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# Scarcity of Safe Assets and Global Neutral Interest Rates*

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**Abstract**

We quantitatively evaluate the role of supply and demand of safe assets in determining neutral interest rates. Using an empirical cross-country state-space model, we find that the net supply of sovereign safe assets available to the private sector in secondary markets is an important driver of neutral rates for 11 advanced economies in the period 1970–2018. We also find that the global accumulation of international reserves in sovereign safe assets since the 1990s (the global savings glut) lowered the net supply of these assets and, thus reduced neutral rates by up to 50 basis points in our sample.

**Key Words**: neutral interest rates, scarcity of safe assets, international reserves, global savings glut.

**JEL Classification**: E21, E43, E52.

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# 1 Introduction

Traditional analyses of neutral interest rates—real short-term interest rates consistent with a zero output gap and inflation at its trend—focus on savings and investment decisions, an approach that predicts similar movements in returns across different types of assets. However, while ample evidence shows that real interest rates on safe assets declined since the early 1990s (e.g., blue line in Figure 1), the measured average return on private capital has remained relatively constant (Gomme et al. (2011); Farhi and Gourio (2018)). These findings cast doubts on economic theories that imply a tight relation between safe interest rates and the return on capital.

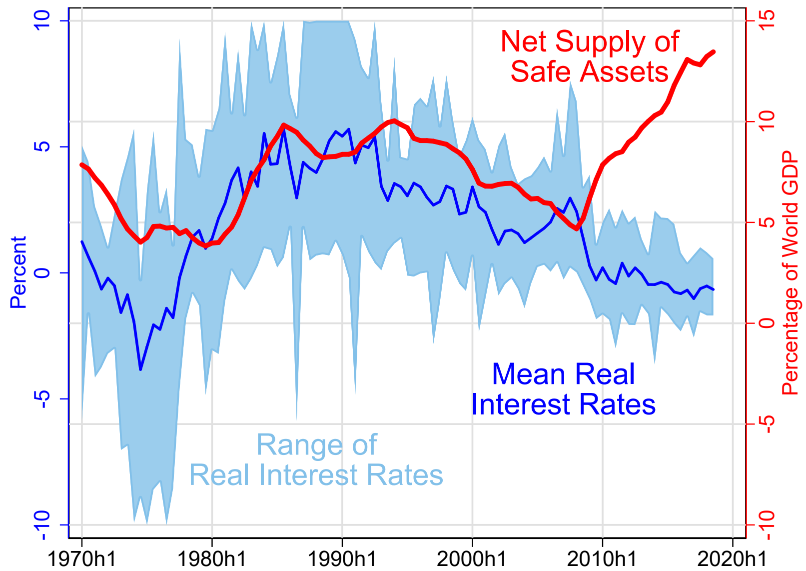
Given this special dynamic in the market for safe assets, there is an increasing focus on an asset market approach to study the determination of safe rates. This approach views these safe rates as determined on a segmented market by portfolio allocation decisions, with institutional investors showing a particular preference for safe assets (Caballero and Farhi (2018)).[1] This view is supported by the evidence of a convenience yield in U.S. Treasury securities (Krishnamurthy and Vissing-Jorgensen (2012); Du et al. (2018)), consistent with a demand curve for the higher safety and liquidity of these bonds.[2]

In a world in which investors show a particular interest in holding safe government assets, the supply of these assets may be important in determining neutral interest rates. We formally test this hypothesis in two steps. First, we construct a measure of global *net supply of safe assets* available to the private sector: the supply of sovereign safe assets net of foreign government holdings and assets never traded in secondary markets. In our benchmark series, we focus on U.S. Treasury securities because of the central role of the U.S. dollar in the global trade, financial, and monetary systems (Gourinchas et al. (2019)). The net supply of U.S. Treasury securities (red line in Figure 1) correlates well with realized safe real interest rates, especially up to 2008. This correlation (not shown before) is consistent with the view that a higher demand for safe assets during the mid-1990s–2008 period was not met by a corresponding increase in their supply, thus pushing down neutral interest rates.

[1]This preference for safe assets can arise from regulatory measures or the relatively higher risk aversion of some agents, such as pension funds and insurance firms, holding specific shares of safe assets in their portfolios as shown by Greenwood and Vissing-Jorgensen (2018)

[2]Greenwood and Vayanos (2010) provide evidence on the relevance of the segmented market view, which they call preferred-habitat view, through two event studies: the U.K. pension reform of 2004, and the U.S. Treasury securities buyback program of 2000-01. Vayanos and Vila (2019) propose a model formalizing the preferred-habitat view that could be related to a preference for safety and liquidity and, consequently, a segmented market for safe government bonds.

Figure 1
Real Interest Rates and Net Supply of Safe Assets




Note: Shaded blue area displays the range of real interest rates, measured by policy rates minus realized core inflation. Solid blue line is the mean real interest rate. Our sample covers the following economies: Australia, Canada, Denmark, the euro area, Japan, Norway, New Zealand, Sweden, Switzerland, the United Kingdom, and the United States. For a better exposition, we exclude values of real rates greater than 10% and less than negative 10%. The solid red line is our measure of net supply of U.S. Treasuries (Section 2).

We then build a panel cross-country state-space model to estimate neutral interest rates for 11 advanced economies. Besides the net supply of safe assets, the model includes determinants of neutral rates, such as productivity, demographics, and their global spillovers, predicted by the investment-and-savings framework. Moreover, because our model does not impose particular effects from productivity and demographics on neutral rates, these variables could also capture shifts in the demand for safe assets. For instance, population aging could imply a larger portfolio allocation in safe assets, as older people tilt their retirement savings toward these assets, leading to lower neutral rates. Our model also uses the convenience yield, which may proxy for other factors relative to safe asset scarcity.

We find that the net supply of safe assets is an important driver of neutral rates. We estimate that changes in the net supply of safe assets account for an average of 20% of the variance of neutral rates across countries. Moreover, net safe assets contributed to the path of neutral rates in important periods of our sample: the first wave of decline in the 1970s, a rebound in the early 1980s, and the steady decline during the 2000s. Since 2008, the increase in net safe assets has prevented neutral rates from declining further because of other factors, especially demographics. These results are consistent with the idea that while larger debts from advanced countries have boosted the supply of safe assets after 2008, higher demand for these assets due to, for instance, an older population, has pushed down neutral rates. We also find that most of the determinants of neutral rates explored in this paper help explain not only the time series of these rates, but also their co-movement.

Finally, we turn to an evaluation of the "global savings glut" hypothesis (Bernanke (2005)). According to it, government policy decisions, such as the concerted effort of many emerging market economies to accumulate international reserves after the Russian and Asian crises of the late 1990s, led to a global excess desire of savings over investment that has driven down global interest rates. In our evaluation, we estimate neutral rates using a counterfactual path of the net supply of safe assets that assumes no accumulation of reserves from 1994 to 2018. We find that global accumulation of international reserves reduced neutral rates by 50 basis points in 2015 (relative to the counterfactual net safe assets) and by 35 basis points in 2018.

**Outline.** The rest of the paper is organized as follows. Section 1.1 provides an overview of the literature related to this paper, highlighting our main contributions. Section 2 details our measure of global net supply of safe assets to the private sector. Section 3 shows evidence from simple panel regressions consistent with the link between net supply of safe assets and real neutral interest rates. Section 4 describes the panel cross-country state-space model. Section 5 discusses the main results of the paper and the many robustness checks. Section 6 concludes and explores potential extensions.

## 1.1 Related Literature

This paper contributes to a growing body of literature that studies the global scarcity of safe assets and its effects in the real economy. In a series of papers, Caballero et al. (2016), Caballero et al. (2017), and Caballero and Farhi (2018) argue that a growing demand for safe assets in countries with less-developed financial markets pushes down the short-term equilibrium interest rate in safe-asset-producing economies (as emphasized also by Bernanke (2005); Bernanke et al. (2011)). Caballero and Farhi (2018) formalize this idea with a model in which safe asset shortages lead to a deflationary safety trap equilibrium when the economy hits the zero lower bound. We contribute to this literature by showing that the global scarcity of safe assets is quantitatively important to determine global neutral interest rates.

This paper is also belongs to the literature evaluating major determinants of neutral rates.[3] Several papers argue for an important role of the demographic transition in advanced economies (e.g., Krueger and Ludwig (2007); Carvalho et al. (2016); Gagnon et al. (2016); Aksoy et al. (2019)). Under this transition, an increase in life expectancy and a decrease in birth rates lead to population aging and lower neutral rates. Another large set of papers finds a tight relation between neutral interest rates and trend gross domestic product (GDP) growth in advanced economies, corroborating the hypothesis that productivity growth is an influential determinant of neutral rates (e.g., Laubach and Williams (2003); Holston et al. (2017)). However, Lunsford and West (2019) find a negative low-frequency correlation between productivity growth and real rates using U.S. data since the late 19th century.[4] Finally, a few papers analyze the role of the scarcity of safe assets in determining neutral rates. Glick (2020) provides suggestive empirical evidence that foreign demand for U.S. safe assets started to increase well before the 2008 Global Financial Crisis, leading him to conjecture a downward pressure in neutral rates from this increased demand for safe assets. Del Negro et al. (2019) estimate that convenience yields are a significant driver of neutral rates, which they interpret as pointing to an imbalance between demand and supply of safe assets. We contribute to this large literature by showing that the supply of safe assets available to the private sector is an important determinant of neutral rates. As opposed to most previous papers, our framework jointly evaluates many different determinants of neutral rates (supply of safe assets, convenience yields, demographics, trend-productivity growth, and cross-country spillovers of the latter two determinants) in a panel of 11 economies.

Finally, this paper is related to a recent literature that focuses on the international co-movement among neutral interest rates. Obstfeld (2020) argues that, in financially open economies, interest rates are determined in part by global market forces, and, thus, developments abroad can exert a decisive force on domestic neutral rates. Kiley (2019) uses several econometric approaches to estimate the neutral interest rate and its determinants and finds that global factors dominate the downward trend in the neutral interest rate

[3]For a recent survey on this literature, see Brand et al. (2018).

[4]Hamilton et al. (2016) find a similar result, estimating a weak relation between growth and real rates.

across 13 advanced economies.[5] Lastly, Clarida (2019) shows that, in a model with international spillovers, the neutral interest rate in each country is a function of global productivity and business cycle factors even if these factors are themselves independent across countries. We contribute to this literature by finding evidence consistent with three drivers for a statistical global common factor in neutral rates: a global determinant (net safe assets), a synchronized cross-country behavior in economy-specific determinants (i.e., productivity growth and demographics), and global spillovers of these economy-specific determinants. Moreover, our finding of net safe assets as a driver of neutral rates' co-movement rationalizes a result from Caballero et al. (2015). They argue that safe asset scarcity has global implications, as net safe asset producers export these assets to net safe asset absorbers until interest rates are equalized across countries, acting as a global factor on interest rates across countries.

## 2 Global Supply of Safe Assets to the Private Sector

In this section, we propose a measure of global supply of safe assets available to the private sector. We adopt a narrow definition of a safe asset: a simple debt instrument that is expected to preserve its value during any event and that has ample market liquidity. Moreover, we focus on sovereign safe assets, as sovereigns' ability to levy taxes inherently makes their debt safer relative to those of the private sector.[6] However, a country can produce safe assets if, and only if, it has good protection of property rights; no default risk; a good track record of exchange rate and price stability; and deep, liquid, and open financial markets. This definition leads to a gross supply of safe assets concentrated in a few advanced economies. Additionally, there is extensive evidence of the central role of the U.S. dollar in the global trade, financial, and monetary systems, with an increasing share since the end of Bretton Woods in trade invoicing, international debt and loans issuance, foreign central banks' international reserves, and foreign exchange turnover.[7] Consequently,

[5] Del Negro et al. (2019) find a similar result, with a common declining trend in global interest rates since the 1980s.

[6] See Caballero et al. (2017) and Pascal and Perotti (2017) for similar definitions for safe assets.

[7] See Gourinchas et al. (2019) and Gourinchas (2019) for additional evidence on the hegemony of the dollar. He et al. (2019) propose a model that emphasizes the importance of relative fundamentals and debt size in the determination of asset safety. Ilzetzki et al. (2019) also emphasize the comparatively scarce supply of (safe) euro-denominated assets as a crucial factor for the dollar dominance. They also document some additional factors that might have limited the euro's role as an anchor currency and global safe asset such as the lack of a financial center, limited geopolitical reach, and U.S. and Chinese dominance in

in our baseline specification, we will use only U.S. government bonds in our measure of safe assets.[8]

We are interested only in the supply of safe assets available to price-sensitive buyers, and, therefore, looking at gross debt levels could be misleading. For instance, a considerable share of U.S. government debt is in the hands of public entities. These intragovernmental holdings are debt obligations that a government owes to its own agencies, including, for example, Medicare trust funds, the Social Security Trust Fund, and Federal Financing Bank securities for the United States. We then consolidate all of these intragovernmental holdings and other non-marketable government debt into one measure of *non-marketable debt*, which we later exclude from total U.S. gross government debt.

Additionally, there is evidence that the demand of foreign governments for U.S. government bonds is price inelastic.[9] We thus need a measure of the amount of safe assets in the hands of foreign governments to be able to net it out from the gross supply of safe assets. We calculate the amount of safe assets in the hands of foreign governments using data from the Treasury International Capital reporting system (TIC) adjusted by Bertaut and Judson (2014), complementing it with data from the Bureau of Economic Analysis. We add up all foreign official holdings of short and long-term U.S. Treasury securities.

With our measures of non-marketable U.S. debt and foreign official holdings of U.S. debt, we proceed to the calculation of our measure of net supply of safe assets. First, we exclude non-marketable debt from the gross supply of government bonds (blue line in Figure 2a) to get a measure of marketable debt (green line in Figure 2a). Then, we exclude foreign official holdings from the measure of marketable debt, getting the net supply of

technology research.

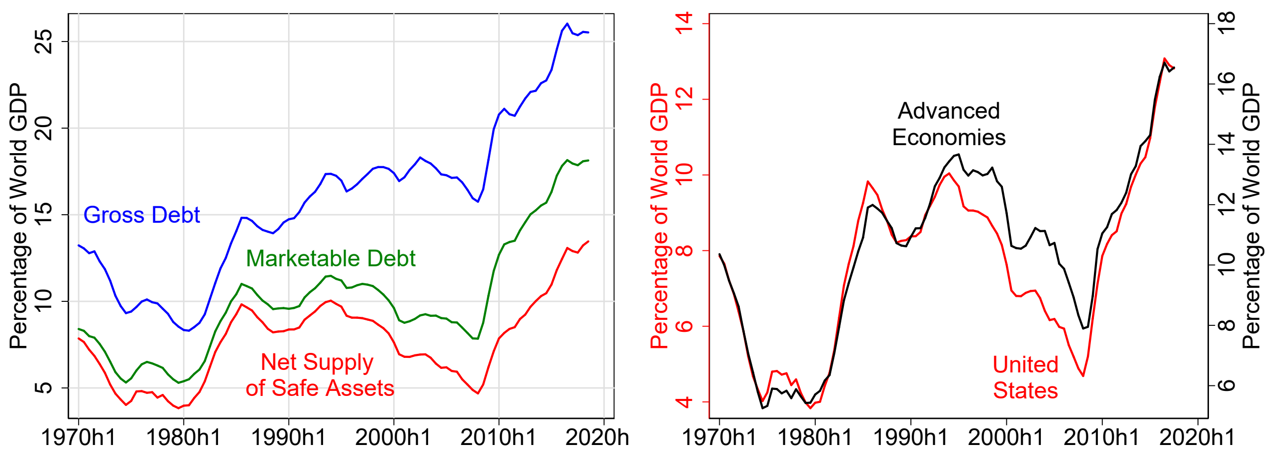
[8]Gorton et al. (2012) propose a broader measure, which consists of all "information insensitive" debt and, thus, includes some private financial-sector debt. We prefer to use the narrower definition because at least part of these information-insensitive assets provided by agencies and the private financial sector ended up not being safe during the past Global Financial Crisis. For instance, Boyarchenko et al. (2019) show that spreads on mortgage backed securities (MBS) backed by U.S. agencies reached high levels in periods such as 1998 and the 2008. Moreover, MBS spreads have robust correlations with credit spreads (Moody's Baa-Aaa). Boyarchenko et al. (2019) interpret these results as evidence that risk factors such as the risk bearing capacity of financial intermediaries are important determinants of MBS spreads.

[9]Gourinchas and Jeanne (2013) provide evidence of a price inelastic demand for safe assets by emerging market economies. They show that capital flows from rich to poor countries are not only low but negatively correlated or uncorrelated with productivity growth, in opposition to the predictions of the standard textbook model. They then show that this result is mostly a feature of public flows, with the accumulation of international reserves playing an important role in generating the puzzle. Additionally, as emphasized by Bernanke (2005), after several financial crises during the 1980s and the 1990s, emerging market economies decided to accumulate international reserves to build "war chests" against sudden stops of capital flows and contain exchange rate appreciations to promote export-led growth.

FIGURE 2
BUILDING MEASURE OF NET SUPPLY OF SAFE ASSETS

(A) Net Safe Assets: United States

(B) Net Safe Assets: Advanced Economies




NOTE: All figures are in percentage points of world GDP. Gross debt is the gross government debt of the United States. Marketable debt includes government bonds that are transferable and can be bought and sold on the secondary market. Net safe assets are marketable debt in the hands of the private sector—i.e., it excludes foreign government holdings from total marketable debt. The net supply of safe assets measure for advanced economies includes bonds from governments of the United States, Germany, France, and the United Kingdom. Sources are listed in Appendix A.

safe assets (red line in Figure 2a). All of these measures are normalized by the world GDP measured in U.S. dollars. Our baseline measure of net safe asset supply to the private sector was at historically low levels during the 1970s, increasing in the early 1980s. It then gradually declined from the mid-1990s to 2009, because of improvements in the U.S. fiscal balance and the surge in international reserve holdings by emerging market economies, as postulated by Bernanke (2005). Then, it sharply increased because of U.S. fiscal deficits during and after the Global Financial Crisis (Figure 2a).[10]

For completeness, we also construct a broader measure of net supply of safe assets including German, French, and British government bonds. We follow a procedure very similar to the one used to construct our U.S. measure.[11] Figure 2b shows that our baseline U.S.-based measure of net safe assets is very similar to our broader one.

[10] Du et al. (2018) document a steady decline in the U.S. Treasury Premium at medium and long-term maturities vis-a-vis government bonds from other G10 countries since the Global Financial Crisis, which might be related to the strong increase in the supply of these bonds since then.

[11] Appendix A provides the details of the calculation of this broader measure of net safe assets including German, French, and British government bonds.

TABLE 1
DETERMINANTS OF NEUTRAL RATES AND REALIZED REAL RATES

| Variable name | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Trend-productivity growth | 0.37*** | | | | | 0.28*** |
| | (0.06) | | | | | (0.06) |
| Birth rate | | -0.00 | | | | -0.02 |
| | | (0.04) | | | | (0.04) |
| Working-age share | | | 0.73*** | | | 0.70*** |
| | | | (0.05) | | | (0.06) |
| Life expectancy | | | | 0.01 | | -0.01 |
| | | | | (0.07) | | (0.07) |
| Trend convenience yield | | | | | -0.91** | -0.38 |
| | | | | | (0.45) | (0.49) |
| Net supply of safe assets | | | | | | 0.06*** |
| | | | | | | (0.02) |
| Observations | 1,060 | 1,060 | 1,060 | 1,060 | 1,060 | 1,060 |
| $R^2$ | 0.04 | 0.00 | 0.14 | 0.00 | 0.00 | 0.18 |

NOTE: Dependent variable is the time difference in the trend of real rates, with these measured by policy rates minus core inflation. Trend is estimated with a Hodrick-Prescott filter on the quarterly data with smoothing parameter of 5000. Regressors are the time difference of variables in Figure 3. Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level. We include intercepts in the regressions, but we omit their results. Data are sampled at half-yearly frequency from 1970 to 2018.

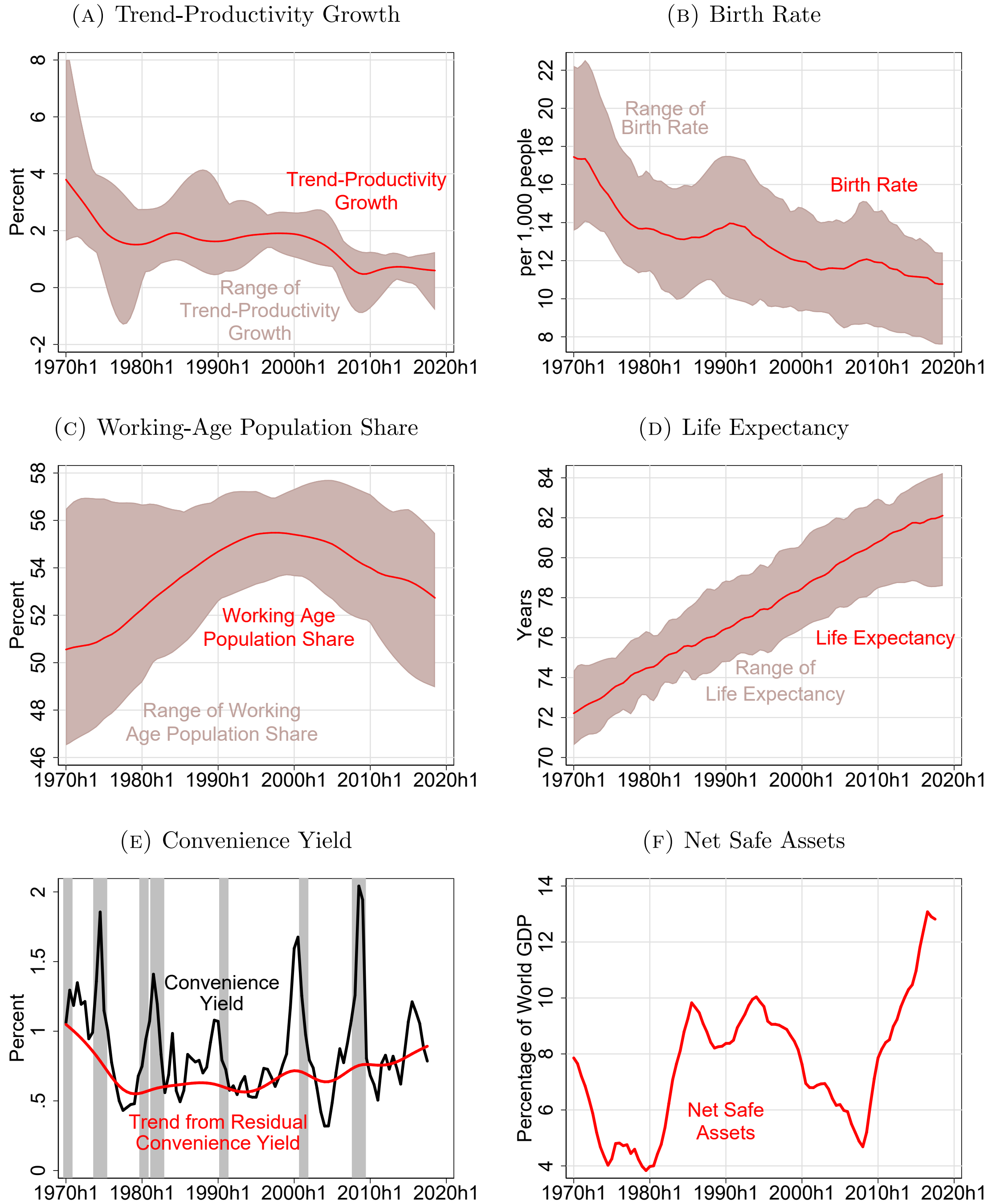
# 3 Regression-Based Empirical Evidence

This section provides simple empirical evidence supporting the relationship between neutral interest rates and the net supply of safe assets to the private sector (described in Section 2). We run panel regressions of real policy rates—policy rates minus realized core inflation—on the net supply of safe assets and several other variables capturing other potential determinants of neutral rates studied in the literature. These regressions are on time differences, where the dependent variable is the change in the trend of real policy rates to focus on its long-run movements.[12] Next, we describe these other variables included in the regressions and their potential effect on neutral rates. Details on the data are in Appendix A.

The first potential determinant of neutral rates that we consider is productivity growth. In a savings-and-investment framework, there are at least two reasons why this determinant is important. First, when productivity growth slows down, it reduces investment opportu-

[12]Whenever we use the trend of a variable, we do so by using a Hodrick-Prescott filter with large smoothing parameter. Additionally, regressions using ordinary least squares using the levels of all variables discussed in this section (accounting or not for country-fixed effects) provide similar results supporting the net supply of safe assets as a determinant of neutral interest rates.

Figure 3
Determinants of Real Neutral Interest Rates




Note: Shaded red areas denote the maximum and minimum of a variable across countries, while the solid line is the cross-country mean. Trend-productivity growth is the trend of an average of four different measures of trend-productivity growth. Birth rate is the total number of live births per 1,000 population. Working-age population share is the ratio of those aged 20 to 60 over total population. Life expectancy is number of years a newborn would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout the person's life. Convenience yield is the spread between AA+ corporate bond yields and U.S. Treasury yields. Trend from residual convenience yield is the trend from the residuals of a regression of convenience yield on our measure of net supply of safe assets (Section 2). Horizontal shadings in Figure 3e indicate periods classified as recessions by the NBER. Data details are in Appendix A.

nities, decreasing investment demand. Second, lower productivity growth also lowers expected income for households, increasing their precautionary savings. Consequently, lower productivity growth should drive down neutral interest rates because of both lower investment demand and higher savings.[13] Productivity could affect neutral rates also through a demand-for-safe-assets channel. With a lower trend-productivity growth, agents could anticipate less returns on their risky assets, making them rely more on safe assets.

We use a measure of productivity growth that is the trend of an average of four different yearly measures of productivity: total factor productivity (TFP), GDP per person employed and two measures of GDP per hour worked. This measure of trend-productivity growth experienced a substantial decline in the early 1970s, a modest rebound in the late 1970s and early-1980s, some stability in the 1990s, and a decline in the 2000s (Figure 3a). A simple regression shows that productivity growth is statistically significant and positively related to real rates (column (1) in Table 1).

Several authors highlight the role of demographic transition as a determinant of neutral interest rates, with many economic channels at work (e.g., Carvalho et al. (2016)). First, higher life expectancy increases the retirement period and, consequently, the incentives to save in anticipation for that period, putting downward pressure on the real interest rate. Second, lower birth rates depress the labor supply and, consequently, increase the capital-labor ratio, decreasing the marginal product of capital and pushing down real interest rates. Third, lower birth rates eventually reduce the share of the population within the working age, curtailing total savings (as non-working people have a lower marginal propensity to save), then driving up real interest rate. Fourth, Aksoy et al. (2019) propose a channel in which aging results in lower interest rates through less innovation, providing evidence that patent applications are positively affected by larger shares of population in the middle age and negatively affected by larger shares of retirees. Fifth, the demographic transition could decrease neutral rates through a higher demand for safe assets, as an aging population tilts the portfolio allocation of its retirement savings toward safe assets.

We then consider three demographic variables in our regressions: birth rate, working-age population share, and life expectancy. Birth rates have been mostly decreasing since the 1970s (Figure 3b). The working-age population share has an inverted U-shape behavior,

[13] While the theoretical relationship between productivity growth and neutral interest rates is compelling, the empirical evidence on this relationship is less straightforward, as discussed by Hamilton et al. (2016) and Lunsford and West (2019).

increasing from the 1970s to mid-1990s and decreasing since the early 2000s (Figure 3c). Life expectancy has risen at a fairly steady pace in most advanced countries since the 1970s (Figure 3d). Regressions for each determinant show that working-age share is significant at a 1% level, while birth rate and life expectancy are not (columns (2)–(4) in Table 1).[14]

We also evaluate a measure of convenience yield, the value investors assign to the liquidity and safety attributes offered by U.S. Treasury securities.[15] As discussed in Del Negro et al. (2019), this variable may point to an imbalance between demand and supply of safe assets. To measure the liquidity and safety attributes of U.S. Treasuries, we use an approach and databases similar to those used by Gilchrist and Zakrajšek (2012). We calculate the bond-by-bond spread between corporate bond yields and U.S. Treasury yields with the same maturity, focusing on bonds with a credit rating AA or higher. We then use the median of such credit spreads at every time period, calling it convenience yield (black line of Figure 3e).[16] Then, to orthogonalize the information of the convenience yield to the one from supply of safe assets, we regress this convenience yield on our measure of net supply of safe assets, retaining the residuals. Finally, we extract the trend of such residual convenience yield to bypass cyclical fluctuations and focus only on long-run developments (red line of Figure 3e).[17] This measure of trend convenience yield falls during the 1970s and has an upward trend since the mid-1990s. A simple regression shows that this trend convenience yield is negatively related to real rates, consistent with it proxying for demand factors for safe assets (column (5) in Table 1).

Finally, we evaluate all variables simultaneously in a regression (column (6) in Table 1). First, net supply of safe assets is significant at a 1% level, corroborating its importance in the determination of real rates. Additionally, productivity growth, and working-age population share are significant at a 1% level. In contrast, birth rates, life expectancy, and the trend convenience yield are not significant.

[14]The working-age share is positively related to real rates, consistent with the results of Aksoy et al. (2019) and contrary to usual savings-and-investment framework predictions.

[15]Krishnamurthy and Vissing-Jorgensen (2012) show a strong negative relation between the spread of AA-rated corporate bonds over U.S. Treasury yields and the outstanding amount of U.S. government debt held by the public normalized by U.S. GDP. They also provide evidence that this negative relation reflects a demand curve for the higher safety and liquidity of Treasuries.

[16]The measure of convenience yield used by Del Negro et al. (2019) is the Moody's Baa corporate bond yields minus U.S. Treasury yield.

[17]We provide more details in Appendix A.1.

# 4 Cross-Country State-Space Model

In this section, we build on Uribe (2018) and construct a panel cross-country state-space model to estimate neutral interest rates for 11 advanced economies using half-yearly data.[18]

## 4.1 Model Specification

For economy $j$ at time period $t$, we model the cyclical and trend components of the unemployment rate, $u_{j,t}$, core-inflation, $\pi_{j,t}$, and policy rate, $i_{j,t}$, as follows:

$$Y_{j,t} \equiv \underbrace{\begin{bmatrix} u_{j,t} \\ \pi_{j,t} \\ i_{j,t} \end{bmatrix}}_{\text{Data}} \equiv \underbrace{\begin{bmatrix} \widehat{u}_{j,t} \\ \widehat{\pi}_{j,t} \\ \widehat{i}_{j,t} \end{bmatrix}}_{\text{Cyclical}} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix} \cdot \underbrace{\begin{bmatrix} X^u_{j,t} \\ X^m_{j,t} \\ X^r_{j,t} \end{bmatrix}}_{\text{Trend}}, \tag{1}$$

$$X^u_{j,t} = X^u_{j,t-1} + x^u_{j,t}, \qquad X^m_{j,t} = \overline{x}^m_j + X^m_{j,t-1} + x^m_{j,t}, \qquad X^r_{j,t} = X^r_{j,t-1} + x^r_{j,t}, \tag{2}$$

$$\widehat{Y}_{j,t} \equiv \left[\widehat{u}_{j,t} \quad \widehat{\pi}_{j,t} \quad \widehat{i}_{j,t}\right]', \qquad Z_{j,t} \equiv \left[x^m_{j,t} \;\; z^p_{j,t} \;\; x^u_{j,t} \;\; z^d_{j,t} \;\; x^r_{j,t} \;\; z^s_{j,t}\right]', \tag{3}$$

$$\widehat{Y}_{j,t} = B \cdot \widehat{Y}_{j,t-1} + C \cdot Z_{j,t}, \tag{4}$$

where $\widehat{u}_{j,t}$, $\widehat{\pi}_{j,t}$ and $\widehat{i}_{j,t}$ are the cyclical components of the unemployment, inflation and policy rates, respectively; $X^u_{j,t}$ is the trend in the unemployment rate; $X^m_{j,t}$ is a common trend in inflation and policy rates, referred to as the monetary trend; and $X^r_{j,t}$ is the trend in policy rates above and beyond the monetary trend, referred to as the *real neutral interest rate*. Cyclical variables follow a vector autoregression of first order, VAR(1), subject to several structural shocks: permanent unemployment-rate shocks $x^u_{j,t}$, permanent monetary shocks $x^m_{j,t}$, changes in real neutral interest rates $x^r_{j,t}$, temporary monetary shocks $z^p_{j,t}$, temporary demand shocks $z^d_{j,t}$, and temporary supply shocks $z^s_{j,t}$. For simplicity, we assume that $x^u_{j,t}$, $x^m_{j,t}$, $z^p_{j,t}$, and $z^s_{j,t}$ are independent and identically distributed with normal distributions, while $z^d_{j,t}$ follows an autoregressive process of order one, AR(1). We then identify these shocks through restrictions on the matrix $C$ of equation (4), later described in Section 4.2.

We model changes in real neutral interest rates $x^r_{j,t}$ as depending on observed data on trend-productivity growth, working-age share, trend convenience yield, net supply of safe

[18] For details on the data used by the state-space model, see Section B.1.

assets, and global spillovers from country-specific determinants. Specifically,

$$x^r_{j,t} = \beta_{pt}\,\Delta pt_{j,t} + \beta_{ws}\,\Delta ws_{j,t} + \beta_{cy}\,\Delta cy_t + \beta_{sa}\,\Delta sa_t + \beta_{row}\,x^r_{-j,t-1}, \quad (5)$$

$$x^r_{-j,t-1} = \sum_{i\neq j}\omega^j_i\left(\beta_{pt}\,\Delta pt_{i,t-1} + \beta_{ws}\,\Delta ws_{i,t-1}\right), \quad (6)$$

where $\Delta pt_{j,t}$ is country $j$'s change in trend-productivity growth; $\Delta ws_{j,t}$ is country $j$'s change in the working-age share; $\Delta cy_t$ is the change in the trend convenience yield; $\Delta sa_t$ is the change in the net supply of safe assets; and $x^r_{-j,t-1}$ is our measure of global spillovers calculated as the change in country-specific determinants of the rest of the world from country $j$'s perspective weighted by the export shares of trade partners ($\omega^j_i$). Finally, we exclude life expectancy and birth rate from the estimation because of their poor correlation with realized real rates across countries (Table 1 of Section 3).

It is possible that our measure of net supply of safe assets reacts to demand shocks for U.S. Treasuries, or more generally to lower levels of interest rates. In these cases, the fiscal authority would take advantage of market conditions to issue more debt, thus implying a negative correlation between the supply of Treasuries and safe interest rates. These circumstances would imply an attenuation bias in our approach, given the positive correlation observed in the data. As argued by Krishnamurthy and Vissing-Jorgensen (2012), we see large and lasting movements in the supply of Treasuries as likely to be insensitive to demand shocks, thus rendering our results robust to this issue.

Our modelling choice (equations 1–5) has several advantages relative to other approaches in the literature. First, we allow cross-country spillovers in the estimation of neutral rates (equation 5). This assumption is consistent with predictions from textbook macroeconomic models that interest rates should be determined internationally, as long as there is some cross-country capital mobility. Moreover, this assumption is important because it can provide us with a finer storytelling ability for the large co-movement in neutral rates estimated by either single-country methods (e.g., Holston et al. (2017)), or cross-country models with global factors (e.g., Del Negro et al. (2019)). Second, as in Uribe (2018), we model changes in our trend variables as shocks possibly affecting our cyclical variables. Thus, our estimated stochastic trends not only provide slow-moving values around which cyclical variables fluctuate, but also may generate impulses triggering new fluctuations in these cyclical variables. Third, we incorporate in our estimation many determinants of neutral rates well cited in the literature, such as demographics and productivity, thus accounting directly for the statistical uncertainty around the relevance of these determinants.

## 4.2 Identification, and Observables

We estimate our panel state-space model with Bayesian techniques, using sign restrictions on matrix $C$ of equation (4) to identify the structural shocks.

We impose the following identification assumptions on matrix C:

$$C = \left[\begin{array}{c:c:c:c:c:c} \cdot & C_{12} \geq 0 & \cdot & C_{14} = -1 & C_{15} = 0 & C_{16} \geq 0 \\ \cdot & C_{22} \leq 0 & \cdot & C_{24} \geq 0 & C_{25} = 0 & C_{26} = 1 \\ \cdot & C_{32} = 1 & \cdot & \cdot & C_{35} = -1 & \cdot \\ \substack{\text{Permanent} \\ \text{Monetary} \\ \text{Shock} \\ (x^m_{j,t})} & \substack{\text{Temporary} \\ \text{Monetary} \\ \text{Shock} \\ (z^p_{j,t})} & \substack{\text{Permanent} \\ \text{Unemployment} \\ \text{Rate Shock} \\ (x^u_{j,t})} & \substack{\text{Temporary} \\ \text{Demand} \\ \text{Shock} \\ (z^d_{j,t})} & \substack{\text{Change in} \\ \text{Real Neutral} \\ \text{Interest Rate} \\ (x^r_{j,t})} & \substack{\text{Temporary} \\ \text{Supply} \\ \text{Shock} \\ (z^s_{j,t})} \end{array}\right],$$

where "·" represents the absence of restrictions. Temporary monetary shocks may contemporaneously increase the unemployment rate ($C_{12} \geq 0$) and decrease inflation ($C_{22} \leq 0$), with the increase in policy rates being normalized to 1 ($C_{32} = 1$). Temporary demand shocks contemporaneously decrease the unemployment rate ($C_{14} = -1$) and may increase inflation ($C_{24} \geq 0$), with the response of monetary policy left unrestricted. Changes in neutral real rates contemporaneously affect neither unemployment rates ($C_{15} = 0$) nor inflation ($C_{25} = 0$), leaving the level of policy rates essentially unchanged ($C_{35} = -1$).[19] Temporary supply shocks increase inflation ($C_{26} = 1$) and may increase unemployment rates, with the response of policy rates left unrestricted.

We close the model by stipulating relationships between model variables and observable variables. Specifically, from equations (1) and (2) we have:

$$\Delta u_{j,t} = (\widehat{u}_{j,t} - \widehat{u}_{j,t-1}) + x^u_{j,t} \tag{7}$$

$$\Delta r_{j,t} = (\widehat{i}_{j,t} - \widehat{i}_{j,t-1}) - (\widehat{\pi}_{j,t} - \widehat{\pi}_{j,t-1}) + x^r_{j,t} \tag{8}$$

$$\Delta i_{j,t} = (\widehat{i}_{j,t} - \widehat{i}_{j,t-1}) + x^m_{j,t} + x^m_j + x^r_{j,t} \tag{9}$$

[19] For simplicity, suppose $x^m_j = 0$ and only a change in the real neutral interest rate occurred: $x^r_{j,t} = 1$. Then, with identification hypothesis that the level of policy rates is unchanged ($\Delta i_{j,t} = 0$), equations (1)–(2) imply $\Delta i_{j,t} = \Delta\widehat{i}_{j,t} + x^m_{j,t} + \overline{x}^m_j + x^r_{j,t}$, and thus $C_{35} = \Delta\widehat{i}_{j,t} = -1$. For $x^m_j \neq 0$, we then assume that $\Delta i_{j,t} = x^m_j$, which is close to zero, thus also yielding $C_{35} = \Delta\widehat{i}_{j,t} = -1$.

where $r_{j,t} = i_{j,t} - \pi_{j,t}$ are observed real interest rates. Then, model (1)–(9) admits a representation for which a Kalman filter may be used to estimate its likelihood.

### 4.3 Priors, Estimation, and Posteriors

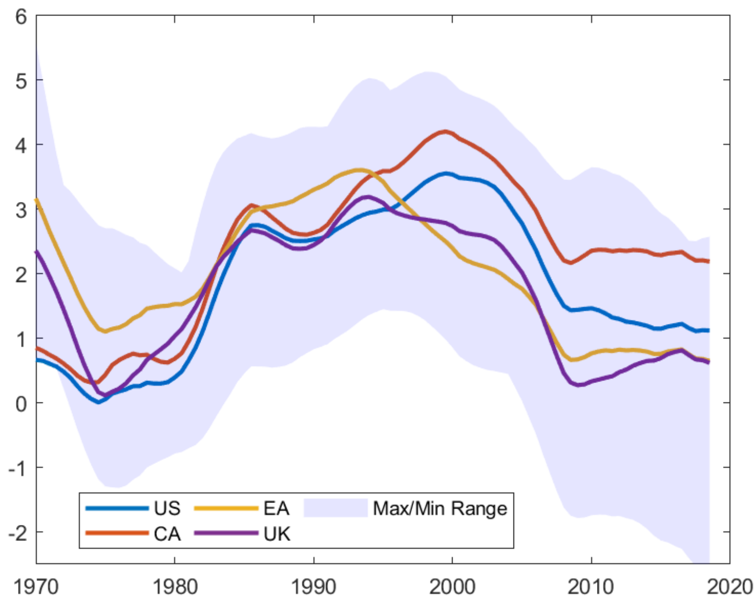
Prior distributions of model parameters follow standard practices in the literature, with three sets of priors worth discussing here, leaving the rest to Appendix B.2. First, priors capturing the effects of permanent monetary shocks, $[C_{1,1}, C_{2,1}, C_{3,1}]'$, are centered on the idea that the level of unemployment, inflation and policy rates do not change upon the shock impact, as in Uribe (2018). We use a similar assumption for permanent unemployment-rate shocks, $[C_{1,3}, C_{2,3}, C_{3,3}]'$. Second, priors for the elasticities of real neutral rates to changes in trend-productivity growth ($\beta_{pt}$), working-age share ($\beta_{ws}$), and convenience yield ($\beta_{cy}$) are uniform around zero, leaving the posterior distribution of these parameters less influenced by their prior distributions. Third, the prior for the elasticity to net safe assets ($\beta_{sa}$) is normal centered at zero, while the effect of global spillovers of country-specific determinants ($\beta_{row}$) has prior with beta distribution tilted toward zero.

Finally, we approximate the posterior distribution of the model parameters using a Metropolis Hastings algorithm to implement the Monte-Carlo Markov Chain method. Specifically, we use 1.5 million draws of the posterior distribution to calculate our results, discarding the first 25% (or 375,000) draws. Elasticity to net safe assets $\beta_{sa}$ has a relatively tight posterior, with median of 0.11, standard deviation of 0.08 and probability of being smaller than 0 of 6%. Elasticity to trend productivity-growth $\beta_{pt}$ also has a tight posterior, with median of 0.77, standard deviation of 0.17 and approximately 0% of draws less than zero. Elasticity to working-age share also has an informative posterior, with median 0.32, standard deviation of 0.18 and probability of being smaller than 0 of 2%. The coefficient of global spillovers ($\beta_{row}$) has informative posteriors but with wider probability intervals: median of 0.59 and standard deviation of 0.21. Finally, the posterior of the elasticity to the convenience yield has a large mass around zero, with median 0.11 and standard deviation of 1.64. See Appendix B for posterior distributions of $\beta_{pt}$, $\beta_{ws}$ $\beta_{cy}$, $\beta_{sa}$, and $\beta_{row}$.

## 5 Neutral Interest Rates of Advanced Economies

Our main finding is that the net supply of safe assets is an important determinant of neutral rates around the world, with reserve accumulation by foreign governments pushing down these neutral rates especially after 2008. We also find that most of the determinants of neutral rates explored in this paper not only help explain fluctuations in these rates, but also their co-movement over time.

Figure 4
Neutral Real Interest Rates Across Advanced Economies




Note: The figure shows neutral interest rates estimated by the model of Section 4 using the median values of the posterior distribution of parameters. Names of economies are abbreviated as US for the United States (blue line), CA for Canada (orange line), EA for the euro area (yellow line), and UK for the United Kingdom (purple line).

## 5.1 Two Waves of Declining Neutral Rates: 1970s and 2000s

Our model points to two waves of decline in neutral interest rates over the period 1970–2018 (Figure 4). In the first wave, from the beginning of the sample to the mid-1970s, neutral rates decreased considerably, with euro-area neutral rates declining from 3% to 1%, while the U.S. one declined from about 0.7% to 0%. At around 1980, neutral rates rebounded, reaching new peaks in 1985–86. Neutral rates then increased again until the late-1990s, when a second wave of decline in neutral rates started again. For some countries, such as the United States and Canada, the model points to a delayed second wave of decline, with rates starting to decrease only in the early 2000s. Neutral rates then reach new sample troughs in 2008, when some countries experience a rebound in their neutral rates, while others see

TABLE 2
VARIANCE DECOMPOSITION OF CHANGES IN NEUTRAL RATES (PERCENT)

| | Countries | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shocks | AL | CA | DN | EA | JA | NO | NZ | SD | SZ | UK | US |
| Net supply of safe assets | 19 | 19 | 22 | 27 | 6 | 15 | 9 | 16 | 23 | 23 | 27 |
| Trend-productivity growth | 47 | 47 | 47 | 40 | 87 | 73 | 82 | 73 | 55 | 59 | 44 |
| Working-age population share | 9 | 22 | 22 | 26 | 5 | 6 | 5 | 5 | 10 | 8 | 16 |
| Trend convenience yield | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Global spillovers[1] | 23 | 10 | 7 | 5 | 1 | 5 | 3 | 5 | 10 | 8 | 11 |

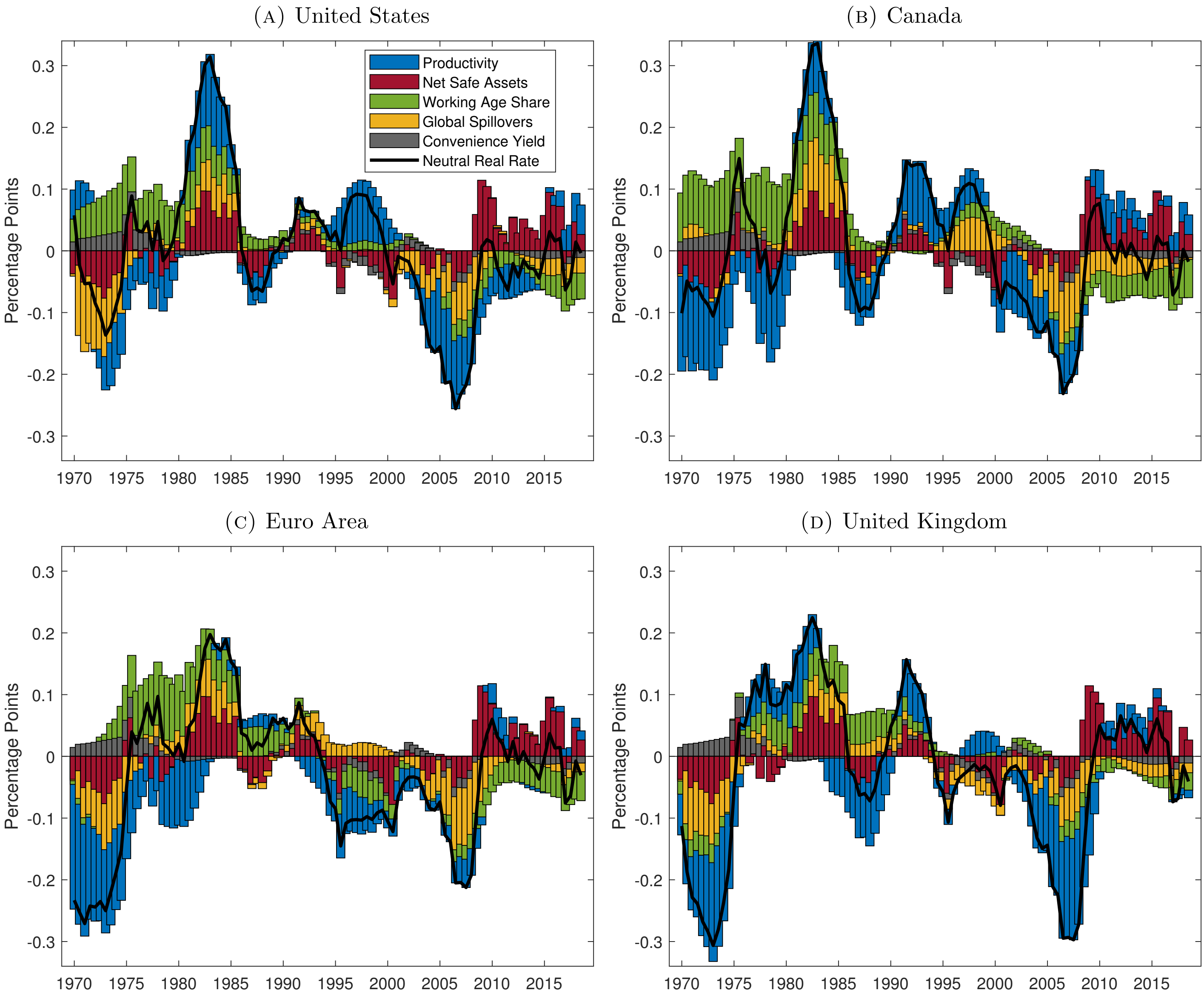
NOTE: The table shows the variance decomposition of changes in real neutral interest rates at the median values of the posterior distribution of parameters. Percentages might not add to 100 because of rounding. Names of economies are abbreviated as AL for Australia, CA for Canada, DN for Denmark, EA for the euro area, JA for Japan, NO for Norway, NZ for New Zealand, SD for Sweden, SZ for Switzerland, UK for the United Kingdom, and US for the United States. [1] "Global spillovers" is defined in equation (6).

further declines. In 2018H2, our model estimates that the U.S. neutral real interest rate was 1.1%, while Canada's was 2.2%, and both the euro area's and the United Kingdom's were 0.6%. As discussed in Section 4, the calculation of neutral rates accounts from time-varying trends in inflation and unemployment rates, which are described in Appendix B.

## 5.2 Safe Assets as an Important Driver of Neutral Real Rates

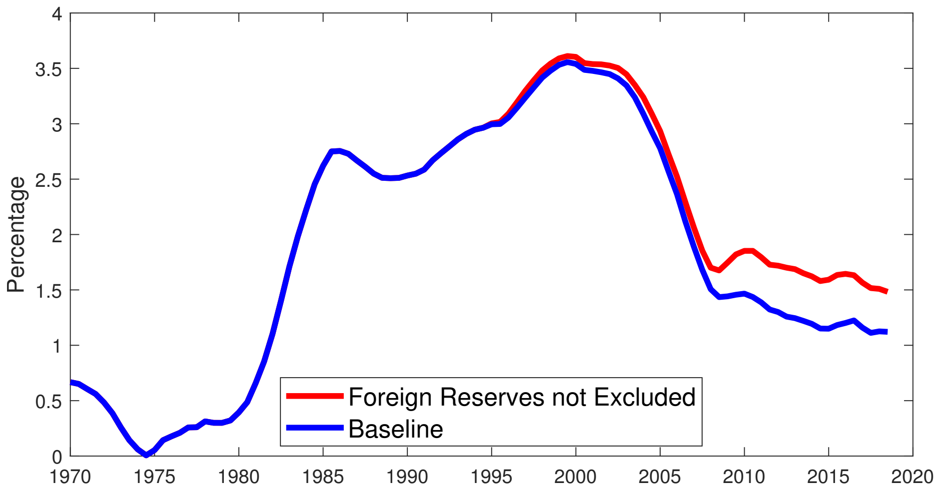
Our model finds net safe assets as an important driver of neutral rates by three different manners. First, the elasticity of neutral real rates to net safe assets is economically significant. The median value of the posterior distribution of $\beta_{sa}$ is 0.11, meaning that a decline of 10 percentage points in the net safe asset supply pushes down neutral rates by 1.1 percentage points. For reference, net safe assets decreased by about 5 percentage points of world GDP from 1994H1 to 2007H2 (Figure 3f). Second, net safe assets plays a relevant role in the variability of neutral rates over the sample period. Specifically, the variance decomposition of neutral real rates (Table 2) shows that fluctuations in net safe assets account for an average of about 20% of the variation of neutral rates across advanced economies. Third, the historical decomposition of neutral rates (Figure 5) shows that net supply of safe assets (red bars) was an important driver in many time periods: during the first wave of decline in the 1970s, the rebound of the early 1980s, and the steady decline during the 2000s. Moreover, the increase in the amount of net safe assets since 2008 has counteracted the downward pressure on neutral rates from other factors, such as demographics.

FIGURE 5
HISTORICAL DECOMPOSITION OF CHANGES IN NEUTRAL REAL RATES




NOTE: The figure shows the historical decomposition of changes in real neutral interest rates (black line) using median values of the posterior distribution of parameters. At each time period, neutral rates are driven by changes in the following variables: trend-productivity growth, denoted by "Productivity" (blue bars); net supply of safe assets, denoted by "Net Safe Assets" (red bars); working-age population share, denoted by "Working Age Share" (green bars); trend convenience yield, denoted by "Convenience Yield" (gray bars); and "Global Spillovers" (yellow bars), where the latter is defined in equation (6).

FIGURE 6
FOREIGN RESERVES ACCUMULATION AND U.S. NEUTRAL REAL RATES




NOTE: The figure shows real neutral interest rates for the baseline model of Section 4 (blue line) and under the counterfactual assumption that net supply of safe assets does not exclude the accumulation of reserves by foreign governments from 1994H2 onward (red line). Both neutral rates are calculated using median values of the posterior distribution of parameters.

## 5.3 Foreign Reserve Accumulation Has Reduced Neutral Rates

Our model estimates that foreign reserve accumulation has pushed down neutral rates, especially after 2008. To evaluate this claim, we conduct a counterfactual exercise in which we feed the model a path of net safe assets that does not exclude the accumulation of international reserves by foreign governments. To simplify the exercise, we suppose a zero reserve accumulation starting in 1994H2, the period in which the series of net supply of safe assets (red line in Figure 2) and marketable debt (Treasuries available to the private sector before subtracting foreign reserves, green line in Figure 2) start to diverge more prominently. Figure 6 shows the paths of estimated neutral rates under the baseline model (blue line) and using the counterfactual series of net safe assets (red line). By the end of 2008, foreign reserve accumulation had pushed down neutral rates by 25 basis points. Moreover, despite the increasing levels of debt after the 2008 crisis, the continued accumulation of foreign reserves further depressed neutral rates, with the negative contribution reaching 50 basis points in 2015. After that, the pace of reserve accumulation decreased, and so too its negative effect on neutral rates. In 2018H2, foreign reserves were weighing down neutral rates by 35 basis points.

## 5.4 Most Other Drivers of Neutral Rates Are Also Important

Among these other drivers, trend-productivity growth plays the largest role. First, the estimated median elasticity of neutral rates to trend-productivity ($\beta_{pt}$) is 0.77, meaning that a decrease in trend-productivity growth of 1 percentage point lowers neutral rates by 0.77 percentage point. Interestingly, this magnitude is not too far from the one-to-one prediction from either Laubach and Williams (2003) or a workhorse new-Keynesian dynamic stochastic general equilibrium model. Second, the contribution of trend-productivity to the variance of neutral rates is quite significant (Table 2): It accounts for an average of 60% of the changes in neutral rates across the 11 economies. Third, changes in trend productivity were important in several historical periods (blue bars in Figure 5), such as the productivity slowdown of the 1970s and 2000s.

We also estimate that demography has played a relevant role in determining neutral rates. As in our regression-based empirical evidence (Section 3) but contrary to predictions from the savings-and-investment framework, our model finds that a lower working-age share of the population pushes down neutral rates. Moreover, the faster decline in working-age shares since the mid-2000s (Figure 3c) has been a drag on neutral rates (green bars in Figure 5). For instance, the cumulative effect of the decline of the working-age share from 2005 to 2018 in the U.S. neutral rates is a negative 77 basis points.

Global spillovers of economy-specific determinants (equation 6) have also been important to explain fluctuations in neutral rates. Represented by the yellow bars in Figure 5, these spillovers have been particularly relevant after 2000. For example, the cumulative effect of these global spillovers for the U.S. neutral rate from 2000 to 2018 is negative 1%. Importantly, what underlies the contributions of these global spillovers across our 11 economies are the productivity slowdown and the faster demographic change that started around 2000.

Finally, we do not find evidence of the convenience yield as an important driver of neutral rates once we control for other determinants. Table 2 shows that it accounts for only a small share of the variance of neutral rates, and Figure 5 points to minor contributions from it to historical changes in neutral rates.

## 5.5 Explaining the Global Co-Movement in Neutral Rates

Most of the determinants of neutral rates explored in this paper also help explain the cross-country co-movement in these rates. To reach this result, it is useful to think about three potential forces explaining this co-movement: (i) global determinants affecting all countries in the same way, the net safe assets and convenience yield, (ii) a synchronized cross-country behavior in economy-specific determinants (i.e., productivity growth and demographics), and (iii) global spillovers of these economy-specific determinants.

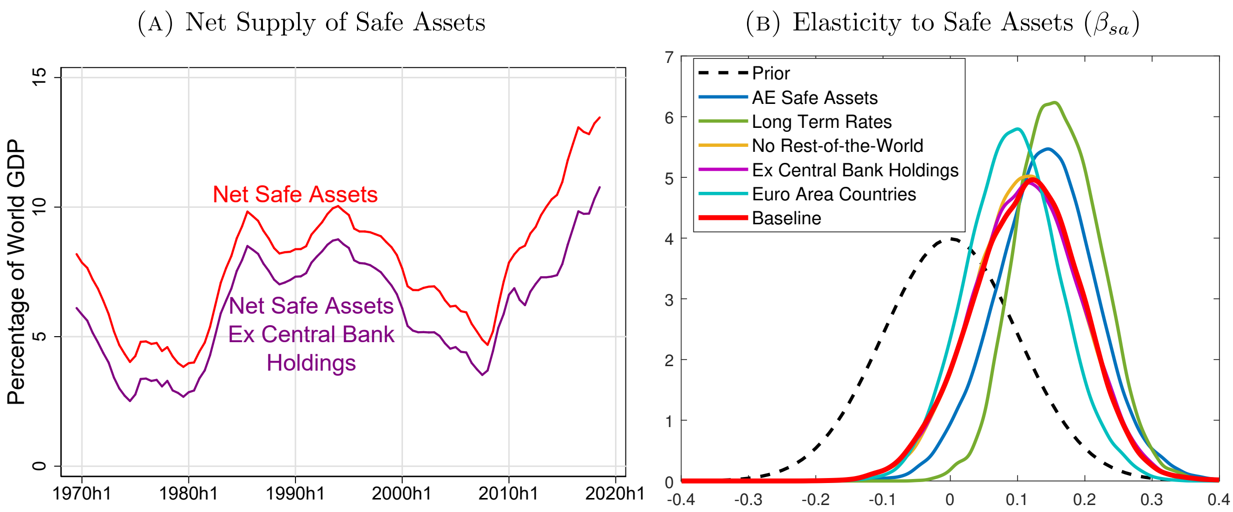
We evaluate these three forces by measuring how they contribute to a simple measure of co-movement: the average pair-wise correlation between countries' changes in neutral rates. To establish a benchmark, we use the baseline series of changes in neutral rates and find an average pair-wise correlation of 0.71. Then, to evaluate the role of country-specific determinants, we calculate our co-movement measure using counterfactual series of changes in neutral rates made only by the contributions of productivity (blue bars in Figure 5) and demographics (green bars in Figure 5). We obtain an average correlation of 0.41, supporting the idea that a co-movement already present at the economy-specific determinants helps explain the co-movement in neutral rates. We then add the contribution of global spillovers (yellow bars in Figure 5) to the previous series of neutral rates and re-calculate the average pair-wise correlation among them. The correlation then increases to 0.60, also supporting the idea that global spillovers are important. Finally, we add the contribution of net supply safe assets (red bars in Figure 5), which then increases the correlation to 0.71. This last increase is explained by our modelling choice of net safe assets affecting all countries' neutral rates in the same way. Trend convenience yield adds little co-movement to neutral rates, consistent with the results in Section 5.4.

## 5.6 Alternative Specifications

In this section, we provide evidence that net safe asset supply is an important determinant of neutral rates under several alternative specifications of our model.

One alternative specification we consider is calculating our measure of net supply of safe assets excluding also holdings of Treasury securities by the Federal Reserve (purple line in Figure 7a). It is unclear whether an increase in these holdings should decrease the amount of safe assets available to the private sector. On one hand, an increase in central bank holdings of sovereign debt only shifts the holdings of the private sector from sovereign debt

FIGURE 7
NET SUPPLY OF SAFE ASSETS IN ALTERNATIVE MODEL SPECIFICATIONS




NOTE: Figure 7a shows the baseline series of net supply of safe assets (red line) and an alternative series that differs from the previous one by also excluding Federal Reserve holdings of U.S. Treasury securities (purple line). Figure 7b shows the prior density distribution of $\beta_{sa}$ (dashed line) and its posterior distributions calculated under many different specifications of the model of Section 4.

to cash (reserve balances in the central bank), thus not changing the nominal amount of net safe assets available to private agents. On the other hand, this shift from sovereign debt to cash in the hands of the private sector might decrease the amount of "effective safe assets" (Caballero and Farhi (2018)). The reason is that returns on sovereign debt are negatively correlated with economic activity, thus implying an insurance value for such asset and increasing its "effective safety." In contrast, returns of reserve balances are invariant to the economic cycle, decreasing its "effective safety." In any case, the posterior distribution of the elasticity of neutral rates to net safe assets ($\beta_{sa}$) calculated by our baseline model (red line in Figure 7b) is barely distinguishable from the one calculated by the model considering Federal Reserve holdings of Treasuries (purple line in Figure 7b).

We also re-estimate our model of Section 4 under many alternative specifications. First, we substitute our baseline measure of net safe assets for the one including many advanced economies (black line of Figure 2b), with the posterior for $\beta_{sa}$ represented by the dark blue line in Figure 7b. Second, we incorporate in our estimation nominal 10-year rates for our sampled 11 countries, where these rates are assumed to have both a monetary and a real neutral interest rate trend (green line in Figure 7b). Third, we shut down global spillovers in neutral rates making $\beta_{row} = 0$ (yellow line in Figure 7b). Forth, we substitute the data for the aggregate of the euro area by data for Germany, France, Italy, Spain, the Netherlands and Belgium (light blue line in Figure 7b). All posterior distributions point to statistically and economically relevant elasticities to net safe assets ($\beta_{sa}$). Moreover, these alternative specifications yield posterior distributions very similar to the baseline one (red line in Figure 7b).

# 6 Conclusion

This paper provides support to an asset market determination of neutral interest rates, in contrast to the literature focusing on determinants predicted by the savings-and-investment approach. To do that, we propose a measure of global safe assets available to the private sector that takes into account foreign government holdings of U.S. government bonds. We then use this measure to estimate neutral interest rates for a panel of 11 advanced economies in the 1970–2018 period. We find that the net supply of safe assets to the private sector is a major driver of neutral rates for these economies, even after controlling for other factors, such as productivity, demographics, and their respective cross-country spillovers. Finally, we evaluate the impact of the so called "global savings glut", proposed by Bernanke (2005), and find that the global accumulation of international reserves contributed to a decline of up to 50 basis points in neutral rates.

Given this paper's evidence supporting an asset market determination of neutral rates, it could be a promising avenue of research to investigate demand-shifters of the market of safe asset. For instance, one could re-interpret traditional determinants of neutral rates as demand-shifters. Population aging may imply a larger portfolio allocation in safe assets, as older people may hold less risky assets in their retirement savings, leading to a higher demand for safe assets, and, then, lower neutral interest rates.[20] Lower trend-productivity growth could lead agents to anticipate less returns on their risky assets, making them rely more on safe assets. Finally, regulations requiring financial firms to hold (i) more capital per risky asset, and (ii) more high-quality liquid assets may also lead to a higher demand for safe assets.

[20]Population aging, for example, increases the demand for safe assets through its impact on the assets of pension funds and their specific regulatory rules, as shown by Greenwood and Vissing-Jorgensen (2018).

# References


**Aksoy, Yunus, Henrique S. Basso, Ron P. Smith, and Tobias Grasl**, "Demographic Structure and Macroeconomic Trends," *American Economic Journal: Macroeconomics*, 2019, *11* (1), 193–222.

**Bergeaud, Antonin, Gilbert Cette, and Rémy Lecat**, "Productivity trends in advanced countries between 1890 and 2012," *Review of Income and Wealth*, 2016, *62* (3), 420–444.

**Bernanke, Ben**, "The Global Savings Glut and the U.S. Current Account Deficit," 2005. Sandridge Lecture, Virginal Economic Association.

**Bernanke, Ben S., Carol Bertaut, Laurie Pounder DeMarco, and Steven Kamin**, "International Capital Flows and the Returns to Safe Assets in the United States, 2003-2007," *International Finance Discussion Papers*, 2011, *1014.* Board of Governors of the Federal Reserve System (U.S.).

**Bertaut, Carol and Ruth Judson**, "Estimating U.S. Cross-Border Securities Positions: New Data and New Methods," *International Finance Discussion Papers*, 2014, *1113.* Board of Governors of the Federal Reserve System (U.S.).

**Boyarchenko, Nina, Andreas Fuster, and David O Lucca**, "Understanding mortgage spreads," *The Review of Financial Studies*, 2019, *32* (10), 3799–3850.

**Brand, Claus, Marcin Bielecki, and Adrian Penalver**, "The Natural Rate of Interest: Estimates, Drivers, and Challenges to Monetary Policy," *Occasional Paper Series*, 2018, *217.* European Central Bank.

**Caballero, Ricardo and Emmanuel Farhi**, "The Safety Trap," *Review of Economic Studies*, 2018, *85* (1), 223–274.

**_ , _ , and Pierre-Olivier Gourinchas**, "Global Imbalances and Currency Wars at the ZLB," *NBER Working Paper*, 2015, *21670.*

**_ , _ , and _** , "Safe Asset Scarcity and Aggregate Demand," *American Economic Review Papers and Proceedings*, 2016, *106* (5), 513–518.

— , — , **and** — , "The Safe Assets Conundrum," *Journal of Economic Perspectives*, 2017, *31* (3), 29–46.

**Carvalho, Carlos, Andrea Ferrero, and Fernanda Nechio**, "Demographics and Real Interest Rates:Inspecting the Mechanism," *European Economic Review*, 2016, *88* (C), 208–226.

**Clarida, Richard**, "The Global Factor in Neutral Policy Rates: Some Implications for Exchange Rates, Monetary Policy, and Policy Coordination," *International Finance*, 2019, *22* (1), 1–18.

**Du, Wenxin, Joanne Im, and Jesse Schreger**, "The U.S. Treasury Premium," *Journal of International Economics*, 2018, *112* (C), 167–181.

**Farhi, Emmanuel and Francois Gourio**, "Accounting for Macro-Finance Trends: Market Power, Intangibles, and Risk Premia," *Brookings Papers on Economic Activity*, 2018, *2018* (2), 147–250.

**Gagnon, Etienne, Benjamin K. Johannsen, and David Lopez-Salido**, "Understanding the New Normal: The Role of Demographics," *Finance and Economics Discussion Series*, 2016, *2016-080.* Board of Governors of the Federal Reserve System (U.S.).

**Gilchrist, Simon and Egon Zakrajšek**, "Credit spreads and business cycle fluctuations," *American Economic Review*, 2012, *102* (4), 1692–1720.

**Glick, Reuven**, "R* and the Global Economy," *Journal of International Money and Finance*, 2020, *102* (C), 1–20.

**Gomme, Paul, B. Ravikumar, and Peter Rupert**, "The Return to Capital and the Business Cycle," *Review of Economic Dynamics*, 2011, *14* (2), 262–278.

**Gorton, Gary, Stefan Lewellen, and Andrew Metrick**, "The Safe-Asset Share," *American Economic Review: Papers & Proceedings*, 2012, *102* (3), 101–106.

**Gourinchas, Pierre-Olivier**, "The Dollar Hegemon? Evidence and Implications for Policy Makers," in "6th Asian Monetary Policy Forum" 2019.

— **and Olivier Jeanne**, "The Allocation Puzzle," *Review of Economic Studies*, 2013, *80* (4), 14841515.

— , **Helene Rey, and Maxime Sauzet**, "The International Monetary and Financial System," *Annual Review of Economics*, 2019, *11*, 859–893.

**Greenwood, Robin and Annette Vissing-Jorgensen**, "The Impact of Pensions and Insurance on Global Yield Curves," 2018. Unpublished.

— **and Dimitri Vayanos**, "Price Pressure in the Government Bond Market," *American Economic Review Papers and Proceedings*, 2010, *100* (2), 585–590.

**Gürkaynak, Refet S, Brian Sack, and Jonathan H Wright**, "The US Treasury yield curve: 1961 to the present," *Journal of monetary Economics*, 2007, *54* (8), 2291–2304.

**Hamilton, James, Ethan Harris, Jan Hatzius, and Kenneth West**, "The Equilibrium Funds Rate: Past, Present, and Future," *IMF Economic Review*, 2016, *64* (4), 660–707.

**He, Zhiguo, Arvind Krishnamurthy, and Konstantin Milbrad**, "A Model of Safe Asset Determination," *American Economic Review*, 2019, *109* (4), 1230–1262.

**Holston, Kathryn, Thomas Laubach, and John C Williams**, "Measuring the Natural Rate of Interest: International Trends and Determinants," *Journal of International Economics*, 2017, *108* (S1), S59–S75.

**Hooper, Peter, Frederic S Mishkin, and Amir Sufi**, "Prospects for Inflation in a High Pressure Economy: Is the Phillips Curve Dead or is It Just Hibernating?," *NBER Working Paper*, 2019, *25792.*

**Ilzetzki, Ethan, Carmen M. Reinhart, and Kenneth S. Rogoff**, "Why is the Euro Punching Below its Weight?," 2019. Unpublished.

**Jones, Bradley**, "Central Bank Reserve Management and International Financial StabilitySome Post-Crisis Reflections," *IMF Working Paper*, 2018, *WP/18/31.*

**Kiley, Michael**, "The Global Equilibrium Real Interest Rate: Concepts, Estimates,and Challenges.," *Finance and Economics Discussion Series*, 2019, *2019-076.* Board of Governors of the Federal Reserve System (U.S.).

**Krishnamurthy, Arvind and Annette Vissing-Jorgensen**, "The Aggregate Demand for Treasury Debt," *Journal of Political Economy*, 2012, *120* (2), 233–267.

**Krueger, Dirk and Alexander Ludwig**, "On the Consequences of Demographic Change for Rates of Returns to Capital, and the Distribution of Wealth and Welfare," *Journal of Monetary Economics*, 2007, *54* (1), 49–87.

**Laubach, Thomas and John C. Williams**, "Measuring the Natural Rate of Interest," *The Review of Economics and Statistics*, 2003, *85* (4), 1063–1070.

**Lunsford, Kurt G. and Kenneth D. West**, "Some Evidence on Secular Drivers of U.S. Safe Real Rates," *American Economic Journal: Macroeconomics*, 2019, *11* (4), 113–139.

**Negro, Marco Del, Domenico Giannone, Marc P. Giannoni, and Andrea Tambalotti**, "Global Trends in Interest Rates," *Journal of International Economics*, 2019, *118* (C), 248–262.

**Obstfeld, Maurice**, "Global Dimensions of U.S. Monetary Policy.," *International Journal of Central Banking*, 2020, *16* (1), 73–132.

**Pascal, Golec and Enrico Perotti**, "Safe Assets: A Review," *Working Paper Series*, 2017, *2035.* European Central Bank.

**Uribe, Martín**, "The Neo-Fisher Effect: Econometric Evidence from Empirical and Optimizing Models," *NBER Working Paper*, 2018, *25089.*

**Vayanos, Dimitri and Jean-Luc Vila**, "A Preferred-Habit Model of the Term Structure of Interest Rates," 2019. Unpublished.

# A Data Description

## A.1 Data Sources

The data set includes half-year data for Australia (AL), Canada (CA), Denmark (DN), euro area (EA), Japan (JA), Norway (NO), New Zealand (NZ), Sweden (SD), Switzerland (SZ), United Kingdom (UK), and United States (US). The sample period goes from 1970 to 2018.

**Unemployment rates:** National agencies and Organisation for Economic Co-operation and Development (OECD)

**Inflation rates:** National agencies and Organisation for Economic Co-operation and Development (OECD)

**Policy interest rates:** National agencies and Organisation for Economic Co-operation and Development (OECD)

**U.S. gross government debt, marketable debt and non-marketable debt:** obtained from U.S. Treasury Monthly Statement of Public Debt (MPSD).

**Foreign governments holdings of safe assets in the United States:** obtained from U.S. Treasury International Capital (TIC) System and Bertaut and Judson (2014) updated through 2017 to exclude foreign government holdings of unsafe assets in the U.S..

**Germany's gross government debt, marketable debt and non-marketable debt:** obtained from Deutsche Bundesbank Monthly Bulletin (Table IX).

**France's gross government debt, marketable debt and non-marketable debt:** obtained from IMF's Historical Public Debt Database (HPDD) from 1970-1997; and obtained from National Institute of Statistics and Economic Studies (INSEE) from 1998-2018.

**U.K. gross government debt, marketable debt and non-marketable debt:** obtained from the Office of National Statistics Public Sector Finance Statistics (ONS).

**World international reserves holdings:** financial assets of the central banks and monetary authorities that are held in different reserve currencies (e.g. the U.S. dollar, the Euro, and the Pound sterling) and which are used to back its liabilities (e.g. the local currency issued and the various bank reserves deposited with the central bank by the government or financial institutions). obtained from the IMF.

**Currency composition of world international reserves:** obtained from the IMF Currency Composition of Official Foreign Exchange Reserves (COFER) database, which shows the the evolution of the currency composition of international reserves. Since 2017, eight currencies are distinguished in COFER data: U.S. dollar; euro; Chinese renminbi; Japanese yen; pound sterling; Australian dollar; Canadian dollar; and Swiss franc. All other currencies are included and indistinguishable in the category other currencies.

**Foreign governments holdings of safe assets in Germany, France, and U.K.:** we calculate international reserves holdings in euros and pound sterling using the IMF Currency Composition of Official Foreign Exchange Reserves (COFER) database. We also use data from Jones (2018) to exclude deposits of Central Banks with foreign commercial banks (excluding the United States), foreign central banks, BIS and the IMF from the measure of international reserves holdings, obtaining a measure of international reserves allocated in safe government bonds.

**Productivity growth:** Trend-productivity growth is the trend of an average of four different yearly measures of productivity: total factor productivity, GDP per person employed, and two measures of GDP per hour worked obtained from the Long-Term Productivity Database[21] (LTP) and the Conference Board Total Economy Database (TED). To obtain the trend, we use an HP-filter smoothing parameter of 2500 on the yearly data before turning it into half-yearly data.

**Birth rate:** average annual number of births during a year per 1,000 persons in the population at midyear. Obtained from the United Nations' 2019 Revision of World Population Prospects (WPP2019).

**Working-age population share:** is the ratio of working-age population (people aged 20 to 60) to total population. Obtained from the United Nations' 2019 Revision of World Population Prospects (WPP2019).

**Life expectancy:** indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its

[21] For details, see Bergeaud et al. (2016).

life. Data are obtained from from the World Banks World Development Indicators (WDI).

**Convenience yield:** As in Gilchrist and Zakrajšek (2012), we start with bond yields quoted in secondary markets from the Lehman/Warga and Merrill/Lynch[22] databases for the period 1973-2018. We then obtain spreads by subtracting the yield from U.S. treasuries with the exact same maturity using the yield curve estimated by Gürkaynak et al. (2007). Then, we use the cross-sectional median of these spreads at each time period, calling it convenience yield. For years before 1973, we use the spread between the Moody's AAA yields and 20-year U.S. treasuries. Then, to orthogonalize the information of the convenience yield to the one from supply of safe assets, we regress this convenience yield on our measure of net supply of safe assets, retaining the residuals. Finally, we extract the trend of such residual convenience yield to bypass cyclical fluctuations and focus only on long-run developments To obtain the trend, we use an HP-filter smoothing parameter of 10000 on the quarterly data before turning it into half-yearly data.

[22]ICE Data Indices, LLC, used with permission.

# B State Space Model Details

## B.1 Data on the State Space Model

To avoid estimates of the trend unemployment being negative, we estimate our state-space model on a transformed series of unemployment rates. Readings $x$ greater than 1% are left unchanged, while readings $x$ less than 1% become $(1 + \log(x))$ percent. Implicitly, this transformation assumes an increasing elasticity of other variables to (untransformed) unemployment rates less than 1%. For instance, this assumption is consistent with a convex Phillips curve for unemployment rates less 1%. Hooper et al. (2019) find evidence of such convex relationship for the United States in the 1950s and 1960s, consistent with the few observations of less than 1% unemployment rates and high inflation rates in our sample during the 1970's.

## B.2 Prior and Posterior Distributions

The prior distributions of the model parameters are described in Table 3. Priors for the elements of $B$ are centered around the assumption that $\hat{Y}_{j,t}$'s follow univariate AR(1) processes, inspired by Minnesota-style priors. Priors for the elements of $C$ with sign restrictions ($C_{1,2}$, $C_{2,2}$, $C_{2,4}$, and $C_{1,6}$) follow gamma distributions. Priors for the reactions of policy rates to demand and supply shocks ($C_{3,4}$ and $C_{3,6}$) are normally distributed and centered at zero. Priors for the columns of $C$ capturing the effect of permanent monetary shocks, $[C_{1,1}, C_{2,1}, C_{3,1}]'$, and permanent unemployment-rate shocks, $[C_{1,3}, C_{2,3}, C_{3,3}]'$, are centered around the idea that the level of unemployment, inflation and policy rates do not change upon the shock impact.[23] The priors for rest of the parameters follow standard practices in the literature. Figure B.1 reports the posterior distributions for the determinants of neutral interest rates.

## B.3 Inflation and Unemployment Trends

We estimate declining monetary trends across all countries in the sample. Figure B.2 details the desinflation experience of a select number of advanced economies, showing both the

[23] Arguments are similar to those used for changes in neutral real interest rates (footnote 19), focusing on equation (7) for permanent unemployment rate shocks and on equation (9) for permanent monetary shocks.

realized inflation rates and the estimated monetary trend. In 1970, we find that monetary trends were at 4.5% in the United States, 5.1% in Canada, 6.5% in the euro area, and 9.9% in the United Kingdom. In 2018H2, the level of these trends decreased to 2.1%, 2.4%, 1.7%, and 2.0%, in these respective economies. For the sake of completeness, Figure B.3 reports our estimated neutral rates against realized real rates.

Figure B.4 reports our estimates for unemployment-rate trends across a select number of economies. Rather than pointing to a global co-movement in these trends, our estimates are consistent with a relevant and alive Phillips curve for many countries and subperiods of our sample. Specifically, there is a negative relationship between cyclical unemployment rates, $\widehat{u}_{j,t}$, and cyclical inflation, $\widehat{u}_{j,t}$.[24] Some notable historical examples seen in Figure B.4 are the 1970s for the United Kingdom and the euro area, and the 1990s, early 2000s, and post-2008 periods for all countries.

As a robustness exercise, we have also estimated our model imposing that trend inflation is at the center of a central bank's numerical target as soon as it is announced.[25] The posterior distribution of $\beta_{sa}$ remains very similar to those shown in Figure 7b, while unemployment gaps become smaller in the end of the sample. For instance, in this alternative estimation, unemployment gaps ($\widehat{u}_{j,t}$) in 2018H2 are negative 0.2 for the United States, 0.4% for Canada, 1.4% for the euro area, and 1.1% for the United Kingdom. In our baseline model, we find the following respective unemployment gaps: negative 1.7%, negative 1.6%, 0% and negative 0.1%.

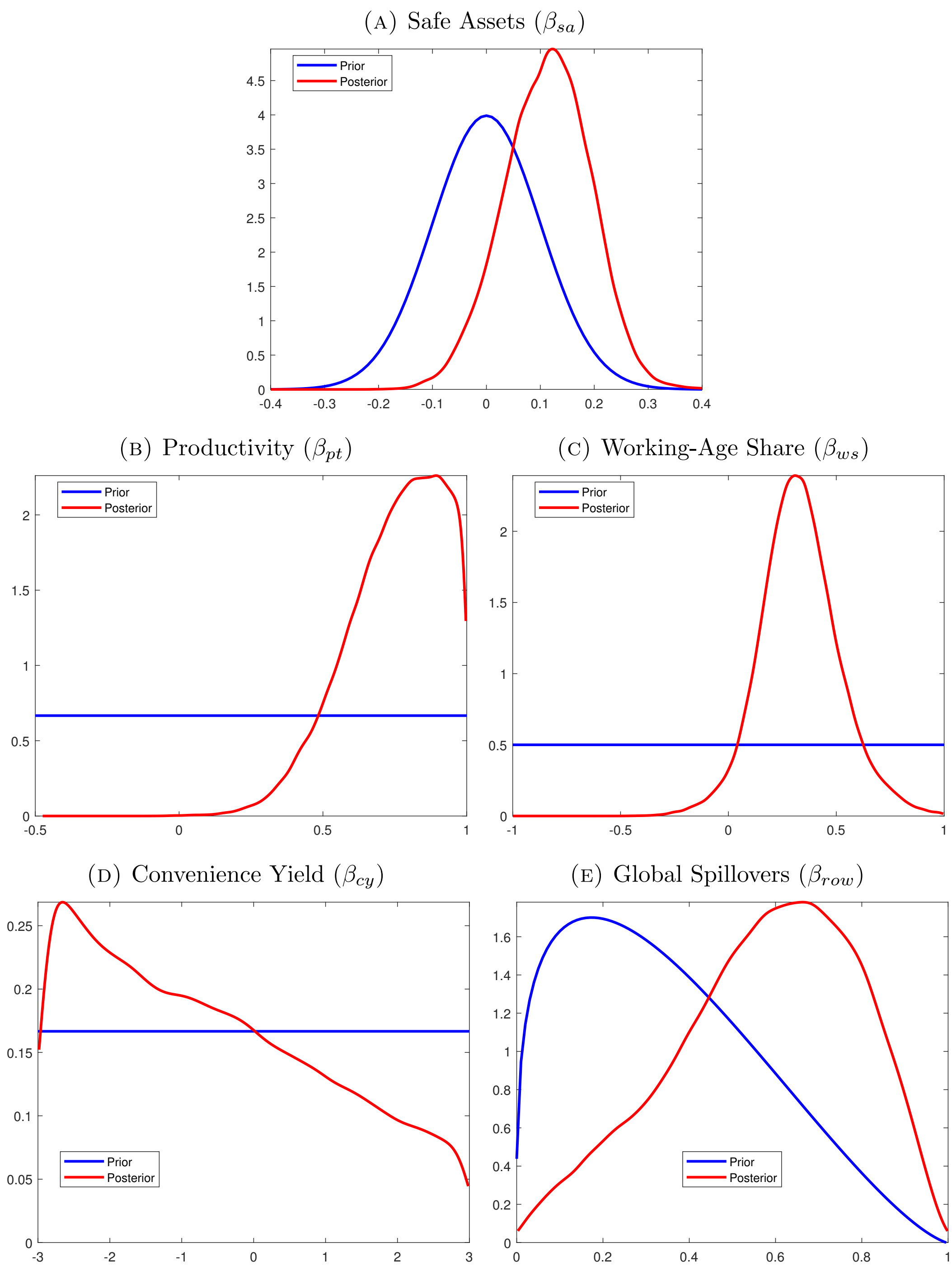
[24] In fact, the estimated median value for $B_{21}$ is -0.16, with its $10^{\text{th}}$ percentile being -0.07.

[25] Based on official statements from central banks, we assume a target of 2% for the United States from 2012 onward, 1.8% for the euro area from 2003 onward, and 2% for Canada from 2001 onward. For the United Kingdom, we assume 2.5% from 1998 to 2003 and 2% from 2004 onward.

Table 3
Cross-Country Panel State-Space Model: Prior Distributions

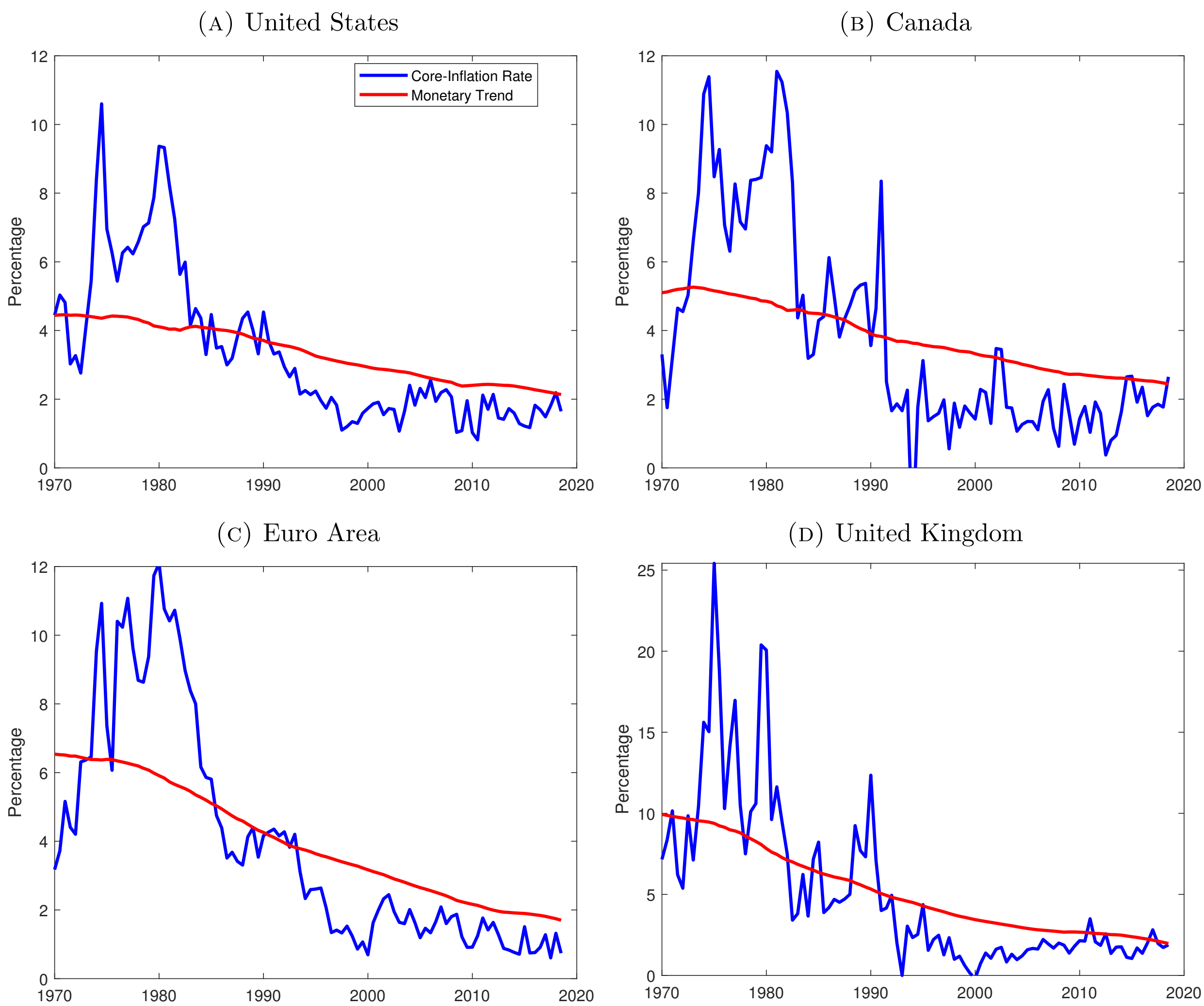
| Parameter | Description | Distribution | Mean | Std |
|---|---|---|---|---|
| $B_{m,m}$ | Diagonal of VAR of cyclical variables | Beta | 0.7 | 0.2 |
| $B_{m,n}$ | Off-diagonal of VAR of cyclical variables | Normal | 0 | 0.25 |
| $C_{1,1}$ | Permanent monetary shock: impact on $\widehat{u}_{j,t}$ | Normal | 0 | 0.5 |
| $C_{2,1}$ | Permanent monetary shock: impact on $\widehat{\pi}_{j,t}$ | Normal | -1 | 0.5 |
| $C_{3,1}$ | Permanent monetary shock: impact on $\widehat{i}_{j,t}$ | Normal | -1 | 0.5 |
| $C_{1,2}$ | Temporary monetary shock: impact on $\widehat{u}_{j,t}$ | Gamma | 0.5 | 0.5 |
| $-C_{2,2}$ | Temporary monetary shock: impact on $\widehat{\pi}_{j,t}$ | Gamma | 1 | 1 |
| $C_{1,3}$ | Permanent unemployment shock: impact on $\widehat{u}_{j,t}$ | Normal | -1 | 0.5 |
| $C_{2,3}$ | Permanent monetary shock: impact on $\widehat{\pi}_{j,t}$ | Normal | 0 | 1 |
| $C_{3,3}$ | Permanent monetary shock: impact on $\widehat{i}_{j,t}$ | Normal | 0 | 1 |
| $C_{2,4}$ | Temporary demand shock: impact on $\widehat{\pi}_{j,t}$ | Gamma | 0.5 | 0.5 |
| $C_{3,4}$ | Temporary demand shock: impact on $\widehat{i}_{j,t}$ | Normal | 0 | 1 |
| $C_{1,6}$ | Temporary supply shock: impact on $\widehat{u}_{j,t}$ | Gamma | 0.5 | 0.5 |
| $C_{3,6}$ | Temporary supply shock: impact on $\widehat{i}_{j,t}$ | Normal | 0 | 1 |
| $\rho^d$ | Temporary demand shock: persistence | Beta | 0.5 | 0.2 |
| $\phi^m$ | Permanent monetary shock: standard deviation | Gamma | 0.2 | 0.1 |
| $\phi^p$ | Transitory monetary shock: standard deviation | Gamma | 1 | 1 |
| $\phi^u$ | Permanent unemployment shock: standard deviation | Gamma | 0.2 | 0.1 |
| $\phi^d$ | Transitory demand shock: standard deviation | Gamma | 1 | 1 |
| $\phi^s$ | Transitory supply shock: standard deviation | Gamma | 1 | 1 |
| $\overline{x}_j^m$ | Monetary trend, linear component | Normal | 0 | 0.1 |
| $\beta_{pt}$ | Elasticity of neutral rate to trend-productivity | Uniform | 0.25 | $1.5\sqrt{1/12}$ |
| $\beta_{ws}$ | Elasticity of neutral rate to working-age share | Uniform | 0 | $2\sqrt{1/12}$ |
| $\beta_{cy}$ | Elasticity of neutral rate to convenience yield | Uniform | 0 | $6\sqrt{1/12}$ |
| $\beta_{sa}$ | Elasticity of neutral rate to net safe assets | Normal | 0 | 0.1 |
| $\beta_{row}$ | Elasticity of neutral rate to rest-of-the-world | Beta | 0.35 | 0.22 |

Figure B.1
Density of Parameters Determining Neutral Real Rates



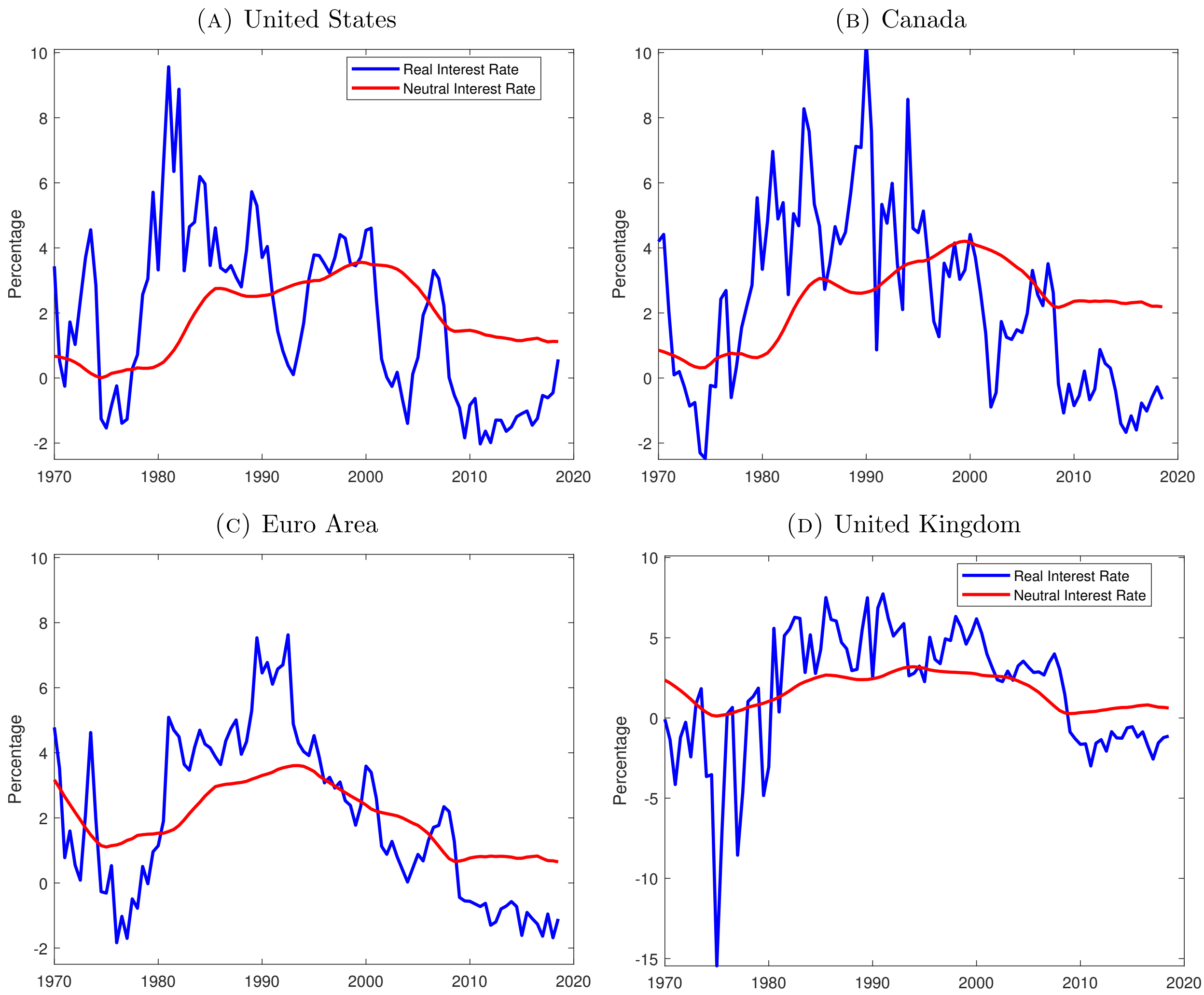

Note: The figure shows the prior (blue line) and posterior (red line) distributions of the elasticity of neutral rates to the following determinants: net supply of safe assets ($\beta_{sa}$), trend-productivity ($\beta_{pt}$), working age share of the population ($\beta_{ws}$), global spillovers from country specific factors ($\beta_{row}$), and convenience yield ($\beta_{cy}$). See Section 4 for details about the model and its variables.

Figure B.2
Inflation Rates Across Select Advanced Economies



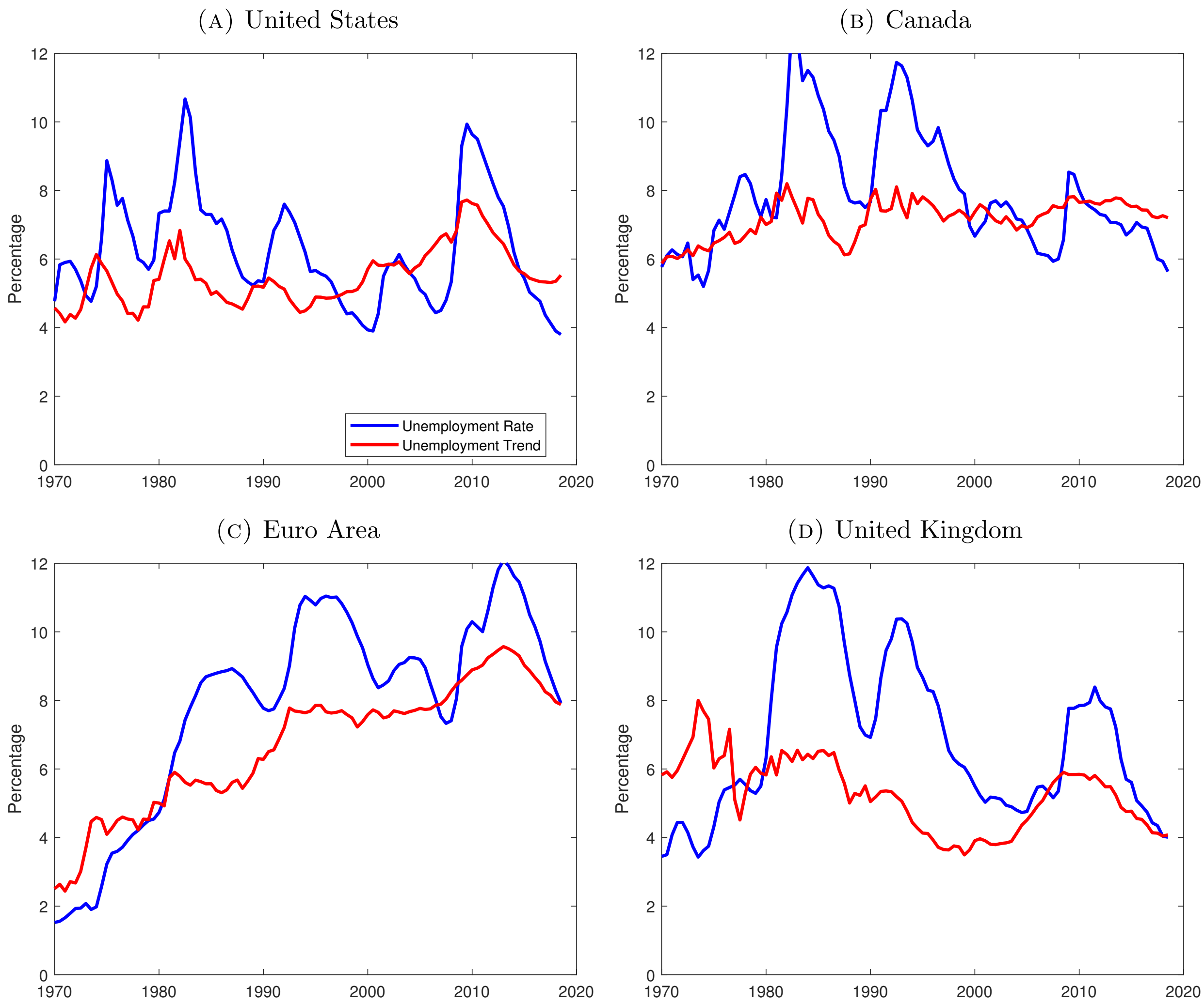

Note: Inflation rates (blue lines) are taken from databases in national agencies and the Organisation for Economic Co-operation and Development. Monetary trends (red lines) are estimated by the model of Section 4 using the median values of the posterior distribution of parameters. Despite excluding one observation (Canadian inflation of negative 2.1% in 1994H1), we choose the scale of the graphs to maximize the comparability of results across countries.

Figure B.3
Real Interest Rates Across Select Advanced Economies




Note: Real interest rates (blue lines) are measured as the difference between the policy interest rate and the realized core-inflation. Neutral interest rates (red lines) are estimated by the model of Section 4 using the median values of the posterior distribution of parameters.

Figure B.4
Unemployment Rates Across Select Advanced Economies




Note: Unemployment rates (blue lines) are taken from databases in national agencies and the Organisation for Economic Co-operation and Development. Unemployment trends (red lines) are estimated by the model of Section 4 using the median values of the posterior distribution of parameters.