending is driven by a reduction in loan *supply* as opposed to demand. In addition, banks' leverage does not change, ruling out alternative explanations based on deleveraging or tightening of financial regulation. We also rule out changes in taxation as the driver of lower investments. In particular, for the post-war period, we show that our main result still holds (i.e, bank liabilities, bank lending, and investments drop) despite a *reduction* in tax rates.

The identification scheme of the VAR is based on long-run restrictions (Blanchard and Quah, 1989). This approach allows us to identify the effects of changes in Treasury debt that are (i) long lasting (i.e., permanent) and (ii) are exogenous with respect to a large set of temporary financial and macroeconomic shocks. We interpret the changes in Treasury debt that we identify to be driven by movements in a long-run target for the ratio of Treasury debt to GDP. The target does not have to be chosen explicitly and could be the result of the overall fiscal policy stance of the government. An important source of movements in the target are changes in the stance of policymakers over the long-run debt-to-GDP target. An example of such a change took place in the early 1920s under President Warren Harding and Secretary of the Treasury Andrew Mellon, who enacted a series of policies to increase tax revenues, stimulate the economy, and repay the debt accumulated during World War I (Cannadine, 2008). A key element of our approach is that we identify changes in the debt-to-GDP target that are orthogonal to short-term movements in the supply of Treasury securities and, thus, likely exogenous to business cycle fluctuations driven by macro and financial shocks. We also undertake an extensive list of additional analyses to rule out alternative interpretations of the results and robustness checks to validate our results.

The model builds on the macro-finance literature by including a banking sector in a standard macro setting. In particular, we build on Gertler and Kiyotaki (2010), in which banks are subject to an agency friction that limits the leverage they can take. As in Krishnamurthy and Vissing-Jorgensen (2012, 2015), both deposits and Treasury debt provide liquidity services.

In the current draft, we perform a qualitative analysis using numerical examples. An increase in the debt to GDP target crowds out bank deposits. With fewer deposits, banks contract lending. With respect to investments and GDP, we find in our numerical examples that an increase in the debt to GDP target reduces both. Investments drop because the substitution from bank to non-bank lending, if present, is only partial. And with lower investments, GDP drops too.

Finally, we explore the effects of an increase in government debt when the real rate on government debt is low or negative. A recent policy discussion (Blanchard, 2019) highlights that if "r<g" (i.e., if the real rate on government debt is less than the growth rate of the economy), the government earns seigniorage-like revenues on government debt, so that issuing public debt and rolling it over can reduce fiscal costs. We show that this is not necessarily the case. Because higher debt to GDP reduces GDP through the reduction in bank lending, the government collects

lower tax revenues if tax rates remain constant. This effect might not be entirely offset by the higher seigniorage-like revenues, especially if the difference between "r" and "g" is small. In other words, the growth rate of the economy, "g," is endogenous and affected by the change in public debt, so that comparing "r" and "g" does not provide enough information to derive adequate policy implications. In particular, an analysis of public debt that abstracts from the interaction between Treasury securities, deposits, and bank lending will underestimate the costs of a fiscal expansion.

1.1 Additional comparison with the literature

On the empirical side, a growing literature emphasizes the link between government and intermediaries' debt due to their role in the provision of safety and liquidity. The closest paper is Krishnamurthy and Vissing-Jorgensen (2015), who also study long-run variations in debt to GDP and their impact on intermediaries. They show how an increase in government debt is associated with a reduction in banks' short term liabilities. A key difference is that our VAR approach allows us to provide a causal identification, whereas Krishnamurthy and Vissing-Jorgensen (2015) state explicitly that their analysis "cannot definitively rule out omitted variables or reverse causality concerns." In addition, on the empirical side, we also document the effects of Treasury debt on bank lending and the economy as a whole. Greenwood, Hanson, and Stein (2015) provide an instrument for Treasury fluctuations, but the instrument applies only to short-term variations. To our knowledge, our paper is the first one that provides a model-free identification of low-frequency variation in debt to GDP. Complementary approaches to study the substitution between Treasury debt and bank deposits are used by Li (2019) (who uses a structural model) and Li, Ma, and Zhao (2020) (who use cross-sectional variations in banks' market power).[1]

On the theoretical side, several other papers study the effects of government liabilities and their interaction with the financial sector. Holmström and Tirole (1998) show that public liquidity is needed when the economy is subject to aggregate risk, but there are no negative effects of large public liquidity on financial intermediation. In Greenwood, Hanson, and Stein (2015), public liquidity crowds out the financial sector too, and this effect is positive in their model because of an externality generated by private intermediaries and modeled along the lines of Stein (2012).

[1]Other studies such as Infante (2020) and Amaral, Corbae, and Quintin (2020) study the effects of an increase in the demand for safe assets on the supply of government and intermediaries' liabilities.

A growing body of literature analyzes government finances and its implications on the financial system. In Li (2017), public liquidity reduces liquidity premia and creates an incentive for intermediaries to take on more risk, which amplifies credit cycles and lengthens the duration of crises. Bolton and Huang (2017) study public liquidity in a framework in which domestic and foreign money provides liquidity. Liu, Schmid, and Yaron (2019) highlight the negative effects on corporate financing of a large supply of Treasury debt. Jiang et al. (2020) analyze the trade-off between insuring taxpayers and bondholders, and Jiang et al. (2021) emphasize the importance of considering risk when computing the government's funding cost.

2 Treasury debt, the financial sector, and the economy: Empirical evidence

This section provides an empirical analysis of the effects of government debt on financial intermediation and the macroeconomy. We first provide the key element of the theoretical framework that we use to guide our empirical analysis (Section 2.1), present the data (Section 2.2), and then the results (Section 2.7).

We find that higher debt to GDP reduces banks' liabilities and bank lending, and transmits to the real economy as contractions in investments and GDP—albeit only in peacetime periods—and a worsening of labor market conditions.

2.1 A simple framework to guide the analysis

To guide our analysis and clarify the approach we follow, we begin by outlining the equations that describe the evolution of Treasury debt and government policies. In this section, we provide a very general formulation that fits a large class of models. A more detailed specification is provided later when we present our full model.

Consider a government that issues debt, faces expenditures and must pay transfers to the private sector, and collects taxes. The government budget constraint is given by

$$B_{t-1} + (\text{government expenses and transfers}) \leq B_t + (\text{tax revenues})\,. \quad (1)$$

The government must finance the government debt B_{t-1} issued in previous periods as well as government expenses and transfers (left-hand side), and uses new debt B_t and taxes for financing.

The key equation related to our empirical analysis is the the one that govern the evolution of Treasury debt B_t:

$$\frac{B_t}{GDP_t} = \left(1-\rho^B\right)\left[\frac{B}{GDP}\text{ target}\right]_t + \rho^B \frac{B_{t-1}}{GDP_{t-1}} + \varepsilon_t^B, \tag{2}$$

where $\rho^B \in (0,1)$ and

$$\left[\frac{B}{GDP}\text{ target}\right]_t = \left[\frac{B}{GDP}\text{ target}\right]_{t-1} + \eta_t.$$

The term in square brackets on the right-hand side of Equation (2), $\left[\frac{B}{GDP}\text{ target}\right]_t$, is the unobserved long-run target for the debt-to-GDP ratio. Debt to GDP, B_t/GDP_t, can fluctuate around the target. The term ε_t^B represents the various factors that could affect the short-run evolution of debt to GDP around its target, such as business cycle and financial fluctuations, or temporary policies. Once debt to GDP is away from its target, and absent further shocks, the government will bring it back to its long-run target over time. The debt-to-GDP target does not have to be explicitly chosen by the government but could be implicitly determined by other policies, as we discuss in more details below. The general framework in Equation (2) is consistent with numerous models that include such a target; see, for instance, Uhlig (2010) and the analysis of government debt and corporate financing of Liu, Schmid, and Yaron (2019).

In our empirical analysis, we want to understand how a change in the debt-to-GDP target affects banking and other macroeconomic and financial variables in the long run. The target could change because of a time-varying stance of policymakers over the "right" long-run average debt to GDP.

We discuss identification in detail in Section 2.5, but we note here that our main results are correctly identified even if changes in the debt-to-GDP target are correlated with several macro and financial shocks. For instance, if the government increases the debt-to-GDP target in response to a recession (i.e., if the government increases spending or cut taxes in response to a recession, financing these expenses with debt that is rolled over), we can still correctly identify most of our results. Section 2.5 provides additional details and discussions of other scenarios that could affect our results. In particular, we are able to identify the long-run effect of a change in the target under weak identification assumptions. In addition, in our empirical analysis, we conduct a long list of analysis to rule out other causal interpretation of our results.

Other possible sources of variations in debt to GDP are changes in long-run growth or interest rate. These changes are sometimes referred to as changes in "r minus g" because the dynamic of debt to GDP depends on real interest rates (i.e., r) relative to real growth (i.e., g). For instance, debt-to-GDP could decrease just because the economy experience growth (i.e., an increase in GDP), with no changes in fiscal policy. While this source of variation in the debt-to-GDP target would not affect the interpretation of our results, Section 2.6 shows that changes in $r - g$ are not the sources of variations in the debt-to-GDP target that we identify.

When the debt-to-GDP target changes, the budget constraint implies that the government will also adjust some of its other policies. For instance, if the government increases the debt-to-GDP target, it can spend more or cut taxes as debt to GDP moves toward the new level. At this point, we do not specify what other fiscal policy variable adjusts when the government changes $\overline{B}$. We return to this point when presenting the results about fiscal variables, in Section 2.8, and when presenting the model, in Section 3.

2.2 Empirical specification

To understand if there is a causal link between changes in the debt-to-GDP ratio and changes in financial sector and macro variables, we need to identify exogenous movements in debt to GDP. To this end, let $Y_t = [\Delta \log (debt/GDP)_t\,,\ \Delta \boldsymbol{x}_t]'$ where $\boldsymbol{x}_t$ includes variables related to the financial sector or the macroeconomy either in level or in logarithm (i.e., each variable in $\Delta \boldsymbol{x}_t$ is either a first difference or a growth rate), and consider the reduced-form VAR

$$Y_t = AY_{t-1} + \boldsymbol{\varepsilon}_t. \tag{3}$$

We first estimate the coefficients of the matrix A using OLS, and then construct the impulse response to an exogenous shock identified using long-run restriction (Blanchard and Quah, 1989). This approach identifies two types of shocks: a shock that has permanent effects on the *level* of debt to GDP, and shocks that have transitory effects on the *level* of debt to GDP and are orthogonal to the first one. The first shock, that has a permanent effect on the level of debt-to-GDP, corresponds to a shock that alters the debt-to-GDP target introduced in Equation (2). With some simplifications, our approach identifies low frequency variations in debt to GDP, and does so in a way that such variations are orthogonal to high-frequency ones, that is, orthogonal to short-term temporary variations.

The identification method based on long-run restrictions has been proposed by Blanchard and Quah (1989) and has been applied to several macro and finance questions. In the macro literature, for example, they have been used to study the effects of technology shocks on hours worked (Gali, 1999; Fisher, 2006). In finance, for example, they have been employed by Hansen, Heaton, and Li (2008) to study the pricing of risk exposure in the long run.

2.3 Data

In our baseline analysis, we use data from 1881 to 2020.[2] A key guiding principle of our approach is to construct a dataset with a sufficiently long sample. This is because the VAR approach with long-run restrictions that we use exploits low-frequency variations in the data and, thus, a long sample is necessary to have enough statistical power. A possible issue with a long sample is that, when building a given time series, we sometimes need to draw from different sources to obtain data. Because different sources might use different data definition, this might create break points in the time series in *level*. However, this is not a problem for our analysis because we first compute *growth rates* or *first differences* for any of the sources we have, and then combine the resulting growth rates or first differences together to build the time series used in the VAR. When multiple sources are available for overlapping years, we compare them to check that they behave similarly, and typically use the source that includes the more recent data for the overlapping part of the sample.

We define debt to GDP as the amount of Treasury securities as a fraction of GDP, excluding debt held by other parts of the government such as the Social Security Trust Fund and the Federal Reserve. We use the series constructed by Henning Bohn (Bohn, 2008) until 1946, and the one constructed by the Federal Reserve Bank of Dallas for the period 1947-2020.

For bank loans, we ideally would need a measure of business lending such as commercial and

[2]Because we include the variables in the VAR in growth rates or first differences, the final sample used in the VAR begins in 1882.

industrial (C&I) loans. However, C&I loans is available only from 1939, so we use all bank loans for the pre-1939 period. We also conduct robustness checks using all bank loans for the entire sample.

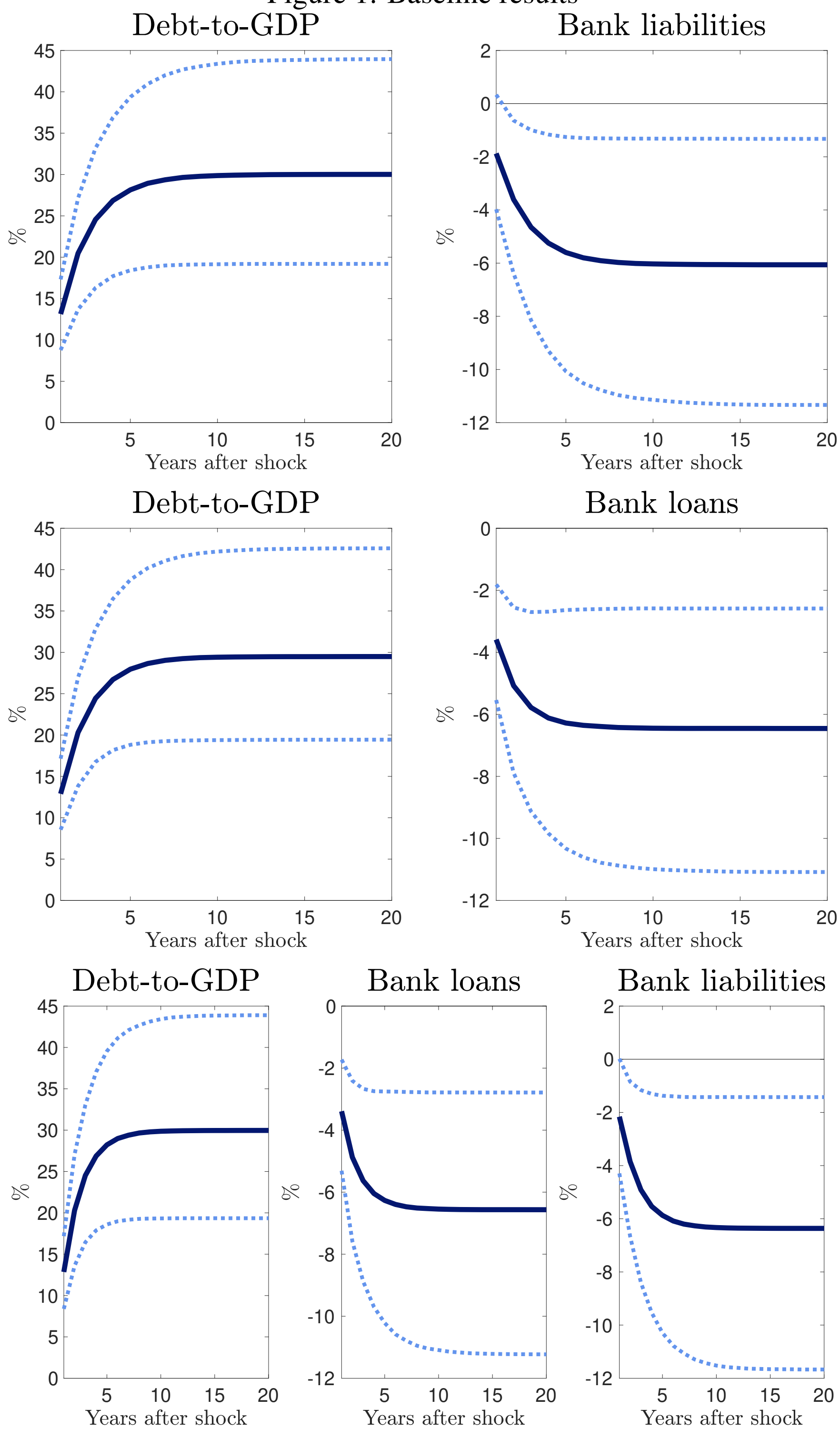
For bank liabilities, our objective is to use a narrow definition guided by the existing related literature. It is well understood that an increase in the supply of Treasury debt crowds out bank liabilities—in particular, wholesale funding such as large time deposits (Li, Ma, and Zhao, 2020)—and that time deposits are related to the supply of business lending (Supera, 2021). In this sense, the objective of using bank liabilities in our empirical analysis is mainly to show that we are capturing the crowding out documented by closely related papers such as Li, Ma, and Zhao (2020), and the main novel contribution of our empirical analysis is to study the effects on other financial and macroeconomic variables. We thus define bank liabilities by restricting attention to large time deposits for the part of the sample for which this data is available (i.e., 1945-2020). For previous years, we use all bank liabilities, removing liabilities held by the government when the data is available, that is, starting in 1896. We also conduct robustness checks using all bank liabilities for the entire sample.

The other variables we use are drawn from several sources. Most data for the post-World War II period is from the Flow of Funds. Financial sector data also draws from All Bank Statistics and Banking and Monetary Statistics. For investments and real GDP, we also use Henning Bohn' data and the Jordà-Schularick-Taylor Macrohistory Database. Data about taxes and government spending is from Ramey and Zubairy (2018), and data about government transfers is from the Bureau of Economic Analysis. Spreads between interest rates on government debt and securities issued by the private sector are from Krishnamurthy and Vissing-Jorgensen (2012). Corporate bond default rates are from Giesecke et al. (2011). Corporate profits and dividends are from Bureau of Economic Analysis. For some of the time series, we restrict the analysis to a sample that starts at a later date because earlier data is not available—we highlight in the discussion when that is the case.

2.4 Baseline results: Treasury debt, bank liabilities, and bank lending

We begin by studying the effects of a change in the debt-to-GDP target on bank liabilities and bank lending. We first consider a two-variable VAR with debt-to-GDP and bank liabilities, another

Figure 1: Baseline results



The solid line is the median impulse-response and the dotted lines denote the 90% confidence bands. Top panel: results of the two-variable VAR that includes debt to GDP and bank liabilities; mid panel: results of the two-variable VAR that includes debt to GDP and bank loans; bottom panel: results of the three-variable VAR that includes debt to GDP, bank loans, and bank liabilities.

two-variable VAR with debt-to-GDP and bank loans, and a third specification that includes all the three variables. We use one lag in most of our analyses, and conduct robustness checks with two lags.

Figure 1 shows the response to an increase to the debt-to-GDP target (solid line) together with the 90% confidence interval. Our focus is on the long-term impact of the shock, that is, the effects of the shocks after several years. As discussed in Section 2.5, the estimation of the long-term impact is robust to several confounding factors.

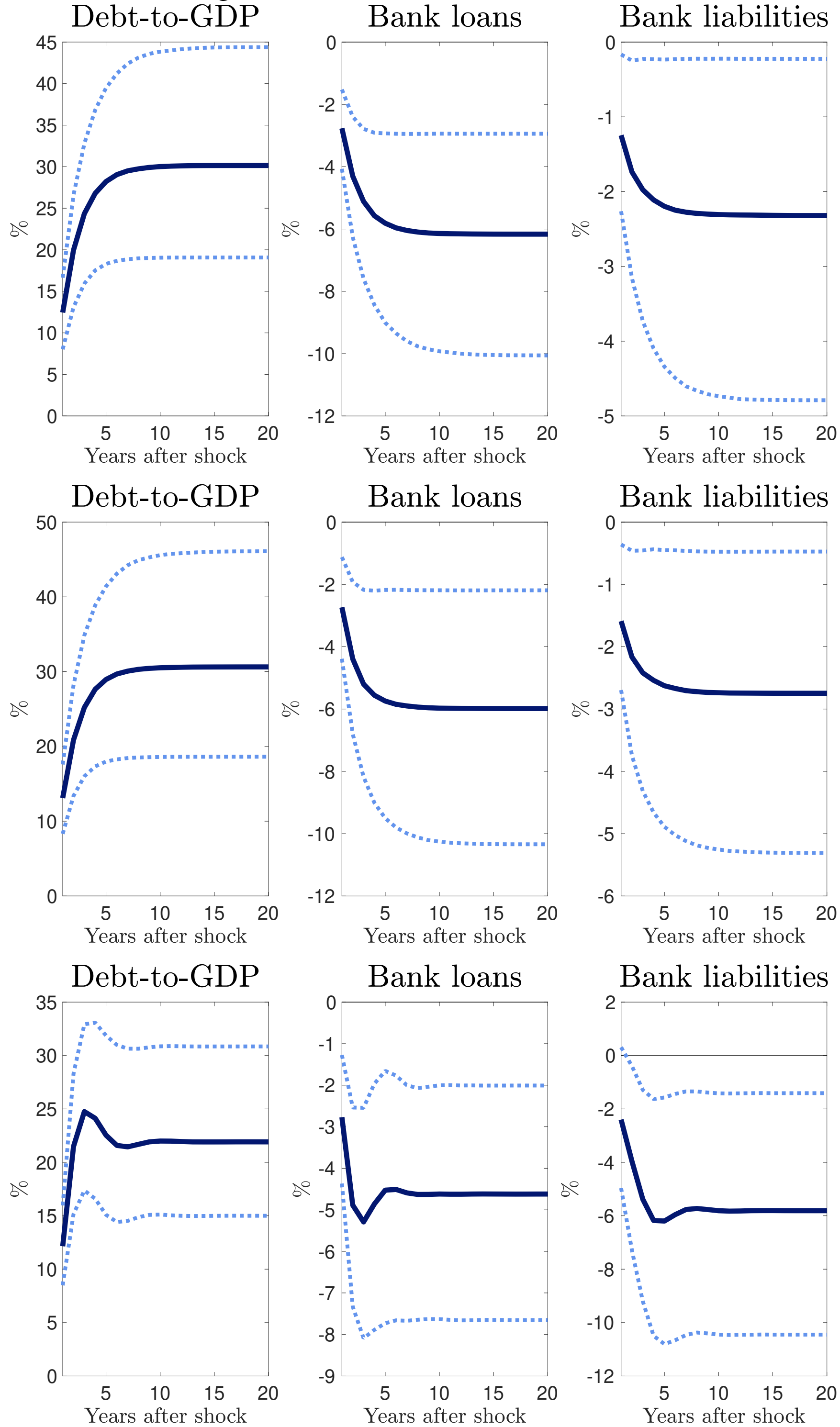
After an increase of debt-to-GDP of about 30%, we observe a reduction in both bank liabilities and bank loans of about 6%. This implies a long-run elasticity of both bank liabilities and bank loans of about 0.21%, in response to a change to the supply of Treasury debt relative to GDP. We emphasize that the magnitude of the results in Figure 1 is about the same independently of whether we use bank liabilities and bank loans separately or we include both in the VAR.

In Figure 2, we provide a first set of robustness checks. In the top and middle panel, we show the results based on alternative definitions of bank loans and bank liabilities that are broader than in our baseline. The top panel uses all loans and all liabilities for the entire sample, and the mid panel defines bank liabilities as all the liabilities net of those held by the government.[3] The results are very similar to the baseline of Figure 1. The magnitude is essentially the same for bank loans, but smaller for bank liabilities. This second result is consistent with the results of Li, Ma, and Zhao (2020), that found a weaker effect of changes in Treasury debt on core funding. In the bottom panel, we run the baseline 3-variable VAR with two lags, and the results are again nearly unchanged.

In Figure 3, we show several sub-sample analyses. We run our baseline VAR with debt-to-GDP, bank loans, and bank liabilities ending our sample in 1920 to exclude the COVID-19 crisis (top panel), ending the sample in 2008 to exclude the 2008 crisis (2nd panel), for the post-World War II (WW2) period (3rd panel), and for the pre-WW2 period (bottom panel). The results are again nearly unchanged. The magnitude are almost identical too, with some differences in bank liabilities for the post- and pre-WW2 periods. This is again related to the definition of bank liabilities, which relies on large time deposits for the post-WW2 period and on all liabilities before that, and is in line with the results of Figure 2 and those of Li, Ma, and Zhao (2020).

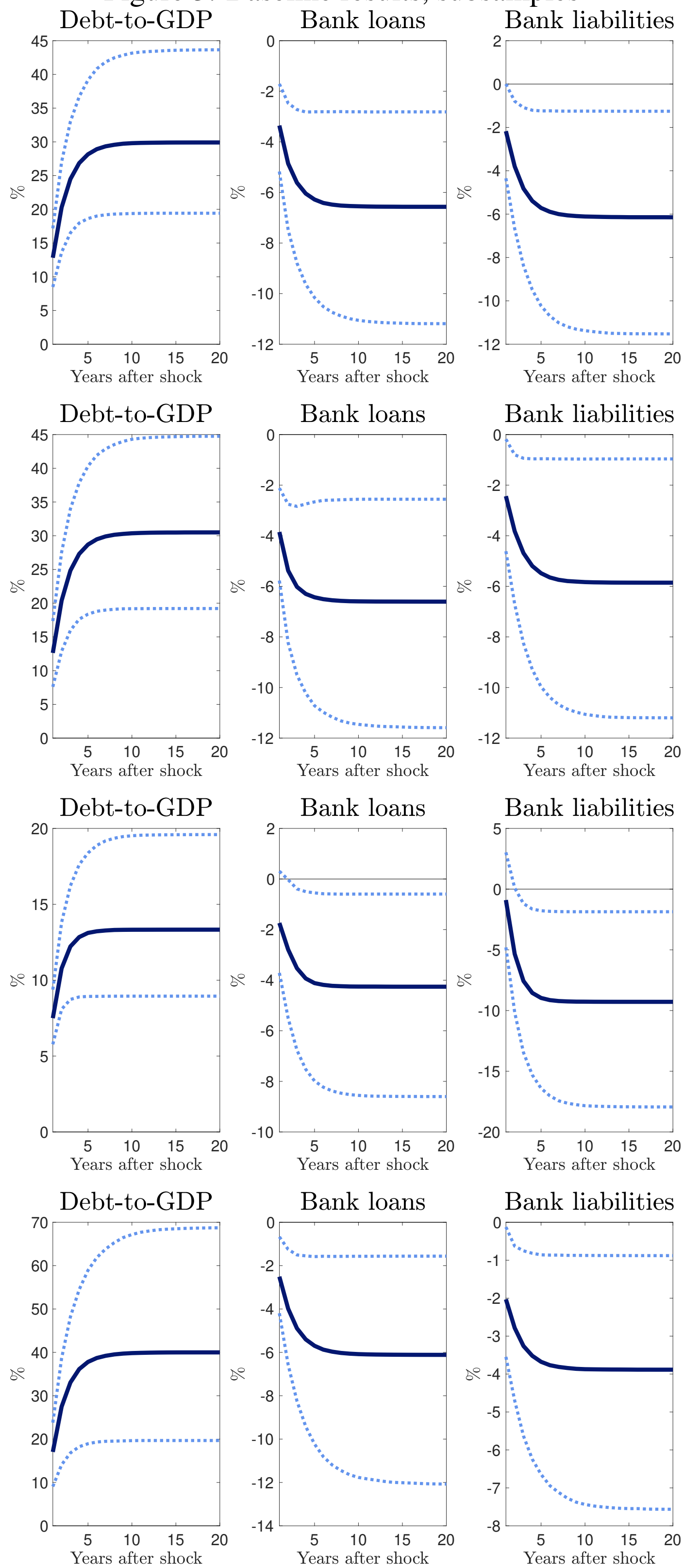
[3]For the mid panel, the data in growth rates start in 1897 because of limitation in the availability of data about the liabilities held by the government.

Figure 2: Baseline results, robustness



The solid line is the median cumulative impulse-response and the dotted lines denote the 90% confidence bands. Top panel: bank loans and liabilities defined as all loans and all liabilities; mid panel: bank liabilities defined as all the liabilities net of those held by the government (sample begins in 1897); bottom panel: baseline with two lags.

Figure 3: Baseline results, subsamples



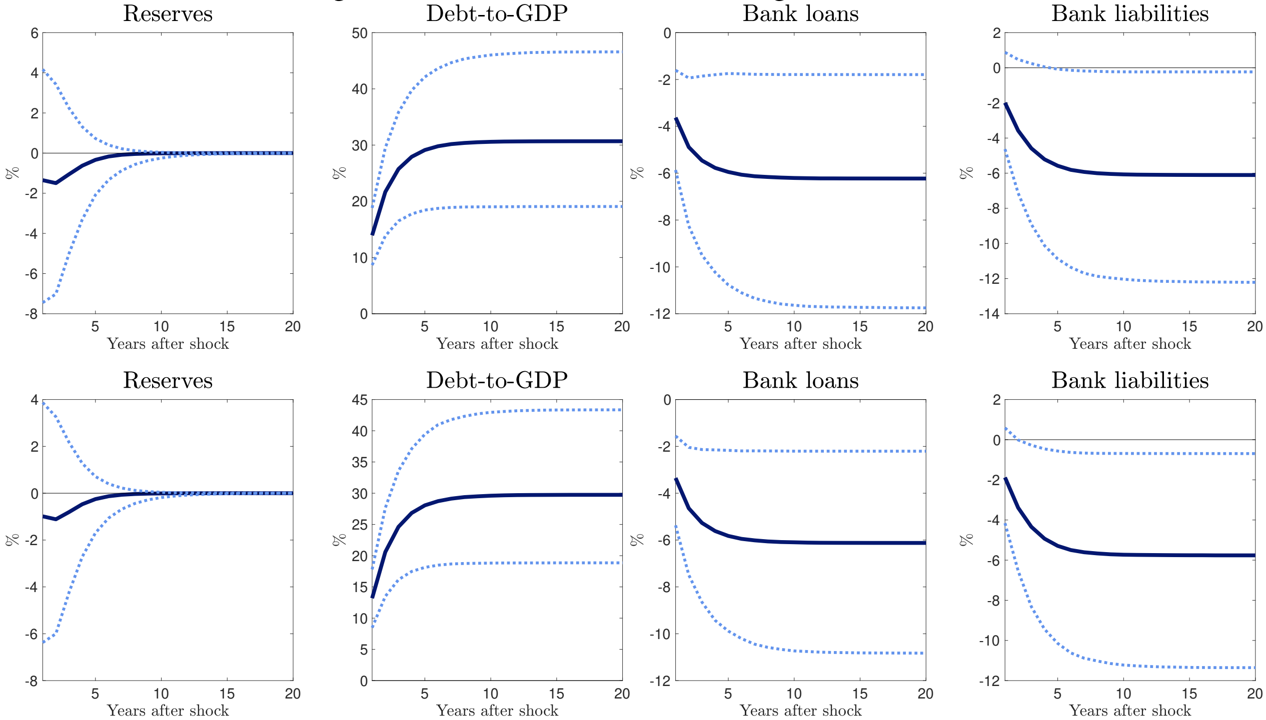
The solid line is the median cumulative impulse-response and the dotted lines denote the 90% confidence bands. Samples: until 2020 (top panel); until 2007 (2nd panel); starting in 1948 (3rd panel); ending in 1938 (bottom panel).

Figure 4 controls for the effects of unconventional monetary policy by including reserves in the VAR. We choose this measure of monetary policy because reserves are a direct measure of the size of the central bank balance sheet. This allows us to control not only for the various quantitative easing programs implemented from 2008 but also for the policies enacted during WW2 that lead the Federal Reserve to purchase a substantial share of Treasury debt. When estimating the VAR, we include reserves-to-GDP in the first position. Because of the way long-run restrictions operate, this ordering allows us to study the effect of a shock that changes the debt-to-GDP target but has no long-term impact on reserves to GDP.

The top panel in Figure 4 shows the results of including reserves-to-GDP ordered first, starting the sample in 1915 (i.e., omitting the years prior to the creation of the Federal Reserve). In the bottom panel, we extend the reserves-to-GDP series back to 1897 using data about the reserves that banks had to hold according to the rules in place during the national banking era. In both cases, the effects on bank loans and bank liabilities are indistinguishable from those of the baseline in Figure 1.

As the last step, we back out the time series of the (structural) shocks to the debt-to-GDP target, using our baseline 3-variable VAR. The results are plotted in Figure 5. Our approach detects large increases in the debt-to-GDP target driven by World War I, followed by a reduction in 1920—the latter is likely driven by the policies of the administration of President Warren Harding, that reduced the top marginal rate from 73% to 25% to boost the economy, cut federal spending, and brought public finances back in order after the end of the war. We also observe a negative shock in 1900 (after the end of the Spanish-American war), a positive shock during the Great Depression—more precisely, in 1933, after the election of President Roosevelt—and one in WW2. Toward the end of the sample, we observe a positive shock in 2001 (i.e., at the time of the last recession prior to 2008, and also the 9/11 terrorist attack), a positive one in 2008 (likely related to the fiscal response to the Great Recession), and a large negative shock in 2011. The latter coincides with a fiscal consolidation undertaken by the second Obama administration while Congress was in part controlled by the Republican party. Overall, the pattern in Figure 5 supports the fact that we are capturing important historical and political factors that affects the dynamic of debt to GDP.

Figure 4: Baseline results, controlling for reserves



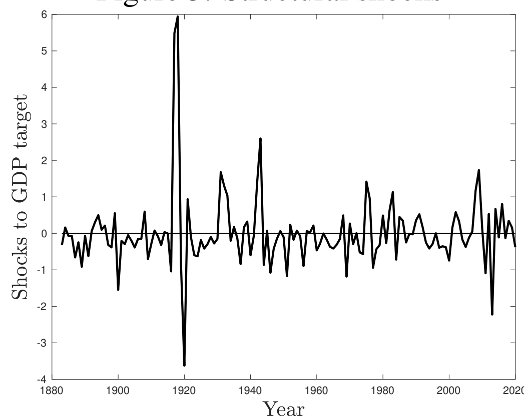
The solid line is the median cumulative impulse-response and the dotted lines denote the 90% confidence bands. Samples: 1914-2020 (top panel) and 1897-2020 (bottom panel).

2.5 Identification: discussion

The long-run identification scheme and the structure of the VAR that we use have the advantage of making sure that we focus on changes in the debt-to-GDP ratio that are not temporary and, thus, are likely not driven by business cycle fluctuations or financial shocks. Indeed, business cycle fluctuations and financial crises alone (i.e., without changes in the long-run target for the debt-to-GDP ratio) give rise to temporary changes in government debt. In the VAR, such changes are captured by shocks that have transitory effects on the level of debt to GDP. Instead, we focus on the shock that has permanent effects on debt to GDP and, by construction, is *orthogonal* to temporary shocks.

If shocks to the debt-to-GDP target are uncorrelated with any other shock in the economy, our approach would clearly work well. That is, we would identify the shocks that move the long-run target of debt to GDP and their effects on macro and financial variables. If shocks to the debt-to-GDP target are correlated with other shocks, we can correctly identify the long-term impact on

Figure 5: Structural shocks



Structural shocks to GDP target, based on the VAR that includes debt to GDP, bank loans, and bank liabilities.

macro and financial variable provided that we feed the VAR with variables normalized by GDP—as we do in our analysis. We explain the rationale of this claim with a few examples.

Consider first the case in which movements in the long-run debt-to-GDP target are correlated with transitory shocks that determine business cycle or financial fluctuations. This would be the case if, for instance, the government increases its debt-to-GDP target when it enters a recession. On impact, our impulse responses will be biased because they will capture the effects of both the new debt-to-GDP target as well as the effects of the recession. But as we look at the impulse response over a longer horizon, the results will be unbiased. The effects of a recession driven by transitory shocks are temporary and will eventually vanish, and the effects that are left can be attributed to the change in the debt-to-GDP target. This logic applies not only to shocks that create temporary booms and recessions, but to any transitory shock that might affect the economy.

Our most important results remain valid even if changes in the debt-to-GDP target are correlated with changes that are responsible for the long-term growth of an economy (i.e., permanent technology shocks). As economies grow over time (i.e., as they are hit by permanent technology shocks), it is well-documented that several aggregate macro and financial variables remain constant as a fraction of GDP—the so-called Kaldor facts. In Section 3, we sketch a model that builds on standard growth theory and replicates these stylized facts. In the model, a shock that permanently improve productivity produces no long-run changes in several aggregate ratios such as investments to GDP, deposits to GDP, and bank lending to GDP. Thus, if the permanent productivity shock is coupled with a shock to the debt-to-GDP target, any long-run effect on ratios such as investments to GDP, deposits to GDP, and bank lending to GDP can be attributed to the movement in the debt-to-GDP target. Similar to the previous case, the VAR results on impact might be biased, but this will not prevent us from correctly estimating the long-run effect of a change in debt-to-GDP target. However, because this logic applies only to variables measured as a fraction of GDP, we would be unable to correctly estimate the effects on GDP itself.

With these considerations in mind, we note that our baseline 3-variable VAR identifies shocks to the debt-to-GDP target that are essentially uncorrelated with GDP growth. This is the case when looking at the correlation with the growth rate of real GDP (correlation=-0.03, p-value=0.69), and with the cycle and growth rate of the trend component of GDP obtained with an HP-filter (log of cycle: correlation=0.01, p-value=0.01; growth rate of trend: correlation=0.05, p-value=0.57).[4] Besides ruling out systematic links with GDP growth, the lack of correlation with the cycle component of GDP shows that our long-run identification approach filters out variations in debt to GDP related to business cycles.

A relevant case in which even our long-term estimates would be biased is a scenario in which movements in the debt-to-GDP target are systematically correlated with permanent shocks that affect the ratio of aggregate macro and financial variables to GDP. The most prominent story along this line would be a change in the debt-to-GDP target taking place during a recession with hysteresis demand effects. In particular, this scenario relies on a recession associated with both (i) a shock that decrease permanently firms' demand for investments and for bank credit (Blanchard and Summers, 1986; Furlanetto et al., 2021) and (ii) an increase in the debt-to-GDP target. If this were the case, the reduction in bank lending and investments we observe would be driven by demand factors, as opposed to a change in the conditions of the banking system that is triggered by a change in banks' liabilities demand and fiscal policy. We rule out this possibility in the next section by providing evidence that the reduction in firms' investments and bank credit is driven by supply considerations (i.e., by a reduction in bank loan supply), as opposed to a reduction in firms' investments and credit demand.

[4]We use a filtering parameter of 100 when applying the HP filter to our annual data.

2.6 Additional results part I: identification

We now deal with some possible identification issues, and we provide evidence that supports our interpretation of the results. We provide three sets of exercises. First, we provide evidence that our VAR identifies shocks to the *supply* of bank lending by showing that firms substitute toward nonbank financing (i.e., commercial paper and corporate bonds) after an increase in the debt-to-GDP target and a reduction in bank liabilities. Second, we provide evidence that our VAR identifies shocks to the *supply* of Treasury securities by showing that prices and quantities move along the demand for Treasury debt identified by Krishnamurthy and Vissing-Jorgensen (2012). Third, we rule out the possibility that variations in the debt-to-GDP target are driven by changes in long-run growth or interest rates. Because of data availability, we run all the robustness checks in this section starting our sample in 1921.[5]

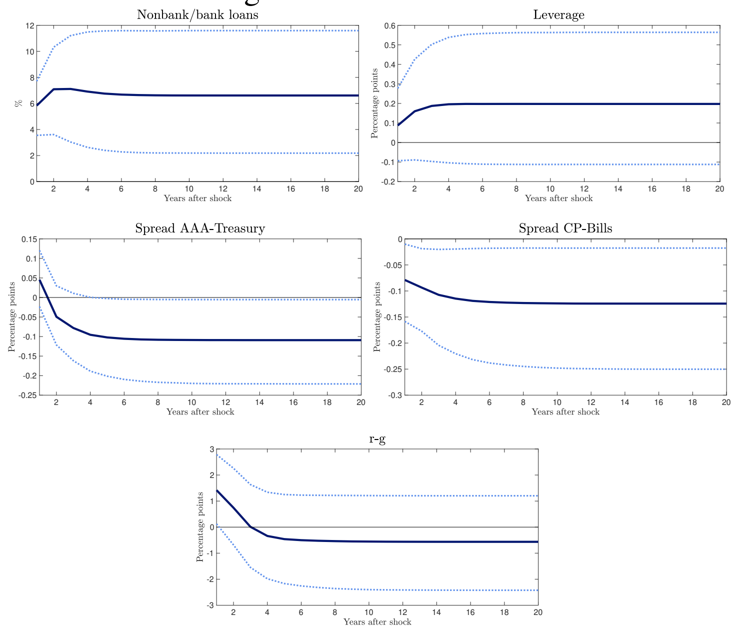
To derive the results of this and the next section, we proceed along the lines of Burnside, Eichenbaum, and Fisher (2004) and Ramey (2011) by using a fixed set of variables in the VAR and rotating other variables of interest.[6] Our approach is to run 3-variable VARs in which we always include debt to GDP and bank lending, and in which we rotate the third variable. We include debt to GDP because it is necessary to identify the shocks to the debt-to-GDP target. We include bank lending because it affects directly firms' investments and, thus, proxies firms' (physical) capital, which is a key state variables in both business cycle macro models (King and Rebelo, 1999) and corporate finance models (Nikolov and Whited, 2014).

As a first step, we show that we are identifying shocks to the supply of bank lending. To this end, we include in the VAR the ratio of nonbank to bank lending (in growth rates), where nonbank lending is defined as the sum of commercial paper and corporate bonds. The top left Figure 6 plots the cumulative impulse response of the ratio of nonbank to bank loans in response to a permanent increase in debt to GDP. This ratio increases and remains higher, the effect is statistically significant, and the magnitude is large. This result says that, when the Treasury supply goes up and banks liabilities and lending drop, firms replace bank loans with other sources of external financing. We thus infer that bank loans become more expensive relative to nonbank

[5]We have also re-run our baseline 3-variable VAR starting in 1921 and the results are nearly unchanged—in fact, the median estimated elasticity is a bit higher at about 0.38 for both bank loans and bank liabilities, in comparison to about 0.21 for the baseline analysis.

[6]In principle, one could include all the variables of interest in a single VAR, but that would require the estimation of a very large number of parameters and would make the inference nearly impossible.

Figure 6: Identification



The solid line is the median cumulative impulse-response to a permanent increase in debt to GDP, and the dotted lines denote the 90% confidence bands. Sample: 1921-2020.

financing, so that firms substitute bank loans with other borrowing. This result provides evidence that we are identifying changes in the supply of bank lending, as opposed to changes in firms' demand for bank loans.

Having shown that we are identifying changes in loan supply, a follow-up question arises. Are these changes in loan supply truly driven by a reduction in bank liabilities, or are they driven by other factors? For instance, after the 2008 Great Recession, the regulatory changes triggered a reduction in bank leverage, and this might have caused a reduction in lending.[7] To this end, the top right panel of Figure 6 shows the result of including leverage in our VAR.[8] The point estimate is positive—the opposite of what could be inferred by looking at the Great Recession alone—and in any case, we do not detect any statistically significant change in leverage.

As a second step, we show that our approach identifies changes in the supply of Treasury debt, as opposed to fluctuations in the demand for Treasury securities. Krishnamurthy and Vissing-

[7]The link between leverage and bank lending is not obvious a priori. Begenau (2020) notes that tighter financial regulation—such as capital requirements—that reduces leverage might increase or decrease lending, and her quantitative analysis calibrated to the later part of our sample shows that tighter regulation increases lending.

[8]Leverage is defined as the ratio of assets to capital of FDIC-insured commercial banks starting in 1934, and the ratio of assets to capital for all banks for the previous years.

Jorgensen (2012) show that there exists a demand for Treasury debt that is downward sloping in the spread with privately-issued financial assets that are safe but slightly less liquid, such as AAA corporate bonds or commercial paper. The mid-left panel of Figure 6 shows the cumulative impulse response on the spread between the interest rate on AAA corporate bonds and 10-year Treasury securities, and the mid-right panel shows the same response for the spread between commercial paper and Treasury bills—we use the spread data constructed by Krishnamurthy and Vissing-Jorgensen (2012). We observe a reduction in both spreads in response to a permanent increase in debt to GDP, showing that we are capturing movements of Treasury supply along a downward sloping demand curve.

Finally, in the bottom panel of Figure 6 we show the cumulative impulse response of $r-g$, that is, the yield on long-term Treasury bonds minus the growth rate of GDP. We observe no long-term effects on $r-g$, showing that changes in $r-g$ are not systematically associated with the changes in the debt-to-GDP target that we identify. In other words, the changes in the debt-to-GDP target that we identify are not driven by changes in interest rates or economic growth, and thus are likely driven by changes in policymakers' preferences over such a target.

2.7 Additional results part II: effects on investments and GDP

We now study the effects on investments and GDP from the crowding out of bank liabilities and bank lending triggered by an increase in the supply of Treasury securities.

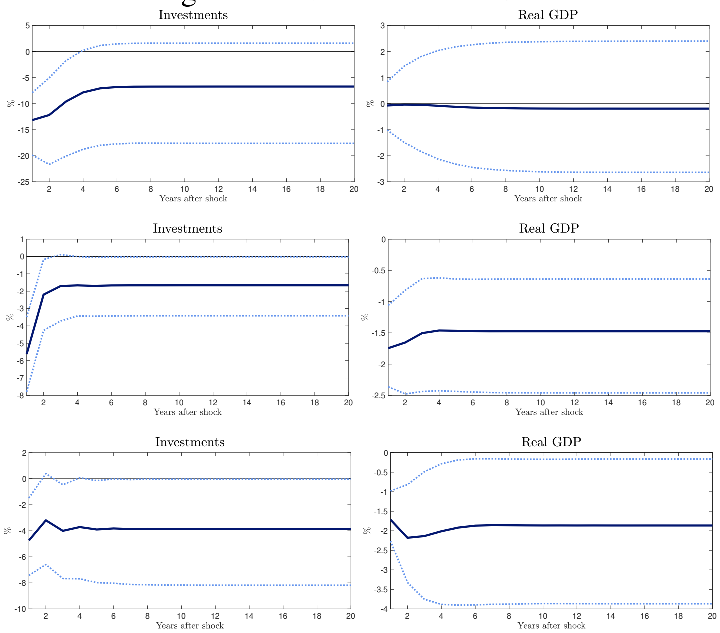
The top panel of Section 2.7 shows the effect of an increase in the debt-to-GDP target on investments to GDP, and GDP. The effect on investments is negative and large, but is significant only on impact. In addition, we observe no systematic effects on GDP. These results, however, could be contaminated by other events—in particular, the influence of WW1 and WW2, so we repeat our analysis for the post-WW2 and pre-WW1 periods.

The mid panel of Section 2.7 shows the results for the post-WW2 periods, and the bottom panel shows the results for the pre-WW1 period.[9] We now detect a significant permanent effect on both investments and GDP and in both subsamples.[10] That is, excluding major wars, the reduc-

[9]For the pre-WW1 period, we extend the sample back to 1871 and 1867 for investments and GDP, respectively, to make sure that we have a long enough sample to capture low-frequency variations in debt to GDP—for GDP, earlier data is available but we start in 1867 to omit the effects of the Civil War. Because we have bank loans data only starting in 1882, we just run a two-variable VAR with debt-to-GDP and either investments to GDP or GDP.

[10]The elasticity of investments with respect to debt to GDP is -0.140 in the post-WW2 period (90% confidence

Figure 7: Investments and GDP



The solid line is the median cumulative impulse-response to a permanent increase in debt to GDP, and the dotted lines denote the 90% confidence bands. "Investments" is defined as the ratio of investments to GDP. The top panel uses the full sample, the mid panel uses post-WW2 data (i.e., 1948-2020), and the bottom panel uses pre-WW1 data (i.e., 1867-1913 and 1871-1913 for investments and GDP, respectively). The bottom panel uses a two-variable VAR with debt to GDP ordered first and investments (left panel) or GDP (right panel) ordered second.

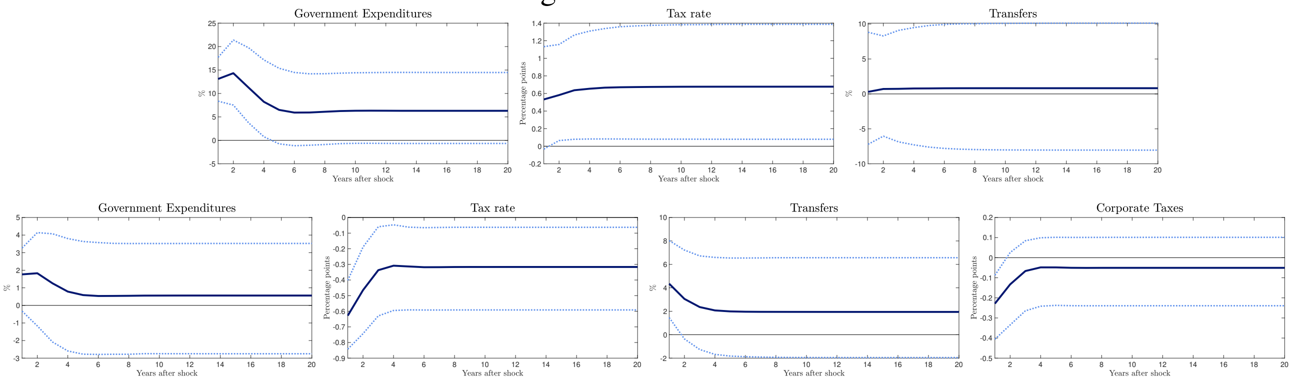
tion in bank lending triggered by the crowding out of bank liabilities reduces the ratio of firms' investments to GDP, and ultimately, GDP itself.

That said, we are cautious about interpreting the effects on GDP as causal, as explained in Section 2.5. In the post-WW2 period, there is a strong correlation between changes in debt-to-GDP target and GDP—including its trend component. In the pre-WW1 period, there is a positive correlation as well, but that is entirely driven by the cyclical component of GDP (correlation of structural shocks with the growth rate of trend GDP =-0.06, p-value =0.68). Not surprisingly, the cumulative impulse-response in the bottom-right panel of Section 2.7 has larger confidence bands than the one for the post-WW2 period.

To sum up, the crowding out of bank liabilities is ultimately transmitted to firms' investments (and possibly GDP) but only during peacetime periods. The next section argues that a possible reason for the difference between peacetime and war periods is that fiscal policy is conducted differently across these times.

interval: -0.001, -0.417) and -0.37 in the pre-WW1 period (90% confidence interval: -0.001, -1.340).

Figure 8: Fiscal variables



The solid line is the median cumulative impulse-response to a permanent increase in debt to GDP, and the dotted lines denote the 90% confidence bands. Government expenditures and transfers are expressed as a fraction of GDP; the tax rate is defined as tax revenues as a fraction of GDP. The top panel uses the full sample (with a start date of 1890 and 1930 for government expenditures and transfers), and the bottom panel uses post-WW2 data (i.e., 1948-2020).

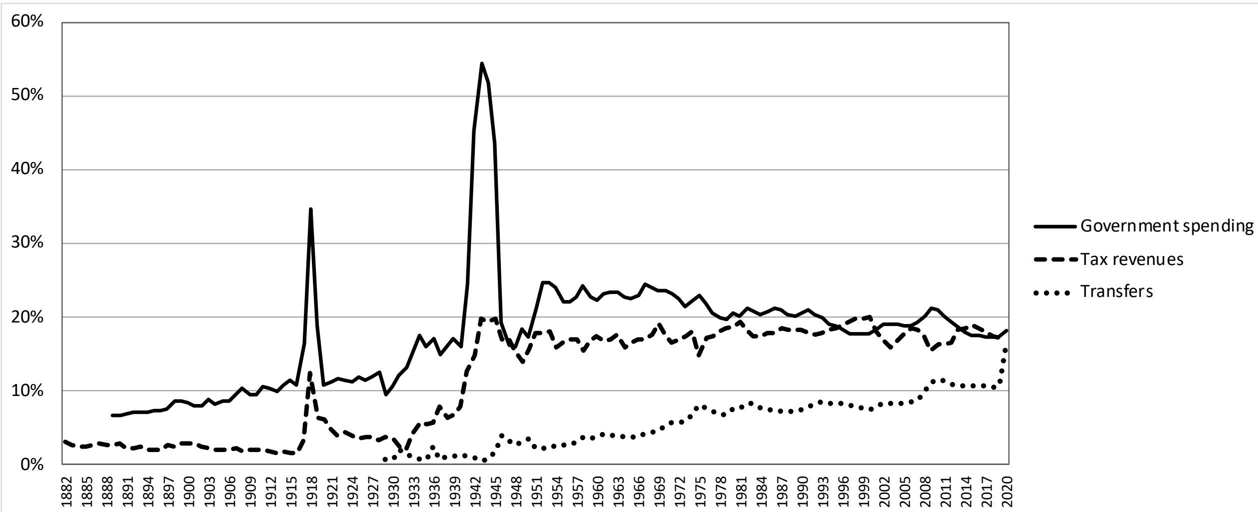
2.8 Additional results part III: fiscal policy

We now turn to the analysis of fiscal variables in connection to changes in the debt-to-GDP target. When the government changes the debt-to-GDP target, it must change some of its fiscal policy variables to achieve the new level of debt-to-GDP. We thus investigate how the change in the debt-to-GDP target is implemented. A key issue is that a change in fiscal variables could produce direct effects on fiscal and macroeconomic variables, above and beyond those that are transmitted through the banking sector. We show, however, that this is not an issue for the interpretation of our results.

The top panel of Figure 8 plots the evolution of government expenditures, tax revenues, and transfers (all defined as a fraction of GDP) after a shock to the debt-to-GDP target, using all the data we have available. (For government expenditure and transfers, the sample starts in 1890 and 1930, respectively, because of lack of earlier data). We observe an increase in government expenditures and taxes, but only the effect on taxes is significant in the long-run. No effect on transfers is observed.

As noted in Section 2.7, some results might be different depending on war versus peacetime periods. In this respect, Figure 9 plots fiscal variables as a percent of GDP and shows that government expenditures and tax revenues increased dramatically during WW1 and WW2. Expenditures reverted to a level close to the pre-war period soon after, but the effect of wars on taxes is more persistent—they slowly decrease in the 1920s and remain permanently higher after WW2. Trans-

Figure 9: Fiscal variables, as % of GDP



Solid line: government spending; dashed line: tax revenues; dotted line: transfers. All variables are defined as a fraction of GDP. Government spending includes consumption and investments at all level of government.

fers have been increasing throughout the sample, with a substantial jump only in 2020 in relation to COVID-19.

We thus consider the evolution of fiscal variables in the post-WW2 period. (Because of limited data availability in the earlier part of the sample, we do not run a sub-sample analysis with pre-WW1 data.) The results are reported in the bottom panel of Figure 8. We now observe no significant changes in government expenditures, a permanent reduction in taxes, and no permanent effects on transfers. We also include in the analysis the evolution of corporate income tax revenues (as a fraction of GDP), which displays no long-term change.

The key result we want to focus on is the fact that taxes either go down or remain constant, depending on whether one looks at total tax revenues or corporate income tax revenues. However, recall from Section 2.7 that investments drop in the post-WW2 period. The crowding out of bank liabilities and reduction in loan supply triggers a reduction in investments, *despite* the taxes not increasing—the effects on investments alone, driven by constant or lower taxes, should be weakly higher investments. Thus, we conclude that the main effect on bank lending and investments that we document is not crucially affected by the possible direct effects of fiscal policy.

2.9 Additional results part IV: firms and labor market

We conclude our empirical analysis by providing a list of results related to other firm variables and the labor market. In short, we find little effects on firms—beyond the reduction in investments documented in Section 2.7—but significant negative effects on labor market variables: a drop in employment and a reduction in the labor share of income. Because of data availability, these results are based on a subsample that varies depending on the time series we analyze (see Figure 10).

We begin by reporting the evolution of a series of firm financial variables after an increase in the debt-to-GDP target, in Figure 10. We observe no permanent effects on corporate bonds default rate (using data from Giesecke et al., 2011), on profits (the top right panel in Figure 10 displays the evolution of profits before taxes, but the result is nearly identical using after-tax profits), and on proprietor equity. We detect, however, a permanent reduction in corporate dividends.

With respect to the labor market, we explore the effects on three variables: nonfarm payroll, unemployment rate, and labor share of income. We identify a statistically significant permanent effect in all three variables—a reduction in payroll and labor share, and an increase in the unemployment rate. The magnitude of the effects is quite large too. A 1% increase in the debt-to-GDP target reduces nonfarm payroll by 0.18%, increases unemployment rate by 0.05 percentage points, and reduces the labor share of income by 0.04 percentage points.

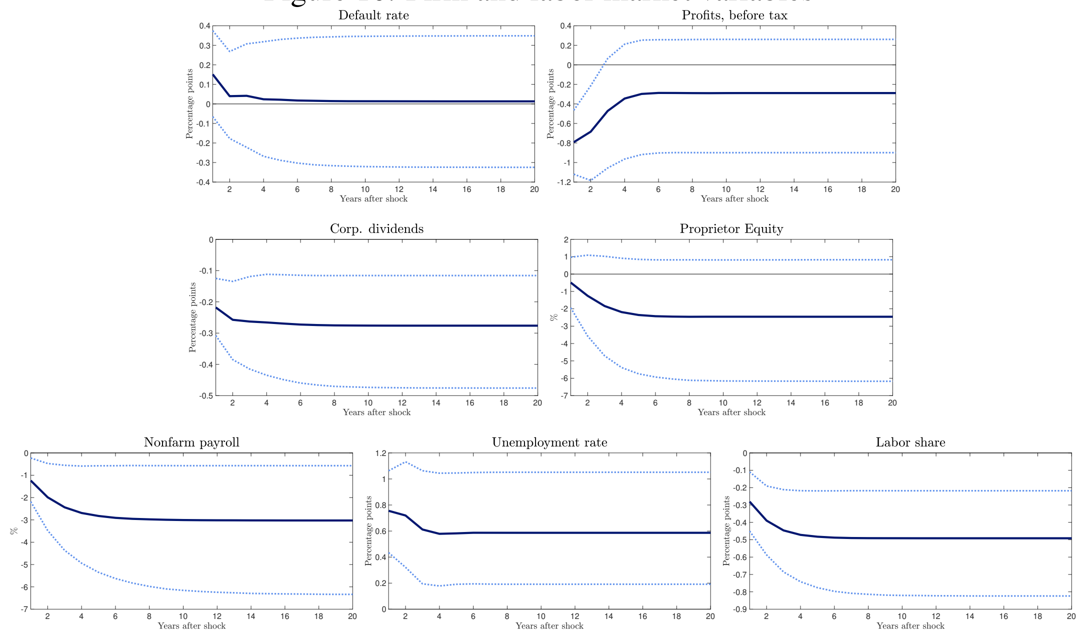
Taken together, these results suggest that workers bear most of the negative consequences of the crowding out of bank liabilities and bank lending that is triggered by an increase in the debt-to-GDP target.

3 Model

This section presents a model that rationalizes the empirical findings presented above, provides insights into the impact of government liabilities on the economy, and can be used for policy analysis. In the current draft, our analysis is qualitative and we illustrate the functioning of the model using numerical examples. We plan to extend our analysis to include a quantitative analysis.

The model has four building blocks: households, banks, firms, and the government. Households value the deposits and government debt not only because of their return but also because of the liquidity they provide. As in Krishnamurthy and Vissing-Jorgensen (2012), we model this fea-

Figure 10: Firm and labor market variables



The solid line is the median cumulative impulse-response to a permanent increase in debt to GDP, and the dotted lines denote the 90% confidence bands. All the variables but nonfarm payroll and unemployment rate are defined as a fraction of GDP. “Default rate” refers to the default rate on corporate bonds. Samples: 1882-2012 for corporate default rate; 1930-2020 for corporate profits and corporate dividends; 1948-2020 for proprietor equity; 1940-2020 for nonfarm payroll; 1949-2020 for unemployment rate; and 1951-2019 for labor share of income.

ture using a Sidrausky-type model in which deposits and Treasury debt enter the utility function. Banks are modeled as in Gertler and Kiyotaki (2010), in which bankers face an agency problem that constrains their ability to borrow using deposits. Firms are similar to standard business cycle models, except for the fact that they use credit from both banks and non-banks. We model this feature using a very general specification and then explore implications of different parameter values. Finally, the government section extends and details the general framework outlined in Section 2.1. The government faces a budget constraint, and sets a target for Treasury debt as well as other policies that determine taxes and expenditures.

Because we analyze long-run changes in government policies and financial variables, it is important that our model is consistent with key stylized facts of the economic growth literature. More specifically, our model builds on a neoclassical growth framework with a balanced growth path, and thus is consistent with the Kaldor facts of economic growth (Kaldor, 1961), that is, the long-run constancy of the growth rate, the capital-output ratio, the share of income attributable to labor and capital, and the real interest rate.

After presenting the model, we study the effects of unanticipated shocks, and in particular, of technology shocks and of a change in the debt-to-GDP target of government debt.

3.1 Households

Households have utility

$$\mathbb{E}_0 \sum_t \beta^t \left[-h\left(L_t\right) + u\left(C_t\right) + v\left(\frac{D_t + B_t}{C_t}\right)\right]$$

where L_t are hours worked, C_t is consumption, D_t are bank deposits, and B_t is government debt. The function $v\left(\cdot\right)$ is increasing and concave and captures the fact that households derive liquidity benefits from bank deposits and government debt.

Households maximize their utility subject to the budget constraint

$$C_t + K_t^{nb} + q_t^d D_t + q_t^b B_t \leq K_{t-1}^{nb}\left[1 + \left(r_t^{nb} - \delta\right)\left(1 - \tau_t^k\right)\right] + \left(D_{t-1} + B_{t-1}\right) + w_t L_t\left(1 - \tau_t^l\right) + \Pi_t + T_t.$$

In each period, households purchase consumption goods C_t and decides their portfolio of investments. Households can provide credit directly to firms by investing in capital K_t^{nb} (where nb stands for “nonbank”), they can deposit D_t at banks, and can purchase government debt B_t. Deposits and government debt are modeled as zero-coupon securities with unitary face value and price q_t^d and q_t^b, respectively.

Households finance their consumption expenditures and investments by drawing on several resources. First, the investments in capital K_{t-1}^{nb} made at $t-1$ pay a return r_t^{nb}, net of depreciation δ and taxes τ_t^k. Second, households have access to bank deposits and investments in Treasury debt made at $t-1$, that is, D_{t-1} and B_{t-1}. Third, households earn labor income $w_t L_t$ (where w_t is wage), net of taxes τ_t^l. Fourth, households get lump-sum dividends Π_t from banks and lump-sum transfers T_t from the government.

The problem of households can be expressed recursively as

$$V_t\left(X_t\right) = \max\left\{ -h\left(L_t\right) + u\left(C_t\right) + v\left(\frac{D_t + B_t}{C_t}\right) + \beta \mathbb{E}_t V_{t+1}\left(X_{t+1}\right)\right\}$$

s.t.

$$C_t + K_t^{nb} + q_t^d D_t + q_t^b B_t \leq X_t + w_t L_t \left(1 - \tau_t^l\right)$$

$$X_{t+1} = K_{t-1}^{nb}\left[1 + \left(r_t^{nb} - \delta\right)\left(1 - \tau_t^k\right)\right] + \left(D_{t-1} + B_{t-1}\right) + \Pi_t + T_t.$$

The first-order conditions with respect to labor L_t, consumption C_t, capital K_t^{nb}, deposits D_t, and government debt B_t imply:

$$h'\left(L_t\right) = V_t'\left(X_t\right) w_t \left(1 - \tau_t^l\right)$$

$$u'\left(C_t\right) - v'\left(\frac{D_t + B_t}{C_t}\right)\frac{D_t + B_t}{C_t^2} = V_t'\left(X_t\right)$$

$$V_t'\left(X_t\right) = \beta \mathbb{E}_t\left\{V_{t+1}'\left(X_{t+1}\right)\left[1 + \left(r_{t+1}^{nb} - \delta\right)\left(1 - \tau_{t+1}^k\right)\right]\right\}$$

$$v'\left(\frac{D_t + B_t}{C_t}\right)\frac{1}{C_t} + \beta \mathbb{E}_t\left\{V_{t+1}'\left(X_{t+1}\right)\right\} = q_t^d V_t'\left(X_t\right)$$

$$q_t^d = q_t^g.$$

In our numerical simulations, we use the following functional form for the utility benefits provided by deposits and government debt:

$$v\left(\frac{D_t + B_t}{C_t}\right) = \psi \frac{\left(\frac{D_t + B_t}{C_t}\right)^{1-\gamma_d}}{1 - \gamma_d}.$$

3.2 Banks

Banks work as in Gertler and Kiyotaki (2010). There is a mass of bankers, and each of them faces a probability $1 - \psi$ of exiting and becoming an household member. Every banker that exits is replaced by a new one, so that the mass of bankers remain constant. The setup of Gertler and Kiyotaki (2010) is very tractable and allows to combine together the choices of all the bankers, without the need to keep track of the distribution of their net worth.

Consider a representative banker with net worth N_t. The banker chooses capital (i.e., bank lending) K_t^b and deposits D_t to maximize

$$v_t^b\left(N_t\right) = \max_{K_t^b, D_t} \mathbb{E}_t\left\{\Lambda_{t+1}\left[\left(1 - \psi\right)\,\tilde{N}_{t+1} + \psi\, v_{t+1}^b\left(N_{t+1}\right)\right]\right\}$$

subject to the budget constraint

$$K_t^b \leq N_t + q_t^d D_t$$

and a constraint that originates from an agency friction:

$$\theta K_t^b (n_t) \leq v_t^b (N_t),$$

and where

$$\tilde{N}_{t+1} = \left(1 + \left(r_{t+1}^b - \delta\right)\left(1 - \tau_{t+1}^k\right)\right) K_t^b - D_t.$$

Bankers collect deposits D_t (issued at price q_t^d) and invest in capital K_t^b. After the investment is made, the banker can divert a fraction θ of the resources invested, leaving nothing for the depositors. To avoid misbehavior, the continuation value of running the bank, $v_t^b(N_t)$, must be at least as large as the resources θK_t^b that can be diverted by the banker. If this incentive constraint holds — as it is the case in equilibrium — the banker does not divert any resource.

Bankers discount the future using the discount factor Λ_{t+1} of households. With probability $1-\psi$, the banker will exit and will give the accumulated net worth N_{t+1} as a dividend to his household. Otherwise, the banker keeps being a banker. When a banker will exist, a member of the household who is currently not a banker will replace him. Therefore, the measure of bankers and workers in the household is constant.

The variable $\tilde{N}_{t+1}$ denotes the net worth in $t+1$ of the representative banker with net worth N_t. The net worth includes the gross proceeds earned from bank lending (i.e., the return r_{t+1}^b net of depreciation δ and taxes τ_{t+1}^k) minus the repayment D_t to depositors. Note that $\tilde{N}_{t+1}$ is not the same as the total net worth of the economy in $t+1$, which accounts for the entry and exit of bankers. The law of motion of aggregate net worth is

$$\begin{aligned}
N_{t+1} &= \underbrace{\psi\left[\left(1 + \left(r_{t+1}^b - \delta\right)\left(1 - \tau_{t+1}^k\right)\right) K_t^b - D_t\right]}_{\text{net worth of bankers that do not exit}} \\
&\quad + \underbrace{(1-\psi)}_{\text{bankers that enters}} \underbrace{\omega\left[\left(1 + \left(r_{t+1}^b - \delta\right)\left(1 - \tau_{t+1}^k\right)\right) K_t^b - D_t\right]}_{\text{endowment of wealth for new bankers}} \\
&= \left[\psi + (1-\psi)\,\omega\right]\left[\left(1 + \left(r_{t+1}^b - \delta\right)\left(1 - \tau_{t+1}^k\right)\right) K_t^b - D_t\right].
\end{aligned}$$

As in Gertler and Kiyotaki (2010), we assume that new bankers that enter at $t+1$ receive an endowment of net worth equal to a fraction $\omega < 1$ of the the net worth of the average banker that does not exit. Because ω is less than one, the term $\psi + (1-\psi)\,\omega < 1$ essentially parametrizes the dividends that are paid by banks to households. In addition, because $\psi + (1-\psi)\,\omega$ is constant, banks' net worth responds relatively slowly to macroeconomic shocks, as it is the case in practice.

The problem of bankers can be solved by guessing and verifying that their value function is proportional to net worth:

$$v_t^b\left(N_t^b\right) = \alpha_t n_t.$$

The verification steps allows us to solve for α_t, which is given by

$$\alpha_t = \frac{\left(1/q_t^d\right)\mathbb{E}_t\left\{\left[\Lambda_{t+1}\left(1-\psi+\psi\,\alpha_{t+1}\right)\right]\right\}}{1-\mathbb{E}_t\left\{\left[\Lambda_{t+1}\left(1-\psi+\psi\alpha_{t+1}\right)\frac{1}{\zeta}\left[\left(1+\left(r_{t+1}^b-\delta\right)\left(1-\tau_{t+1}^k\right)\right)-1/q_t^d\right]\right]\right\}}.$$

3.3 Firms

Firms are modeled as static players that get credit from households and banks, hire workers, and produce. The production function is given by

$$Y_t = \left(K_{t-1}\right)^{\alpha}\left(A_t L_t\right)^{1-\alpha}$$

where A_t is aggregate TFP, K_{t-1} is capital, and L_t is labor. Firms' choose capital K_{t-1} at time t, but because capital in the overall economy is predetermined at time $t-1$, we follow the notation used before and index it by $t-1$. Capital K_{t-1} used by firms is a composite of capital rented from households, K_{t-1}^{nb}, and capital rented from banks, K_{t-1}^{b}:

$$K_{t-1} = \left[\gamma^K\left(K_{t-1}^{nb}\right)^{\nu} + \left(1-\gamma^K\right)\left(K_{t-1}^{b}\right)^{\nu}\right]^{\frac{1}{\nu}}. \tag{4}$$

This specification is very flexible and allows us to consider very different cases. For instance, as $\nu \to 1$, K_{t-1}^{nb} and K_{t-1}^{b} are perfect substitutes. We interpret this scenario as the case in which firms can very easily substitute bank credit with non-bank credit, and vice versa. At the opposite case, in which $\nu \to -\infty$, K_{t-1}^{nb} and K_{t-1}^{b} are perfect complement. This case would arise, for instance, if firms face a collateral constraint of the form $K_{t-1}^{b} \leq \theta K_{t-1}^{nb}$, that is, if banks require the assets

K_{t-1}^{nb} as collateral.

Our choice of considering a labor-augmenting TFP (i.e., to raise A_t to the power of $1-\alpha$) is motivated by our objective of building a model that produces a balanced growth path. That is, this specification is necessary to obtain a model in which a permanent technology shock does not alter the ratio of aggregate variables to GDP in the long run.

Firms' profits are given by

$$\Pi_t^{nb} = (K_{t-1})^{\alpha} (A_t L_t)^{1-\alpha} - r_t^{nb} K_{t-1}^{nb} - r_t^{b} K_{t-1}^{b} - w_t L_t$$

and their first-order conditions with respect to K_{t-1}^{nb}, K_{t-1}^{b}, and L_t are

$$(A_t L_t)^{1-\alpha} \alpha (K_{t-1})^{\alpha-1} \frac{\partial K_{t-1}}{\partial K_{t-1}^{nb}} = r_t^{nb}$$

$$(A_t L_t)^{1-\alpha} \alpha (K_{t-1})^{\alpha-1} \frac{\partial K_{t-1}}{\partial K_{t-1}^{b}} = r_t^{b}$$

$$(1-\alpha)(K_{t-1})^{\alpha} A_t^{1-\alpha} (L_t)^{-\alpha} = w_t.$$

Productivity A_t evolves according to the law of motion

$$A_t = \left(1-\rho^A\right) \overline{A} + \rho A_{t-1} + \varepsilon_t^A$$

where $\overline{A}$ is the average productivity and ε_t^A is a productivity shock.

3.4 Government

The government faces the budget constraint

$$q_t^b B_t + \tau_t^l w_t L_t + \tau_t^k \left[\left(r_t^{nb} - \delta\right) K_{t-1}^{nb} + \left(r_t^{b} - \delta\right) K_{t-1}^{b}\right] = B_{t-1} + G_t + T_t.$$

Government outlays include the repayment of bonds issued in $t-1$, the purchase of goods and services G_t, and lump-sum transfers to households T_t. The government finances these expenditures by issuing new debt B_t and raising taxes. Taxes are levied on labor income and capital income. Labor income $w_t L_t$ is taxed at rate τ_t^l. Capital income $\left(r_t^{nb} - \delta\right) K_{t-1}^{nb} + \left(r_t^{b} - \delta\right) K_{t-1}^{b}$ is taxed at rate τ_t^k.

Government debt evolves according to the law of motion

$$\frac{B_t}{Y_t} = \left(1 - \rho^B\right) \bar{b} + \rho^B \frac{B_{t-1}}{Y_{t-1}} + \varepsilon_t^B$$

where Y_t is GDP. The long-run target for Treasury debt is $\bar{b}$. Thus, to replicate the empirical analysis in the context of the model, we need to study the effects of a permanent increase in $\bar{b}$.

To complete the description of the government, we need to specify three additional equations. This is because the government chooses five policy instruments (i.e., τ_t^l, τ_t^k, G_t, T_t, and B_t) and we have already provided two equations (i.e., the budget constraint and the law of motion of B_t). The three remaining equations specify the dynamic of three of the four policy instruments τ_t^l, τ_t^k, G_t, T_t, with the fourth being residually determined by the government budget constraint. In what follows, we provide equations that specify τ_t^l, τ_t^k, and G_t, so that transfers T_t are residually determined by the budget constraint. We assume taxes to be constant:

$$\tau_t^l = \bar{\tau}^l, \qquad \tau_t^k = \bar{\tau}^k$$

and government expenditure to be given by

$$\frac{G_t}{Y_t} = \left(1 - \rho^G\right) \bar{g} + \rho^G \frac{G_{t-1}}{Y_{t-1}} + \varepsilon_t^G$$

where $\bar{g}$ is the target of public expenditure as a fraction of GDP.

The choice to have transfers T_t residually determined by the budget constraint is not inconsequential, but it produces the cleanest results. Because transfers T_t enters in a non-distortionary way in the households' budget constraint. In contrast, taxes on labor and capital are distortionary, and government expenditure G_t enters the resource constraint. In the next section, we argue that some results are even stronger when taxes are allowed to adjust. We will discuss the effects of letting G_t adjust in future drafts of the paper.

3.5 Numerical examples

We use some numerical examples to illustrate the functioning of the model. Our ultimate objective is to have a fully quantitative analysis that disciplines the model and can be used for policy analysis, but we have not yet completed that step. The numerical examples are based on the effects of one-time unanticipated shocks that hit the economy in steady state.

We summarize the implications of the numerical examples by providing a series of result statements. The relevance of these results is just qualitative because our model is not fully calibrated; hence, we do not report quantitative results. The specific parameter values required for these results are not important, with two important exception. First, because we assumed that the utility of consumption and the disutility of labor are separable, we need to assume $u(C) = \log C$. This is a standard requirement to obtain a model with a balanced growth path. The requirement can be relaxed to have a more general risk aversion parameter or Epstein-Zin utility, as long as consumption and leisure utility are modeled with non-separable preferences. Second, we have solved the model under parameter values that imply that the incentive compatibility constraint of banks is binding in equilibrium.

3.5.1 Technology shocks

We begin by summarizing the effects of technology shocks. Because our model admits a balance growth path, neither temporary nor permanent technology shocks have an effect on the long-run value of aggregate variables as a fraction of GDP.

With respect to temporary shocks, the same result holds if we introduce a temporary shock that affects not only productivity but also any of the parameter of the model. Because temporary shocks are mean reverting, they do not affect the steady state of the economy and, thus, have no long-term effects.

Result 1. *The model admits a balanced-growth path. That is, from the initial steady state, and in response to a permanent shock to $\overline{A}$, the economy converges to a new steady state in which labor, government debt over GDP B/Y, investments over GDP $\delta\left(K^b + K^{nb}\right)/Y$, capital over GDP K^{nb}/Y and K^b/Y, and deposits over GDP D/Y are the same as in the initial steady-state.*

Result 2. *After a temporary shock, the economy reverts back to the original steady state. In particular, government debt over GDP B/Y, investments over GDP $\delta\left(K^b + K^{nb}\right)/Y$, capital* *over GDP K^{nb}/Y and K^b/Y, and deposits over GDP D/Y are the same as in the initial steady-state.*

3.5.2 Shocks to the debt-to-GDP target

Next, we study the effect of an increase in the debt-to-GDP target $\bar{b}$. We begin by letting transfers T_t adjusting in response to the change in $\bar{b}$.

Result 3. *A shock that permanently increases the debt-to-GDP target $\bar{b}$ produces the following effects:*

- *Bank deposits to GDP, D/Y, and bank lending to GDP, K^b/Y, decrease;*
- *The spread between the return on non-bank lending and government debt, $\left(r^{nb} - \delta\right) - \left(1/q_t^b - 1\right)$, decreases;*
- *Non-bank capital as a ratio to GDP, K^{nb}/Y, can increase or decrease;*
- *Investment to GDP, $\delta\left(K^b + K^{nb}\right)/Y$, decreases;*
- *GDP, Y, decreases;*
- *Transfers, T, and transfers to GDP, T/Y, could increase or decrease;*

The effect on bank deposits and bank lending follow from the substitution between deposits and government debt. Households value both deposits and government debt for their liquidity and, because of the substitutability between the two, an increase in government debt crowds out deposits. With fewer deposits, banks cut lending.

The spread between the return on non-bank lending and government debt, $\left(r^{nb} - \delta\right) - \left(1/q_t^b - 1\right)$, correspond to the spread between AAA corporate debt and Treasury debt. Krishnamurthy and Vissing-Jorgensen (2012) show that the demand for Treasury debt is downward sloping in this spread. As in the data, an increase in government debt reduces its liquidity premium and, thus, the spread.

The provision of non-bank credit to the economy (i.e., K^{nb}) can increase or decrease. This result crucially depends on the elasticity of substitution between bank capital K^b and non-bank capital K^{nb}, which is given by ν in the model (see Equation (4)). When ν is close to one, the two capital are highly substitutable. Hence, a reduction in bank lending is offset by an increase in K^{nb}. If instead ν is smaller and possibly negative, the two capital are more complements, and the reduction in bank lending triggers a reduction in K^{nb}.

The effects on investments and GDP is negative. Even if bank and non-bank capital are highly substitutable, we always assume that $\nu < 1$ in Equation (4) so that both bank and non-bank capital are used in equilibrium — as it is the case in practice. Hence, even if K^{nb} replaces K^b, the substitution is always partial, and investments drop. With the drop in investments, GDP is lower too.

The effects on fiscal variable is overall uncertain. Recall that transfers are the "residual category" in the sense that they adjust to satisfy the budget constraint. Hence, we will discuss the effects on transfers T and transfers to GDP, T/Y. Both transfers and transfers to GDP could increase or decrease, and this is related to two effects. One of this effect is in turn connected to the "r<g" in the current policy discussion, that is, the fact that empirically, the interest rate on government debt, denote by "r," is less then the growth rate of the economy, denoted by "g" (see e.g. Blanchard, 2019).

To understand the effects on transfers T, recall first that GDP drops as a result of an increase in $\bar{b}$. With a lower GDP, the government collects fewer tax revenues, and this effect reduces T. Second, if $q^b < 1$ (i.e., if the net return on government debt is positive), the government needs to get additional resources to pay the interest on higher debt, which also reduces transfers T. But if $q^b > 1$, which is the case when the liquidity premium of the government is so high that government debt earns a negative net real return, issuing additional debt allows the government to collect more revenues from the liquidity premium on government debt. This case is referred to as "r<g" in the policy discussion — in the model, "r" is $1/q^b - 1$ and in steady state, the growth rate "g" of the economy is zero. This second effect increases transfers and, if big enough, offsets the decrease in tax revenues implying that T might go up overall.

In connection to the current policy discussion, it is thus worth emphasizing that "r<g" is not a sufficient condition that allows the government to generate more revenues by increasing government debt. The key point is that the growth rate "g" of the economy is affected by the change in the debt-to-GDP target $\bar{b}$. That is, an increase in $\bar{b}$ reduces GDP and, thus, the revenues collected through taxes. As a result, the gap between "r" and "g" needs to be sufficiently large to obtain an overall increase in government revenues associated with an increase in government debt. In this sense, it is particularly important to have derived this result in a model in which tax rates are fixed and non-distortionary transfers adjusts to satisfy the budget constraint. The result is even stronger if we fix T and allow the tax rate τ_t^l or τ_t^k to adjust to satisfy the budget constraint. That

is, the revenue shortfall produced by the reduction in GDP needs to be compensated by higher tax rates, which in turn will reduce GDP even further because they increase distortions. The argument derived here complements the "r<g" analysis associated with risk (Liu, Schmid, and Yaron, 2019; Jiang et al., 2020, 2021).

4 Conclusions

Government debt is high and growing. What are its effects on the financial sector and the economy?

In the empirical evidence, we have documented the effect of higher Treasury debt to GDP on financial and macroeconomic variables. Higher debt to GDP reduces banks' liabilities and bank lending and, ultimately, lead to a reduction in investments and a worsening of labor market conditions.

In the theoretical analysis, we have presented a simple dynamic model that rationalizes this result. A crucial element of the model is that government debt and bank deposits provide liquidity services to households and are substitute. Hence, an increase in government debt crowds out bank deposits and, as a result, bank lending, investments, and GDP.

The model also provides some insights about the "r<g" policy discussion, that is, the effects of increasing government debt when liquidity premia on safe assets are high. In this case, the government essentially borrows at a negative rate, so increasing government debt boosts the seigniorage-like revenues that the government earn on its debt. But because the higher government debt crowds out bank lending and reduces GDP, total government revenues might fall. Hence, a negative real rate is not sufficient to justify additional borrowing by the government.

This paper is still a work in progress. We plan to extend our analysis to include a quantitative assessment of the model results and a policy analysis to determine the optimal level of public debt.

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