Interest Rates, Global Risk and Inflation Expectations: Drivers of US Dollar Exchange Rates

Kerstin Bernoth* Helmut Herwartz† Lasse Trienens‡

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Abstract

Using a data-driven identification approach of structural vector autoregressive models, we analyse the factors driving the US dollar exchange rate for a sample of eight advanced countries over the period 1980M1 to 2022M6. We find that the exchange rates are significantly affected not only by US monetary policy, but also by shocks to inflation expectations associated with shifts in fiscal sustainability concerns. In addition, external shocks related to global risk aversion and the convenience yield that investors are willing to give up to hold US dollar assets have a significant impact on the US dollar exchange rate. All three shocks considered make an important contribution to explaining US dollar exchange rate changes, with external shocks being the most impactful on average. Moreover, we find evidence that the monetary policy response to shocks to long-run inflation expectations has changed over time, suggesting shifts in monetary policy reaction functions.

Keywords: exchange rates, convenience yield, global financial cycle, global risk, monetary policy, monetary-fiscal policy mix.

JEL Classification: E52, C32, E43, F31, G15, F41

*Email: kbernoth@diw.de German Institute for Economic Research (DIW Berlin), Department Macroeconomics.

†Email: hherwartz@uni-goettingen.de University of Goettingen, Chair for Econometrics.

‡Email: lasse.trienens@uni-goettingen.de University of Goettingen, Chair for Econometrics.

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1 Introduction

Given the sharp rise in inflation observed since 2021, the US Federal Reserve has rapidly raised interest rates after years of accommodative monetary policy. Simultaneously, over the past two decades, global financial markets have experienced several episodes of heightened risk aversion due to a series of crises that have shaken economies worldwide, such as the global financial crisis (GFC), the Covid-19 pandemic, and the energy crisis triggered by Russia's invasion of Ukraine. Government debt in the US and many industrialized countries has soared to record levels, fueling concerns that fiscal policy may pose a long-term risk to price stability. In this paper, we analyse the factors driving the US dollar exchange rate, taking into account the complex interactions within the quartet of exchange rates, interest rates, global risk aversion and long-term inflation expectations. Given the dominant role of the US dollar in trade invoicing, asset issuance, and official reserve holdings worldwide, understanding its drivers is of great importance.

Many studies have analysed the response of the US dollar exchange rate to monetary policy. However, the evidence is far from conclusive. Some studies confirm the prediction of standard open economy models that monetary policy tightening causes the exchange rate to appreciate immediately and then depreciate in subsequent periods (e.g. Faust & Rogers (2003); Kim & Roubini (2000)). Others find that the depreciation starts with a lag, a pattern that has been dubbed the 'delayed overshooting puzzle' (Eichenbaum & Evans, 1995; Scholl & Uhlig, 2008; Müller et al., 2024). However, there are also studies showing the opposite result, that US monetary tightening can have a depreciating effect on the US dollar exchange rate (Stavrakeva & Tang, 2019; Ilzetzki & Jin, 2021; Gürkaynak et al., 2021). It has been demonstrated that the response of exchange rates to monetary policy is contingent upon time. One potential explanation for this variation is the informational content conveyed by the central bank through its monetary policy decisions (Nakamura & Steinsson, 2018; Gürkaynak et al., 2021; Müller et al., 2024).

But next to monetary policy also fiscal policy plays a pivotal role in explaining exchange rate movements. Recent studies show that the credibility of the fiscal authority in terms of debt sustainability has an impact on long-term inflation expectations (e.g. Bianchi &

Melosi (2022) and Herwartz & Trienens (2024)). Long-term inflation expectations, in turn, are important drivers of exchange rates (Schmitt-Grohé & Uribe, 2022). Gürkaynak et al. (2021) show that both inflation and inflation target shocks are suitable for explaining the abnormal behaviour of exchange rates, such as the depreciating reaction to a monetary policy tightening. And finally, recent literature stresses that primarily the US dollar exchange rates is determined also by the role of the United States as a global safe haven and the vulnerability of the US dollar exchange rate to global risk aversion (e.g. Krishnamurthy & Vissing-Jorgensen (2012); Krishnamurthy & Lustig (2019); Rey (2015); Miranda-Agrippino & Rey (2022)). The objective of our research is to integrate these factors into an explanation of the dynamics of the US dollar exchange rate.

To analyse the causal relationships between short-term US interest rates, the US dollar exchange rate and long-term US inflation expectations, we identify three structural shocks that drive our model variables.[1] The first is a standard US short-term nominal interest rate shock.[2] The second shock is measured as exogenous innovations to long-term US inflation expectations. Following Bianchi et al. (2023a), Cochrane (2023), and Herwartz & Trienens (2024), we interpret this shock as a fiscally induced inflation shock resulting from uncovered changes in fiscal policy. Finally, similarly to Bernoth & Herwartz (2021) and Cormun & De Leo (2022), we identify an external shock, measured as an exogenous change in the US dollar exchange rate, which we will show to be related to global risk aversion and the US dollar convenience yield.

For the identification of the structural shocks, we apply a data-based identification approach of structural vector autoregressive (SVAR) models that take advantage of the uniqueness of independent components in linear non-Gaussian systems (Comon, 1994).[3] Model

[1]Given the importance of the interest rate differential between the two countries in determining exchange rates, we also estimated the model with four shocks by adding a foreign nominal interest rate shock. However, it turns out that the US and foreign nominal interest rate shocks are highly correlated. For identification reasons, we therefore refrain from adding the foreign nominal interest rate shock.

[2]Note that we are explicitly not talking about a monetary policy shock here. As elucidated by Müller et al. (2024) and Gürkaynak et al. (2021), among others, interest rate shocks encompass both a monetary policy shock and a central bank's proprietary insights regarding the real economy, such as the natural interest rate. However, since interest rates are important determinants of exchange rates and we aim for full model identification, we focus on interest rate shocks.

[3]Identification by means of independent components as detected in this work has been successfully employed in the context of US monetary policy analysis and exchange rate modelling (see, e.g., Bernoth & Herwartz, 2021; Jarociński, 2022; Herwartz et al., 2022b,c) and (Herwartz & Wang, 2023)

implied structural shocks have sound economic properties. The main advantage of this full-system identification approach is that it does not impose explicit restrictions on the behaviour of our model variables while allowing for a full and simultaneous interaction between them. We then trace the dynamic responses of changes in US short-term interest rates, the US dollar exchange rate, and long-run inflation expectations.

Using a monthly data set covering the period 1980M1 to 2022M12 and a cross-section of eight advanced economies, i.e. Australia, Canada, Germany, Japan, New Zealand, Sweden, Switzerland, and the United Kingdom, we find that external factors, US monetary and fiscal policies influence the US dollar exchange rate. When there is a tightening of US monetary policy, the US dollar tends to appreciate. An unexpected rise in inflation expectations, e.g. due to a deterioration in the credibility of the fiscal authority in stabilising high levels of debt, leads to a depreciation of the US dollar, which underlines the close monetary-fiscal interdependence. An external shock in the form of an unexpected appreciation of the US dollar, which can be linked to a decline in global risk appetite, leads to a depreciation of the US dollar in the following months. The historical decomposition shows that all three shocks considered make an important contribution to explaining US dollar exchange rate changes, with external shocks being of somewhat greater importance on average.

As a robustness test, we estimate our model for different sub-samples. A pre- and post-GFC period and the Volcker period. We find evidence of time dependence primarily in the response of US short-term interest rates and the US dollar exchange rate to shocks to inflation expectations. During the Volcker era and in the post-crisis period, short-term US interest rates rose in response to a positive shock to long-term inflation expectations and the value of the US dollar appreciated. We interpret this as the Fed having pursued an active monetary policy stance. Between the late 1980s and the onset of the GFC, there are indications that the US Federal Reserve adopted a more passive monetary stance, as evidenced by the decrease in US short-term interest rates, though this decrease was small.

Our work is linked to a number of important areas of research. First, this paper contributes to the large body of research on the impact of monetary policy on exchange rates. Previous literature has used various assumptions to identify exogenous monetary policy shocks, which turn out to be too restrictive for the research question under investigation.

For instance, recursive approaches, as used by Hnatkovska et al. (2016), must either assume that the policy rate does not directly affect exchange rates or that central banks do not respond to the exchange rate, both of which are highly controversial.[4] Identification with sign restrictions, as applied, for example, by Faust & Rogers (2003); Scholl & Uhlig (2008) and Kim et al. (2017), allows simultaneous linking of financial variables, but has the disadvantage of being based on otherwise stringent assumptions about the qualitative effects of monetary policy shocks (Baumeister & Hamilton, 2019). While narrative arguments for identification - or similarly - high frequency information (see, for instance Romer & Romer, 2004; Jarociński & Karadi, 2020; Müller et al., 2024) typically aim at the reliable detection of partially identified shocks, their scope is limited for full system identification in light of restrictive exogeneity conditions and demanding assumptions with regard to instrument relevance. The main advantage of the data-based identification approach used in this paper is that it does not impose explicit restrictions on the behaviour of our model variables while allowing for a full and simultaneous interaction between them.

Furthermore, this study is related to the literature on the global financial cycle (Rey, 2015; Miranda-Agrippino & Rey, 2020) and to recent studies showing that the response of the US dollar exchange rate in particular is significantly influenced by global risk factors (Krishnamurthy & Lustig, 2019; Kalemli-Özcan, 2019; Georgiadis et al., 2021; Cormun & De Leo, 2022). We also contribute to the growing body of research that sheds light on how the role of the United States as the provider of the dominant global currency with safe-haven status has influenced the dynamics of the US dollar exchange rate (Gourinchas et al., 2010; Bruno & Shin, 2015; Maggiori, 2017; Ilzetzki & Jin, 2021; Jiang et al., 2021).

By explicitly distinguishing between short-term interest rate shocks and shocks to long-run inflation expectations, we also add to the branch of the literature showing that the persistence of monetary policy shocks plays an important role in the response of macroeconomic variables (Williamson, 2016; Uribe, 2022; Evans & McGough, 2018; Garin et al., 2018; Garcia-Schmidt & Woodford, 2019; Lukmanova & Rabitsch, 2020; Bilbiie, 2022; Uribe, 2022). It allows us to verify Schmitt-Grohé & Uribe (2022)'s result that, in contrast to a

[4] See also Gertler & Karadi (2015) and Caldara & Herbst (2019), who caution against the recursive approach in VARs that model both macroeconomic and financial variables.

temporary monetary tightening, which leads to an appreciation of the US dollar, a persistent monetary shock in form of an increase in long-run inflation expectation depreciates the US dollar.

By arguing that our inflation expectations shock is related to a deterioration in the credibility of the fiscal authority's willingness and ability to stabilise debt, our paper also contributes to the literature examining the impact of fiscal policy on exchange rates. In the fiscal theory of the price level (FTPL) from an international perspective, Jiang (2021a) and Jiang (2021b) emphasise the pivotal role of the United States. While a deterioration in fiscal conditions in the US leads to a depreciation of the US dollar, fiscal conditions in other advanced economies have less significance for exchange rate developments. And finally, we also contribute to the literature on monetary and fiscal interactions and state-dependent neo-Fisherian effects by analysing how US interest rates respond to inflation expectation shocks and how this has affected the exchange rate response over time (Sargent & Wallace, 1981; Leeper, 1991; Sims, 1994; Woodford, 1995; Cochrane, 2001; Herwartz & Trienens, 2024).[5]

The remainder of this paper proceeds as follows. In the next section, the data and the VAR model are presented and the data-based identification approach is described in detail. Section 3 presents the theoretical features of the structural shocks and the assignment of sound economic labels to the statistically identified shocks. Section 4 presents the estimation results of the macroeconomic response profiles to the identified shocks. Section 5 explores whether interest rates and exchange rates react differently over time. Section 6 concludes. The appendices provide further information on the implementation of the data-based identification (Appendix A), on the data sources (Appendix B), on the diagnostic tests for normality and fundamentalness (Appendix C) and on the structural parameter estimates (Appendix D).

[5]Neo-Fisherian effects are defined as a one-to-one relationship between the response of nominal interest rates and inflation in the short run. Interest rates and inflation response that only comove under specific economic conditions imply a state-dependent viability of neo-Fisherian effects.

2 Empirical model

2.1 Data

We analyze the causal relationship between short-term nominal interest rates, exchange rates and long-term inflation expectations by means of a set of country-specific structural VARs. This section briefly sketches the employed VAR models in reduced and structural form and encounters the sufficient conditions for uniqueness of independent structural shocks.

Our empirical analysis employs monthly data spanning the period 1980M1 to 2022M6.[6] Throughout, we consider the United States as the domestic country, while a set of eight foreign countries, i.e., the United Kingdom, Japan, Canada, New Zealand, Australia, Sweden, Switzerland and Germany, give rise to a cross section of alternative empirical model implementations. The country selection obtains from the following considerations. First, we want to focus on advanced economies. Various studies, in fact, show that exchange rate behavior differ significantly between emerging and advanced economies (Kalemli-Özcan, 2019; Kalemli-Özcan & Varela, 2021). Hence, mixing these two types of economies could lead to inconclusive results. Second, we would like to look at a time period as long as possible to have sufficient sample information to examine the hypothesis that a potential change of structural relations can be traced back to changes in the importance of the US dollar as an international reserve currency. Third, we intend to compare our results with those of Schmitt-Grohé & Uribe (2022), who focus their analysis on the United Kingdom, Japan, and Canada. Therefore, our dataset includes these three economies as well, but we also provide evidence on the robustness of the results by using an extended set of economies (including Australia, Germany, New Zealand, Sweden, and Switzerland).

2.2 A cross section of structural VARs

Conditional on presample values $y_0, y_1, ..., y_{1-p}$, we consider a set of eight country specific VARs of dimension $K = 3$. Omitting a country indexation for notational clarity, the models

[6] We also split the full sample information into pre-crisis and post-crisis sub-samples to shed light on the eventually modified transmission of structural shocks after the GFC and the Great Recession (see Section 5.1).

read in their reduced and structural form, respectively, as

$$y_t = \nu + A_1 y_{t-1} + \ldots + A_p y_{t-p} + u_t, \quad (1)$$

$$= \nu + A_1 y_{t-1} + \ldots + A_p y_{t-p} + D\epsilon_t,\ t = 1, 2, ..., T. \quad (2)$$

By assumption, the model in (1) is causal, i.e., $\det(A(z)) \neq 0\ \forall |z| \leq 1$, where $A(L) = I_K - A_1 L - A_2 L^2 - \ldots - A_p L^p$ and L is the lag operator such that, e.g., $L\Delta y_t = \Delta y_{t-1}$. The corresponding Wold representation reads as $Y_t = \Phi(L)u_t,\ \mathrm{Cov}[u_t] = \Sigma_u$. Finally, u_t is a serially uncorrelated vector process with mean zero and covariance Σ_u, ϵ_t signifies structural innovations with mean zero and variance one, ν is a vector of intercepts, $A_1, A_2, \ldots, A_p$ are $K \times K$ parameter matrices. By means of OLS or ML estimation the reduced form parameters and the residuals u_t can be estimated consistently.

The vector of endogenous variables, y_t, consists of three variables. The first is the US one year treasury bill rate, i_t. We choose a maturity of one year because, as Gertler & Karadi (2015) and Rüth (2020) also argue, a monetary policy interest rate indicator with such slightly longer maturity has a wider distance to the zero lower bound and is also an effective strategy to capture the role of forward guidance during the Great Recession following the GFC. The second is the log nominal FX rate in foreign currency per US dollar, and a measure of long-run US inflation expectations, respectively, s_t. And third, $\hat{\pi}_t$ serves as an indicator of fiscally induced inflation (Bianchi et al., 2023a) or, alternatively, as an indicator of persistent shifts in monetary policy (Uribe, 2022, see a more detailed discussion on this in section 3.1.3). Like Lukmanova & Rabitsch (2020), we use here the mean of inflation expectations for the next ten years from the Survey of Professional Forecasters (SPF).[7] As discussed further below, the sampled variables r_t, s_t and $\hat{\pi}_t$ are not cointegrated according to conventional diagnostics, so we estimate the model in first differences. Thus, with Δ denoting the first difference operator, i.e. $\Delta y_t = y_t - y_{t-1}$, the vector of endogenous variables is $y_t = (\Delta i_t, \Delta s_t, \Delta \pi_t^e)'$.

We have also considered $K = 4$ dimensional models including foreign treasury yields, i_t^*. With regard to the three shocks of interest in this work, the informational content of the four dimensional system is similar to the one of trivariate models. For instance, regarding

[7] Lukmanova & Rabitsch (2020) show that differences across specifications with alternative inflation target measures are minor and that estimation results are robust across various measures of low-frequency inflation, including 10-year ahead inflation expectations of the SPF.

largest available samples for the UK, Japan, and Canada the correlations (i.e., $K = 3$ vs. $K = 4$) between model specific US short-term interest rate shock are 0.894, 0.943, and 0.973, respectively. For the remaining two shocks, the respective six correlation statistics are between 0.961 and 0.988.

2.3 Identification based on the uniqueness of the non-Gaussian independent components

An important contribution of our work to the existing literature is its innovative identification of structural shocks that account for potential bidirectional causalities among the variables in u_t (and, hence, y_t) in a largely agnostic manner. By assumption, the structural parameter matrix D in (2) is nonsingular.[8] Hence,

$$\epsilon_t = D^{-1}u_t \text{ and } \mathrm{Cov}[u_t] = DD' =: \Sigma_u. \tag{3}$$

It is well known that, in a Gaussian framework ($u_t \sim N(0, \Sigma_u)$), the identification of the parameter matrix D requires external information (e.g. the assumption of a recursive causal structure; Sims, 1980), since rotations of Gaussian random vectors are observationally equivalent. An important result in Comon (1994) states that the linear transmission scheme on the left hand side of (3) allows for a unique recovery of D from (estimates of) u_t, if (i) the components of ϵ_t are mutually independent, and (ii) at most one of the elements ϵ_{it} exhibits a Gaussian distribution. It is worth noting that, for the present case of analyzing financial market variables and outcomes, the deviations from Gaussianity (e.g. fat tails) are well established in the respective literature. In this context, Jarociński (2022) explores the non-Gaussian properties of monetary policy shocks and uses independent components analysis by Comon (1994) to identify their underlying structure. The author notes that the identified shocks provide an intuitive interpretation and plausible effects. Furthermore, despite not imposing external information, the shocks are remarkably similar to those identified in the existing literature using Gaussian methods. Hence, independent components detection

[8] We also follow the convention to investigate effects of positive structural shocks and assume that the diagonal elements of D greater than zero.

appears as a promising solution to achieve identification in a data-based manner.[9]

The data-based approach to identification that we pursue in this study consists of determining the country specific matrices D such that joint dependence among the implied shocks $\epsilon_t = D^{-1}u_t$ is minimal in terms of a flexible non-parametric dependence measure, namely the so-called Cramér-von-Mises (CvM) distance of Genest et al. (2007).[10] While the use of economic a-priori information fixes the structural shocks by construction, shocks identified by means of a statistical criterion (such as mutual independence) do not necessarily feature sound economic properties. Herwartz & Lütkepohl (2014) discuss the problem of so-called 'shock-labeling' in detail. In fact, using data-based identification in SVARs requires the assignment of sound economic labels to the detected shocks as an additional modelling step. To support the economic labelling of the statistically identified shocks (i.e. independent components), we provide an extensive literature review in Section 3 below on the theoretical and empirical transmission channels that shape the contemporaneous relationships among short-term US yields, exchange rates, and long-term inflation expectations. This helps us plausibly identify the expected impact of exogenous shocks hitting the dynamic system of three endogenous variables under consideration.

Moreover, we exploit two particular merits that are specific to the present joint analysis of a cross section of eight structural VARs. First, as the statistical identification scheme is fully agnostic and economic theory is supposed to apply to all advanced economies considered, finding qualitatively similar D matrices for the set of SVARs can be considered as stronger and 'cross-confirming' evidence in favor of a particular causal structure in comparison with single country models. Specifically, the mean group perspective might be used to explicitly test specific (joint) hypotheses on the structural parameters in D. Second, in the present analysis

[9] By means of Monte-Carlo experiments Herwartz et al. (2022a) compare several alternative data-based approaches to identification in SVARs. An important finding of this study is that nonparametric variants of independent component analysis, such as those employed in this study, perform accurate and largely robust under a wide variety of data-generating models, including scenarios of heteroskedastic shocks that are likely to affect our model variables due to the coverage of the GFC. While informative (co)variance changes have also been suggested for SVAR identification in a number of papers (e.g., Rigobon, 2003; Lanne & Lütkepohl, 2008), we consider the robust performance of independent component analysis in a cross-section of VAR models as an important merit of the identification of shocks in the form of independent components.

[10] For more details on the adopted ICA-based approach to identification and a formal representation of this estimator see Appendix A. For computation, we employ modified functions of the R package *svars* of Lange et al. (2017).

the country specific models comprise common US variables such that (some) economically identical shocks can be expected to drive the observable dynamics in country specific SVARs. In this regard, (very) high empirical correlations among shocks that we retrieve from distinct country specific models provides further support to the chosen economic labels and enhance the cross-confirming informational content of regarding a set of SVARs.

3 Shock labelling

This section begins with a review of the current theoretical and empirical literature that provides evidence on the links between short-term US nominal interest rates, the US dollar exchange rate, and long-term US inflation expectations. This guides us in plausibly determining the impact effects that one expects for the three exogenous shocks considered within the SVAR analysis. Subsequently, we utilize the identification approach described in Section 2.3 to extract the structural shocks that are later used in the impulse response exercises. Furthermore, we provide a more detailed analysis of the identified structural shocks to gain a better understanding of their interpretation and dynamics.

3.1 Expected effect directions based on a literature review

3.1.1 Short-term interest rate shock

The first shock considered is the temporary innovation to the short-term US nominal interest rate (*US IR shock*). The reaction of the US dollar exchange rate to an exogenous increase in US interest rates is not clear-cut in theory. There are theoretical arguments for effects in both directions. In a seminal paper, Dornbusch (2017) puts forth the argument that in response to a contractionary monetary policy shock, the exchange rate initially appreciates, followed by a subsequent depreciation in subsequent periods, a phenomenon that has been dubbed the 'overshooting hypothesis'. Krishnamurthy & Lustig (2019) add the consideration that when the Fed tightens monetary policy, bond markets assume that a reduction in the supply of safe dollar assets is imminent. As a result, the marginal willingness of global investors to pay for the safety and liquidity of dollar-denominated assets increases, leading to an appreciation of the dollar.

However, there are also arguments for a depreciating effect of a US monetary tightening on the US dollar exchange rate. One is that higher interest rates increase the debt service burden on companies and governments, which reduces overall investment and growth prospects, while also increasing pressure on the banking system. As pointed out by Gürkaynak et al. (2021), another argument is that an increase of US policy rates may signal higher than expected inflation, which invokes a depreciation of the US dollar.

The ambiguity of the impact of a monetary policy shock on exchange rates is also reflected in the empirical literature. While several studies confirm an immediate positive relationship between the US dollar exchange rate (appreciation) and US interest rates (e.g. Müller et al. (2024), Rüth (2020), and Schmitt-Grohé & Uribe (2022)). It is also frequently observed that the exchange rate tends to appreciate further in subsequent periods, in contrast to the predictions of Dornbusch's hypothesis, and only begins to depreciate much later. This pattern is commonly referred to as the 'delayed overshooting puzzle' (Eichenbaum & Evans, 1995; Scholl & Uhlig, 2008). Stavrakeva & Tang (2019) finds even the opposite that the exchange rate depreciates in response to a monetary policy tightening shock. The author attributes this to the signalling effect of monetary policy dominating in times of crisis. An unexpected tightening of US monetary policy signals economic strength, leading to a decline in risk aversion and higher expected inflation in the US. Inoue & Rossi (2019) add that the exchange rate responses differ with the effects of monetary policy on agents' expectations of risk premia in the short, medium, and long run during specific episodes.

Finally, as argued by Müller et al. (2024) and Nakamura & Steinsson (2018), markets are unable to discern whether an unanticipated increase in the policy rate is the result of a monetary policy shock or a rise in the natural rate of interest. The former has an appreciating effect on the exchange rate, whereas the latter has a depreciating effect. The overall exchange rate effect is therefore contingent upon market perceptions. Nakamura & Steinsson (2018) identify that one-third of interest rate surprises are attributable to monetary policy shocks, with the remaining thirds attributable to innovations in the natural rate. Consequently, without explicitly differentiating between the two, estimates of US interest rate shocks could encompass an aggregation of both structural movements and demonstrate an insignificant exchange rate response. Thus, the response of the US dollar exchange rate to a monetary policy shock might be state-dependent, and consequently, the theoretical sign is left open.

Economic theory suggests that the response of long-run inflation expectations to a contractionary monetary policy shocks is ambiguous. According to a DSGE model of Lukmanova & Rabitsch (2020), the on-impact response of the inflation target to a positive nominal US interest rate shock should be either zero under full information, when households can distinguish between monetary and different types of financial shocks, or negative under imperfect information. However, the response could also be positive. In line with the FTPL, monetary tightening destabilises the present value of future surpluses. In the absence of sufficient fiscal adjustment, combined with high public debt levels, concerns about the sustainability of public finances may arise, leading households to reduce their asset holdings and increase their cash holdings. The resulting increase in liquidity puts upward pressure on current inflation, thereby rebalancing the real value of debt with the diminished present value of surpluses. In the presence of price rigidities, this process would translate into an increase in trend inflation (Cochrane, 2023). Moreover, Cochrane (2001, 2023) finds that an increasing average maturity structure of public debt amplifies the response of expected inflation to monetary shocks.

The empirical literature confirms that the response of long-run inflation expectations to a contractionary monetary policy shock is not clear-cut. Lukmanova & Wouters (2022) find that the (perceived) inflation target proxied by long-term inflation expectations reacts negatively and returns to its initial level. Thus, the effect on long-run inflation is neutral. Nakamura & Steinsson (2018) show that monetary policy announcements significantly affect inflation expectations with a ten-year horizon. They estimate that break-even inflation implied by 2-year and 3-year forward rates responds positively but statistically insignificantly, while break-even inflation based on 5-year and 10-year forward rates responds significantly negatively to a contractionary monetary policy shock. Beechey et al. (2011); Gürkaynak et al. (2010) confirm that long-term inflation expectations decline in response to a positive monetary policy shock. Allowing for potential state dependence, we leave the theoretical sign of the expected response of long-run inflation expectations to an unexpected rise in interest rates in Table 1 open.

3.1.2 External shock

The second shock considered in this study measures an unexpected change in the US dollar exchange rate, which we refer to as the *external shock*, analogous to Cormun & De Leo (2022). As we explain in detail in section 3.3.2, the external shock is closely linked to a change in global risk aversion. This is also confirmed by Corbo & Di Casola (2022), who interpret an exogenous exchange rate shock as a change in the overall risk premium charged by investors for holding assets in a foreign currency. According to Krishnamurthy & Lustig (2019), the US dollar appreciates when the marginal willingness of (foreign) investors to pay for US dollar-denominated safe assets increases, which is the case, for example, when global risk appetite declines. As a result, US short term interest rates decline. The theoretical model by Lukmanova & Wouters (2022) supports the negative response of the short-term interest rate to external finance premium shocks. Thus, the theoretical impact effect of an external shock on the short-term US interest rate is negative.

To our knowledge, so far there is little theoretical and empirical evidence in the literature on how an exogenous shock to the US dollar affects long-run inflation expectations. Lukmanova & Wouters (2022) model three types of financial shocks into the Taylor rule, i.e. a risk premium, term premium, and external finance premium shock. Their external finance premium shock comes closed to the external shock identified in our estimations. They show that under information frictions, when households cannot distinguish between monetary and different types of financial shocks, ten-year inflation expectations immediately and significantly decline after an external financial premium shock and reverts to its initial level thereafter. Orlowski & Soper (2019) and Netsunajev & Winkelmann (2014) investigate interactions between global market risk proxied by the VIX and long-term US inflation expectations. Both find that a positive shock to the VIX significantly dampen inflation expectations. This negative relationship becomes particularly pronounced at turbulent market periods or crises, which are accompanied by expectations of disinflation and economic weakness. Therefore, the expected theoretical response of long-run US inflation expectations to an external shock is zero or negative in Table 1.

3.1.3 Inflation expectations shock

The third shock considered is a US long-term inflation expectations shock (*US IE shock*). There are two theories in the academic literature as to the origin of this shock. First, researchers such as Mumtaz & Theodoridis (2018); Uribe (2022); Schmitt-Grohé & Uribe (2022) and Lukmanova & Rabitsch (2020) argue that trend inflation is driven by an inflation targeting shock induced by the monetary authority. This is also pointed out by Nautz et al. (2019), who shows that shifts in US long-term inflation expectations are often the result of changes in expectations about the Federal Reserve's inflation target. This view is consistent with the view that "inflation is always and everywhere a monetary phenomenon" (Friedman, 1963). Second, the core principle of the FTPL is that inflation aligns the market value of government debt with the present value of primary surpluses. Consequently, in addition to monetary policy, fiscal policy also plays an important role in determining inflation. Large fiscal imbalances combined with a weakening fiscal (funding) credibility may lead trend inflation to increase as argued for example by Leeper (1991); Woodford (1995, 2001); Sims (1994); Dupor (2000); Bassetto (2002) and Cochrane (2001, 2022b,a). Recent studies by Bianchi et al. (2023a) for the US and Barro & Bianchi (2023) for a cross-section of advanced economies support the view that "persistently high inflation is always and everywhere a fiscal phenomenon" (Sargent, 2013), suggesting that shocks to unfunded fiscal transfers are the main drivers of trend inflation and long-run inflation expectations. In section 3.3.1 we show that the shock to long-run inflation expectations in the US is significantly related to US fiscal policy.[11]

Theoretical models do not provide a clear indication of the direction in which short-term US interest rates are expected to react to a shock to long-term inflation expectations. In particular, it may depend on the precise design of the monetary reaction function but also on the degree of fiscal backing (e.g., Leeper, 1991; Woodford, 1995; Leeper, 2013; De Michelis & Iacoviello, 2016; Smets & Wouters, 2024). For instance, an independent central bank

[11] According to the analysis by Bernanke (2003) and the stepping on a rake hypothesis by Sims (2011), monetary shocks without fiscal backing destabilize the present value of surpluses, thereby also fostering a change in inflation expectations to revert the implied budget constraint violation. Nonetheless, according to the results by Bianchi et al. (2023a), fiscal policy dominates the occurrence of these violations in post-WWII data, leading us to interpret these shocks as fiscally induced US inflation expectation shocks.

will raise policy rates in response to a positive shock to long-term inflation expectations (so-called active monetary policy). Herwartz & Trienens (2024) discuss that under active monetary policy, the resulting downward pressure on the present value of surpluses requires fiscal backing to enable the central bank to set the interest rate over the inflation response. Otherwise, increased interest payments fuel fiscal sustainability concerns and cause households to reduce their bond holdings, thereby amplifying the increase in consumption. The additional rise in inflation, in turn, creates a one-to-one comovement in inflation and yields (i.e. the neo-Fisherian effect), that prevents the central bank from stimulating real interest rates. In policy regimes with intermediate active and passive fiscal policies discussed by Smets & Wouters (2024), nominal yields rise modestly and effectively reverse the rise in inflation (expectations) when public transfers increase with a high degree of fiscal backing. On the other hand, if the US Federal Reserve were to respond to a rise in inflation expectations by raising interest rates without significant fiscal backing, this could lead to an uncontrollable inflationary spiral and push the economy into recession, as pointed out by Bianchi & Ilut (2017) and Cochrane (2022c). Conversely, a shock to long-term inflation expectations combined with increased political pressure, serious concerns about fiscal sustainability, economic growth or financial stability may lead the central bank to be more passive, resulting in an immediate neutral to negative policy rate response (so-called passive monetary policy).

The empirical literature is even more inconclusive as to how a shock to inflation expectations affects short-term interest rates. Uribe (2022) and Schmitt-Grohé & Uribe (2022) show an initially neutral reaction of short-term yields to changes in inflation expectations, which then gradually becomes positive. Lukmanova & Rabitsch (2020) find an initial negative impact on short-term nominal US interest rates, which turns positive after a few quarters, when focusing on the post-2008 phase. Using data from 1960 to 2007, Bianchi et al. (2023a) find an immediate negative response of the Fed funds rate to unobserved unfunded fiscal shocks that persists for five years.[12] Bianchi & Melosi (2017) show that short-term yields had an immediate positive response to fiscal imbalances before 2008, which turned negative thereafter. Bianchi et al. (2023b) find a negative interest rate response under political pressure before the appointment of Paul Volcker as US Fed Chairman in the early 1980s, as well as

[12] Unfunded fiscal shocks are defined as shocks to transfers that are not backed by future fiscal adjustments.

during the Donald Trump administration. Herwartz & Trienens (2024) show that a positive interest rate response only occurs in a high yield environment, possibly due to a monetary authority that follows the Taylor rule. In a low interest rate environment, they find, in line with Bianchi & Melosi (2017) and the FTPL, that if a central bank is passive (e.g. due to political pressure, economic growth concerns, financial stability, or fiscal sustainability concerns), this leads to a muted, possibly even negative reaction of short-term interest rates after inflation expectations shocks. All in all, we conclude from this literature review that the reaction of short-term nominal interest rates to an inflation expectation shock is state- and time-dependent and that we cannot make a clear statement about the direction.

The response of exchange rates to a positive shock to US long-term inflation expectations should depend, on the one hand, on the response of currency risk premia and, on the other, on the response of interest rates, as suggested by purchasing power parity. Empirical estimates by Schmitt-Grohé & Uribe (2022) find an immediate depreciation, which they refer to as the neo-Fisher effect of the open economy. Using a VAR model for Japan, De Michelis & Iacoviello (2016) find that inflation-targeting shocks result in a temporary real appreciation (depreciation) when interest rates rise faster (slower) than inflation. In the international context, the FTPL literature provides support for nominal and real depreciation effects when inflation expectation shocks are accompanied by public budget concerns (see, e.g., Jiang, 2021a,b). However, since the impact of a long-run inflation expectations shock on the US dollar exchange rate is one of our research questions, we do not take an a-priori stand on the expected sign.

Table 1 summarizes the theoretical sign pattern behind our shocks. Given that we consider a set of country specific SVARs it is worth pointing out that the cross section dimension does not only enable mean group estimation and inference for core parameters of interest. In addition, from the model outline it is evident that two shocks (i.e. the short term interest rate shock and the inflation expectations shock) should be present in each SVAR. Therefore, empirical correlations among shocks retrieved from the set of SVARs convey useful information to cross-confirm the economic labels attached to empirical shocks.

Table 1: Theoretical sign patterns of structural shocks

Variable	US IR shock	External shock	US IE shock
i_t	$+$	$-$	?
s_t	?	$+$	?
π_t^*	?	$0/-$	$+$

3.2 Estimated effect directions and identification

The uniqueness of the identified components $\epsilon_{k,t}$, as determined in this study, only holds under informative deviations from the joint Gaussian model. In addition, structural impulse response estimates, as determined in this study, are only reliable if the shocks can be considered fundamental. Diagnostic results documented in Appendix C confirm that both statistical preconditions (i.e. non-Gaussianity and fundamentalness) are fulfilled for the considered set of empirical (S)VARs. As a further underpinning of the informational content of the shocks retrieved from the model in (1) we notice that the variables in y_t are not cointegrated according to conventional diagnostics. For instance, testing for cointegration among US interest rates and inflation expectations with full sample information yields an ADF-statistic of -1.502 which lacks significance at conventional levels.

The discussion of theoretical impact effect directions (see Table 1) reveals that we consider, in particular, the marginal response of US interest rates and US inflation expectations to an external shock as important for a sound economic labelling of the statistically identified shocks. Noting that our analysis covers cross sectional results for a total of eight structural models, it is interesting to unravel how far the unrestricted data-based estimates allow for a cross sectionally (almost) uniform interpretation. In this regard, the empirical estimates of the structural parameter d_{12} could be considered of special importance, as the theoretical discussion postulates negative impact effects of the external shock on US short-term interest rates.

Instead of providing a set of metric estimation results, Table 2 displays the absolute frequencies of estimated effect directions on impact (left hand side panel) and for the sum of structural IRFs from $h = 0$ up to horizon $h = 3$ (i.e. effects within one quarter, right hand side panel). As it turns out, several a-priori unrestricted structural parameter estimates imply effect directions that are (almost) common for the entire cross section. For instance, while the impact effects of the external shock on exchange rate changes are positive by construction, its average effects on all variables within the first quarter have been left agnostically open. In this regard, observing that these effects on the system variables point into the same direction for at least six economies can be interpreted as a strong cross-confirmation of identification outcomes that is achieved by the consideration of a set of SVARs instead of single model analysis. US interest rates largely respond negatively to unexpected increases in the FX rates. More specifically, the documented directional estimates are theory-confirming for seven (out of eight) economies when focusing on impact and within-quarter effects, respectively. It is worth pointing out that the responses of interest rates to shocks to long-term US inflation expectations are positive for for seven and eight economies when looking on impact and within-quarter effects, suggesting that the US Fed is targeting inflation, on average.

Although the sensitivity of these responses will be discussed in detail below, it is worth highlighting that the empirical analysis points to effect directions of structural shocks that apply to (almost) all foreign economies under scrutiny. For instance, at the cross-sectional level, exchange rates respond positively to US interest rate shocks and negatively to shocks to inflation expectations. Moreover, inflation expectations tend to fall in response to an unexpected depreciation of the US dollar. Given both the diagnostic evidence pointing to the fundamentalness of the structural shocks and the cross sectionally comparable results for several structural parameters, we can - in summary - conclude that the agnostic data-based approach to identification yields structural shocks featuring sound economic labels. Accordingly, it is tempting to address how these shocks affect short-term US treasury yields, US dollar exchange rates or long-run inflation expectations.

Table 2: Empirical impact directions of structural shocks

	On Impact ($h=0$)			Within one quarter ($h=0,1,2,3$)		
	US IR shock	External shock	US IE shock	US IR shock	External shock	US IE shock
i_t	$+(8)-(0)$	$+(1)-(7)$	$+(7)-(1)$	$+(8)-(0)$	$+(1)-(7)$	$+(8)-(0)$
s_t	$+(7)-(1)$	$+(8)-(0)$	$+(2)-(6)$	$+(7)-(1)$	$+(8)-(0)$	$+(0)-(8)$
π_t^e	$+(3)-(5)$	$+(2)-(6)$	$+(8)-(0)$	$+(8)-(0)$	$+(0)-(8)$	$+(8)-(0)$

Notes: The table shows the absolute number directional estimates obtained in the sample of eight economies (AUS, CAN, CHE, DEU, GBR, JPN, NZL, SWE). Identified SVAR models are estimated with the sample period 1980-2022. Explicit parameter estimates are documented in Appendix D. *US IR shock* stands for short-term US interest rate shock, *External shock* for the exogenous innovations of the US dollar exchange rate and *US IR shock* for the long-term US inflation expectations shock.

3.3 A closer analysis of the shocks in the model

3.3.1 Inflation expectations shocks and fiscal credibility

In this section, we show that the US inflation expectations shock that we have identified is determined significantly by the sustainability of US fiscal policy. This is in line with Bernanke (2003), Leeper & Leith (2016), Herwartz & Trienens (2024) and Smets & Wouters (2024), who argue that trend inflation is not determined by monetary policy alone, but also by fiscal policy.

The literature on monetary-induced shocks to inflation expectations, in particular the work of Uribe (2022), focuses on the viability of the Fisher effect. This effect, rooted in standard New Keynesian theory with flexible prices in the long run, postulates that nominal yields and inflation move together one-to-one in the long run. Uribe (2022) captures this cointegrated relationship with a common permanent component (CPC) in yields and inflation. An increase (or decrease) in the CPC indicates that both inflation and yields increase (or decrease) in the long run. Focusing on the short-run dynamics, Uribe (2022) argues that changes in the CPC driven by persistent monetary shocks lead to a one-to-one co-movement of yields and inflation already in the short run (i.e. neo-Fisherian effects) (see, also De Michelis & Iacoviello, 2016; Lukmanova & Rabitsch, 2020; Lukmanova & Wouters, 2022).

The FTPL complements the view of a monetary determination of trend inflation. It postulates that the price level gradually adjust the current official debt ratio to a level that the government can politically operate depending on fiscal and monetary conditions (Cochrane, 2023). When price rigidities exist, this adjustment process is likely to drive trend inflation. Bianchi et al. (2023a) show, that uncovered fiscal shocks were key drivers of trend inflation in the 1960s and early 1970s. Smets & Wouters (2024) argue that unfunded fiscal and supply shocks drove inflation after COVID-19. However, not only exogenous fiscal shocks but also endogenous shifts in fiscal policy can lead to budget violations and thus affect price developments. In principle, any macroeconomic shock with unbalanced effects on fiscal expenditure and revenue could change inflation in order to maintain the intertemporal budget constraint. In contrast to the literature on monetary-induced inflation expectation shocks, the causality and short-run effects of shifts in long-run inflation expectations are different. The central bank primarily responds to the inflationary consequences of endogenous and exogenous fiscal imbalances based on its current reaction function, rather than causing them.[13]

In order to reconcile the disparate views on the drivers of trend inflation, Herwartz & Trienens (2024) undertake an analysis of the properties of the CPC, as identified by Uribe (2022). The results indicate a robust correlation between the CPC and the public debt ratio. Furthermore, in line with the FTPL, they demonstrate that the short-run nominal and real interest rate responses to changes in the CPC (i.e. neo-Fisherian effects) are contingent upon the prevailing monetary and fiscal reaction function. This indicates that changes in the CPC are aligned with the inflation concept within the FTPL and occur to offset violations of the intertemporal budget constraint. In other words, an increase in inflation expectations is a consequence of a decline in the fiscal authority's credibility to repay debt with future surpluses.

To further examine the relationship between inflation expectations and the fiscal credibility to repay debt, Figure 1 plots our identified cummulated US long-term inflation expectations together with the CPC. Additionally, we also show the (normalized) inverse of the debt to GDP (DtGDP) ratio as a measure for the general fiscal stance, where changes result, among other things, from covered and uncovered public budget balances. Until the mid 1980s and from the early 1990s until 1996, a continuous negative trend in US inflation expectation shocks can be observed, coinciding with a decline in the CPC. This observation is consistent with the disinflationary Volcker period, which exerted strong disciplinary pressure (Bianchi & Ilut, 2017). After the GFC in 2008, the cumulative US inflation expectation shocks rise only moderately. This corroborates the conclusion of Cochrane (2022b) that the sharp increase in government debt during this period was primarily funded, thereby maintaining inflationary resilience. In accordance with the partially uncovered nature of the increase in government debt following the global pandemic (Cochrane, 2022b; Barro & Bianchi, 2023; Smets

[13] As discussed earlier, neutral policy rate responses result in a negative real interest rate response after a surge in inflation, while positive policy rate responses lead to a positive real interest rate response with fiscal backing, and a neutral real interest rate response without fiscal backing (Leeper, 1991; Smets & Wouters, 2024).

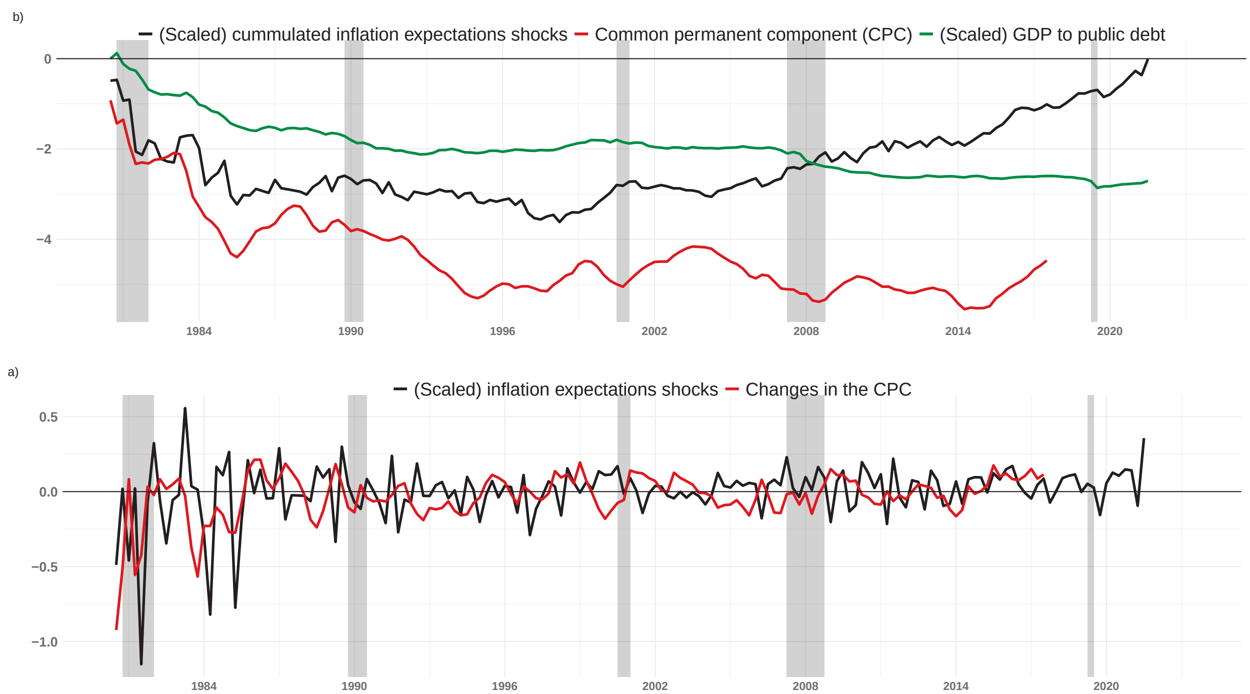

Figure 1: US IE shocks (rescaled) and CPC changes (upper panel) and correlation results (lower panel). The latter is normalized to start from zero by subtracting the observation from 1980Q3. The sample period is 1981Q2-2022Q2. CPC data are only available until 2018Q2. Shaded areas correspond to recessions as classified by the NBER.

& Wouters, 2024), the inflation expectation shocks in the USA demonstrate a pronounced cumulative increase following the year 2020.

The correlation between US IE shocks and changes in the CPC is approximately 0.3, which exceeds the significance criterion of $2/\sqrt{T}$. In contrast, the correlations for US interest rate and external shocks are close to zero. We see this as evidence that the identified US inflation expectations shocks are significantly related to fiscal policy, namely the fiscal authority's credibility in maintaining stable public finances.

3.3.2 External shocks, global risk and US dollar convenience yields

According to Krishnamurthy & Vissing-Jorgensen (2012); Engel & Wu (2018); Krishnamurthy & Lustig (2019), and Jiang et al. (2021), important drivers of fluctuations in US dollar exchange rates are shifts in the demand and supply of safe dollar assets. The US dollar exchange rate clears the global market of these safe assets. The supply of safe dollar assets is largely determined by monetary policy, while the demand for US dollar safe assets is significantly impacted by global risk, as highlighted in the literature on the existence of a global financial cycle (Rey, 2015; Miranda-Agrippino & Rey, 2022). During periods of relatively low global risk appetite, global cross-border capital flows contract and demand for safe US dollar assets increases, causing the US dollar to appreciate.

Against this background, we examine whether the external shock is indeed related to the attractiveness of US dollar assets to international investors and to global risk aversion. The upper (lower) panel of Figure 2 shows outcomes of rolling regressions in the spirit of Lilley et al. (2022) for changes of the US Treasury basis (ΔTB_t) and of the VXO ($\Delta log(VXO_t)$) on the external shock. The treasury basis is determined as the average of the differences between the yield on an actual one-year US Treasury and the yield on an equivalent synthetic US Treasury constructed from G10 foreign bonds. According Krishnamurthy & Lustig (2019), the US Treasury basis proxies the so-called convenience yield on US Treasury securities, which also reflects the value that investors place on liquidity and safety. Moreover, $\Delta log(VXO_t)$ is a proxy for global risk appetite calculated as the monthly change in the log implied volatility of the S&P100 stock index.

Until mid-2003, the cross-sectional average of the rolling estimates suggests an insignif-

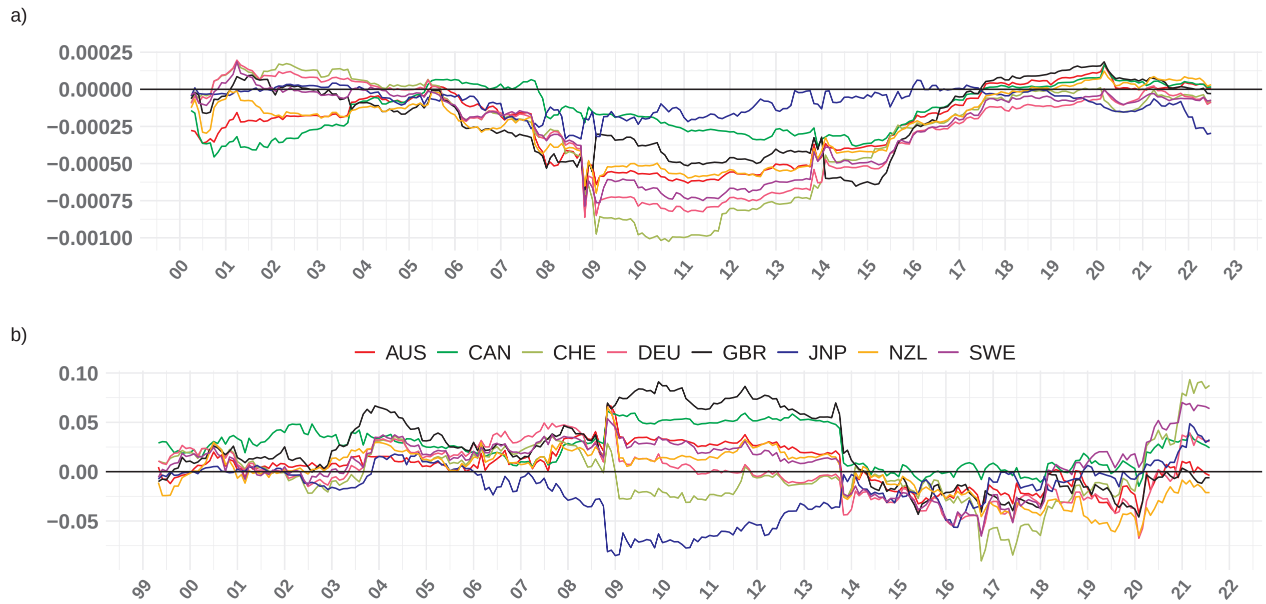

Figure 2: Historical immediate effects of external shocks

Notes: The figure shows the estimated slope coefficients for the rolling regressions

$$y_s = \alpha + \beta_0 \epsilon_{2,s} + u_s, \; s = \tau_1, \tau_1 + 1, \ldots, \tau_2,$$

where $y = \Delta TB$ (upper panel) and $y = \Delta log(VXO)$ (lower panel), $\epsilon_{2,s}$ is the external shock and τ_1 (τ_2) is the lower (upper) bound of rolling samples of size 60. Owing to data availability, rolling regressions start in 2000M3. For panels (a) and (b) the sample ends in 2022M6 and 2021M8, respectively.

icant relationship between the external shock and the convenience yield. However, from 2004 onwards, the average slope coefficient becomes significantly negative. Around 2007, there is an abrupt and sustained further decline in the estimated slope coefficients. From mid-2011, the average slope coefficient increases again and becomes insignificant around 2018. These results suggest that convenience yields process to considerable extent information inherent in the identified external shock. In particular, during periods of high uncertainty and global risk, the role of the US dollar as the primary global safe-haven asset is a strong driver of US dollar exchange rate developments that remain unexplained by US monetary policy shocks. This provides evidence for the existence of a so-called convenience yield channel of monetary policy, describing the spill over of US monetary policy to through changes in the demand for and supply of safe US dollar assets.

The collection of cross-sectional evidence from rolling regressions for $\Delta logVXO$ suggests a significant positive relationship between the external shock and the VXO, indicating that the US dollar experiences external appreciations (depreciations) in periods when global risk appetite is low (high). This positive link became, on average, stronger during the GFC and thereafter between 2008 and 2014. However, we also see some variation across economies. For Japan, Switzerland, and, in part, Germany, the relationship between VXO changes and the external shock turns negative during the GFC such that an unexpected appreciation of the US dollar against the respective currencies is associated with a decline in global risk appetite. As a possible explanation it is worth noting that these currencies are also seen as safe havens by international investors. Hence, in times of crisis, the US dollar does not appreciate unexpectedly against these three currencies, as it is the case for the remaining currencies. Interestingly, between 2014 and 2021 the mean group estimate of the rolling window coefficient on VXO is no longer positive, but significantly negative, suggesting that an unexpected appreciation of the US dollar is associated with periods of low global risk appetite. We leave it to further research to determine why this sign reversal occurred.

In sum, the identified external shock is significantly related to a conventional proxy for global risk aversion, albeit with changing signs. Thus, we find that the dynamics of the US dollar exchange rate that are unrelated to monetary policy can be explained, to a significant extent, by global risk factors. Further, contrary to the finding of Lilley et al. (2022), this holds not only after the onset of the GFC in 2007, but throughout the investigated sample period.

4 Dynamic responses to model shocks

Figure 3 shows the cumulative impulse responses functions (IRFs) to our model shocks, i.e. the US interest rate shock (IR shock), the external shock and the shock to long-run US inflation expectations (IE shock). The shocks are normalized by construction so that the impulse responses shown in this study reflect the effects of a structural shock of magnitude 1. The horizontal axis measures time in months. The vertical axis measures the cumulative change in interest rates and inflation in annual percentage points ($0.05 \mathrel{\hat{=}} 5\%$), and the cumulative change in the exchange rate (which is defined in log first differences) in percent. Due to space considerations, we summarize estimation results by providing IRF estimates for all considered economies jointly. Note that this collection of estimates lacks a complementation with model specific confidence bands. Instead, we evaluate 'overall' significance of the displayed dynamics in terms of mean group criteria (Pesaran & Smith, 1995).

The first column of Figure 3 shows the response to a contractionary US interest rate shock. As previously noted, an increase in value represents an appreciation of the US dollar. We find that the US dollar appreciates immediately by, on average, half a percentage point (Panel (b)). Only after approximately one year does the US dollar begin to depreciate, albeit at a slow rate. This pattern corresponds to the delayed overshooting result established, for example, by Eichenbaum & Evans (1995). However, as will be demonstrated in section 5.1, this result is significantly dependent on the analysed time period.

We estimate that US inflation expectations initially increase in the first year following a contractionary US interest rate shock (panel (c)). However, they subsequently decline in accordance with our prediction and the findings of previous studies, including those by Beechey et al. (2011), Gürkaynak et al. (2010), Nakamura & Steinsson (2018) and Lukmanova & Wouters (2022). The initial rise may be attributed to the necessity for markets to ascertain whether the interest rate shock is indicative of a monetary policy shock or a shock to the neutral interest rate (Müller et al., 2024). The former is presumed to exert a negative impact on inflation expectations, whereas the latter is expected to have a positive effect.

The second column of figure 3 shows the responses to an external shock in the form of an unexpected appreciation of the US dollar exchange rate. In line with our prediction, the cross-sectional analysis shows a significant and immediate decline in US short-term interest rates, which becomes more pronounced in the first few months and persists thereafter (panel (a)). The explanation is that the external shock is closely associated with a decline in global risk appetite. This decline increases the willingness of international investors to hold US dollar-denominated assets and depresses their yields. We thus confirm the theoretical finding of Lukmanova & Wouters (2022).

The US dollar exchange rates remain at the elevated level following an external shock as shown in panel (b). Inflation expectations in the US decline significantly and persistently in response to a positive external shock (panel (c)), which is consistent with the findings of Lukmanova & Wouters (2022), Orlowski & Soper (2019) and Netsunajev & Winkelmann

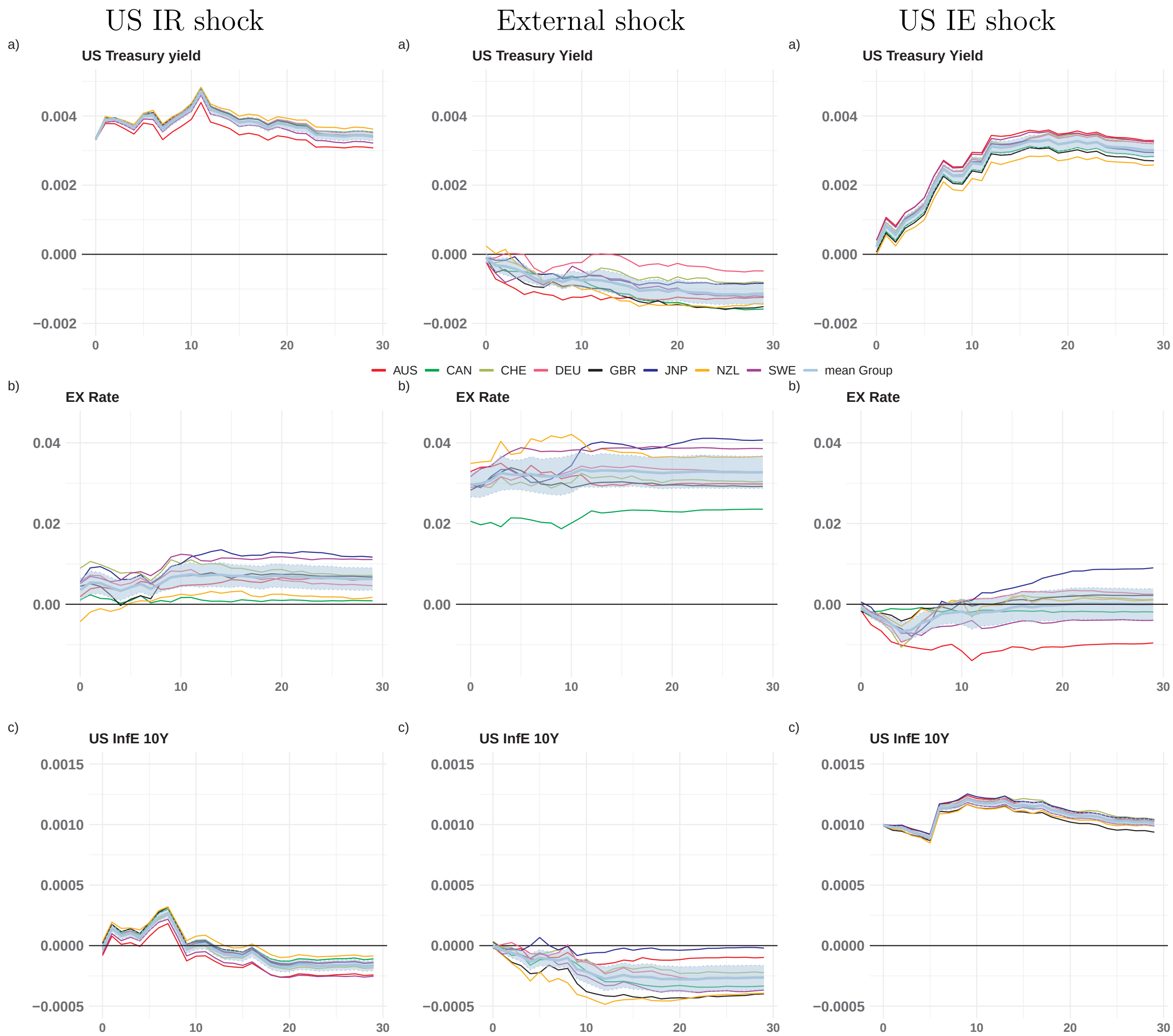

Figure 3: Full sample IRFs, 1980M1-2022M6

Notes: Cumulative responses to US interest rate shocks (*US IR shocks*, external shocks, and US inflation expectations shocks) up to an horizon of $H = 30$ months. Endogenous variables are US Treasury yields (12M), nominal EX rates, and US inflation exectations (10Y). Sample periods are 1980M1-2022M6 (AUS, CAN, CHE, DEU, GBR, JPN, NZL, SWE). Shaded areas show inferential results for mean group estimators, i.e. pointwise intervals covering arithmetic means $\pm$ 2 standard deviations of the mean group estimator. The shocks are normalized by construction so that the impulse responses shown in this figure reflect the effects of a structural shock of magnitude 1. The horizontal axis measures time in months. The vertical axis measures changes in interest rates and inflation in annual percentage points (e.g., $0.05 \mathrel{\hat{=}} 5\%$), and changes in the exchange rate in percent.

(2014). Thus, as explained by Orlowski & Soper (2019), the increased global risk associated with the external shock raises concerns about economic weakness and disinflationary tendencies.

The third column of Figure 3 shows the responses to a positive shock to long-term inflation expectations that we consider to be associated with the fiscal authority's credibility to stabilize large debt. We find that US short-term interest rates rise in the first 12 months and remain at elevated levels thereafter (panel (a)). We interpret this as an indication of an active monetary policy stance, i.e. a central bank with an inflation targeting reaction function. However, as explained later in section 5.1, we find that the response of short-term interest rates varies considerably for the different sub-samples considered. This is in line with Bianchi & Melosi (2017), Bianchi & Ilut (2017), Herwartz & Trienens (2024) and Smets & Wouters (2024), who show that the monetary reaction function change over time in the wake of different political and institutional constellations.

As shown in panel (b), we find, on average, a significant immediate depreciation of bilateral US dollar exchange rates in response to a positive shock to US inflation expectations, which is in line with the result of Schmitt-Grohé & Uribe (2022) and Lukmanova & Rabitsch (2020). After a few months, this depreciation disappears. Given the above evidence that long-run inflation expectations are significantly influenced by, among other things, the credibility of fiscal policy and the sustainability of public finances, our result confirms our hypothesis that the US dollar exchange rate also has an important fiscal policy component.

To summarise, US dollar exchange rates are impacted not only by US monetary policy, reflected in US interest rates, they are also affected by global risk aversion reflected by exogenous US dollar demand shocks as well long-run inflation expectations that are determined, among other factors, by fiscal sustainability considerations. In response to a tightening of US monetary policy, the US dollar appreciates. In response to a sustained rise in inflation expectations, e.g. as a result of an unsustainable increase in government debt paired with a deterioration of the fiscal authority's credibility, the US dollar depreciates. An unexpected appreciation of the US dollar, which can be associated with a decline in global risk appetite, leads to a depreciation of the US dollar in the following months.

In terms of information efficiency, it is worth noting that we have attributed the main drivers of US dollar exchange rates to structural shocks that are well defined and confirmed in the cross-section. Therefore, it is unlikely that the marginal reaction profiles discussed suffer from biases resulting from contamination of the identified shocks, which may be one reason for the rather inconclusive empirical results of the drivers of the US exchange rate in the existing literature so far. Moreover, beyond the stylised orthogonality conditions, these shocks can also be interpreted as independent components. Therefore, the described identification of the main determinants of US dollar rates is also well immunised against higher order dependencies between the structural origins of interest rates, inflation expectations and international yield opportunities and associated risks.

5 Sensitivity tests

5.1 Volcker-, pre- and post-crisis period

There is evidence in the literature that the responses of interest rates, inflation expectations, and exchange rates to macroeconomic shocks depends on the sample period. In the context of short-run interest rate responses, the existing literature on the FTPL suggests that the response of interest rates to inflation expectation shocks is contingent upon the monetary reaction function, resulting in state-dependent interest rate responses (Leeper, 1991; Bianchi & Melosi, 2017; Smets & Wouters, 2024). Further, there is evidence that the response of exchange rates to macroeconomic shocks depends on the sample period. For example, Eichenbaum & Evans (1995), using data from January 1974 to 1990, reports significant delayed overshooting of exchange rates following monetary shocks, while Scholl & Uhlig (2008), using a sample from 1975 to 2002, finds a more subdued pattern of exchange rates. This finding is consistent with the conclusion of Kim et al. (2017) that the delayed overshooting puzzle is a phenomenon that emerged predominantly during the 1980s, and is related to the Volcker era. Likewise, Bernoth et al. (2022) find a structural break in the magnitude of US dollar excess returns in 2007 with the onset of the GFC, which may also indicate a change in the response of the US dollar exchange rate to macroeconomic shocks.

Thus, this section examines whether the shock responses of US interest rates, inflation expectations and US dollar exchange rates of the eight considered economies are time variant. For this purpose, we repeat our SVAR estimations for three sub-samples: the Volcker-period from 1980M1 to 1987M7, a pre-crisis period from 1987M8 to 2007M4, and a post-crisis period from 2008M4 to 2022M6. Figure 4 shows the results.[14]

In consideration of the limitations of space, we describe only those estimation results for which we find significant differences across the three sub-periods under examination. As shown in the first column of Figure 4, only in the post-crisis period, we confirm our earlier result that the US dollar significantly appreciates in response to a contractionary US interest rate shock. For the pre-crisis period, we also find an US Dollar appreciation, however, this response is not significant. During the Volcker era, the exchange rate response fluctuates around zero and is insignificant throughout. A suitable explanation is discussed above. According to Müller et al. (2024), the US interest rate shock can be interpreted as an aggregate of monetary and natural interest rate shocks. While the former is generally estimated to have an appreciating effect on exchange rate, the latter has a depreciating effect. Our sub-sample IRFs indicate that in the post-crisis period our US interest rate shock is dominated by monetary policy shocks, while it represent a mix of the two in the two other sub-samples.

[14] As we demonstrate in Section 3.3.2, the nature of exchange rate dynamics is subject to a transition process starting from the late 1980s as well as the mid-2007. To capture only the new external variation, we exclude the transition period and leave a one-year gap between the two sub-samples. Following the findings of Eichenbaum & Evans (1995) for the Volcker sample, we truncate our sample just before 1990.

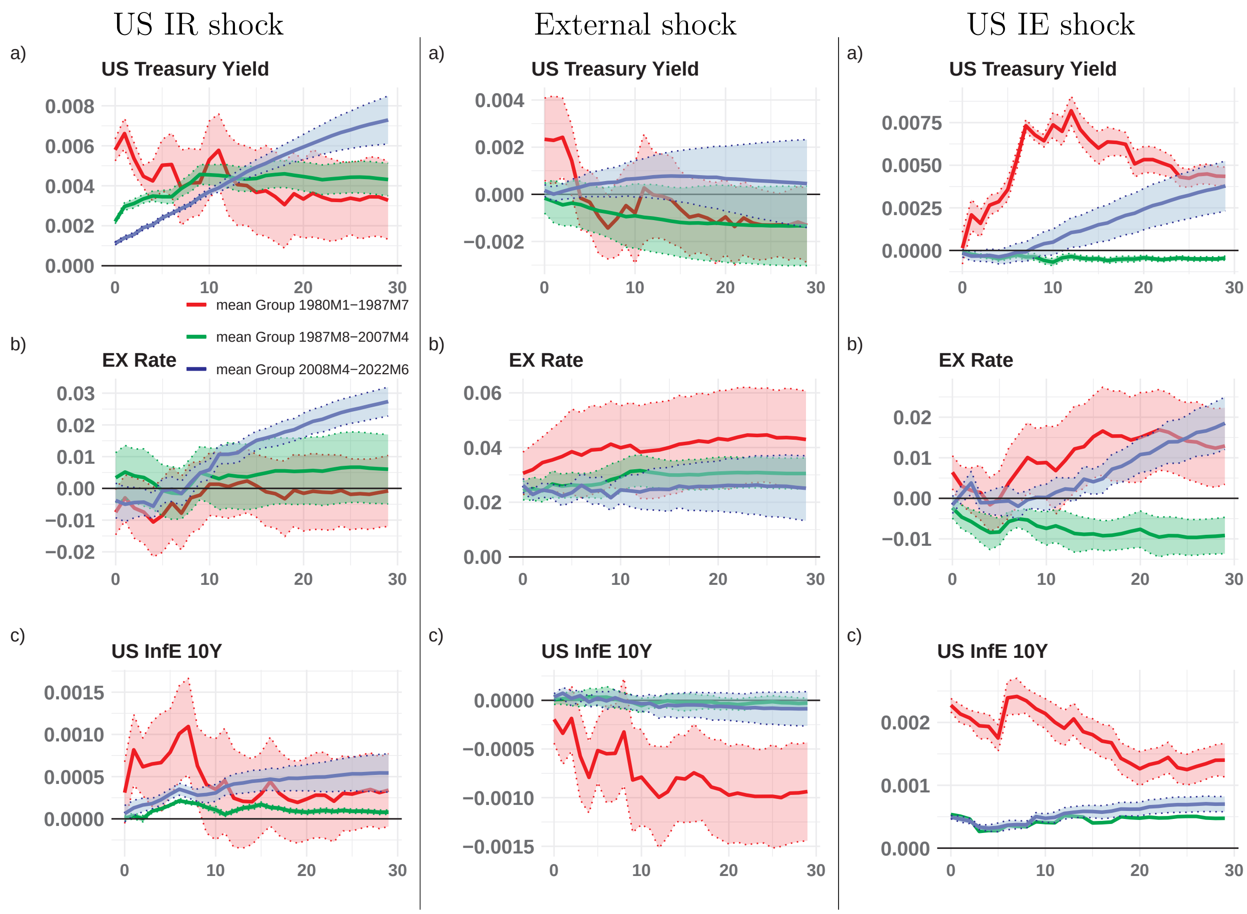

Figure 4: Sub-samples mean group results, 1980M1-2022M6

Notes: The figure displays mean group results conditional on three sub-samples for responses to US interest rate shocks (first column), external shocks (second), and US inflation expectations shocks (third). Red-colored results are based on the sub-samples 1980M6-1987M7; green-colored results are conditional on subsamples 1987M78-2007M4; blue-colored results are conditional on sub-samples 2008M4-2022M6 (AUS, CAN, CHE, DEU, GBR, JPN, NZL, SWE). The endogenous variables considered are the US treasury yields with a one-year maturity, the bilateral exchange rates against the USD, and US inflation expectations (10Y).

As illustrated in the second column of Figure 2, the response pattern of inflation expectations to external shocks also differs significantly across the three considered time periods (panel (c)). This finding is consistent with that of Orlowski & Soper (2019), who also reports that the impact of market risk on US inflation expectations varies over time. Restricting observations to the pre- and post-crisis periods reveals that the reaction of US long-run inflation expectations to external shocks is insignificant over the full 30-month horizon. However, during the Volcker period, the full-sample result is confirmed, namely that inflation expectations largely declined in response to external shocks. This probably reflected the increased market risk, at the time accompanied by expectations of disinflation and economic weakness.

We also find time dependence in the response of US short-term nominal yields and the US dollar exchange rate to US inflation expectations shocks (panels (a) and (b), third column). During the Volcker era and after the GFC, US short-term yields responded positively to shocks to inflation expectations, reflecting a Taylor rule-based reaction function (Bianchi & Ilut, 2017; Herwartz & Trienens, 2024), albeit with a lag of a few months in the post-GFC period. Accordingly, the US dollar exchange rate appreciated significantly. However, in the pre-crisis period between 1987 and 2007, the estimates show a negative response of US Treasury yields, indicating a shift towards a more passive monetary policy, on average. This is in line with Romer & Romer (2023), who argue that a recession in the early 1990s fostered a shift towards more passive monetary policies. Similarly, Cieslak et al. (2023) and Herwartz & Trienens (2024) also document a passive monetary stance in the early 1990 and 2000s. This policy shift could be explained by concerns regarding economic growth, financial stability, and fiscal sustainability in the aftermath of the dot-com crisis and the fiscal deficits experienced in the US following 9/11. Accordingly, the median group estimates also indicate a significant US Dollar depreciation in this period.

6 Historical decomposition analysis

In this section, we analyse historical decompositions to assess the relevance of the US interest rate shocks, external shocks, and US inflation expectation shocks for the variation in the bilateral US dollar exchange rate against the eight advanced economies under investigation. Figure 5 shows the average percentage contribution of the three shocks to absolute changes in the exchange rates. Given the finding of time-dependent effects in the previous section, we conduct this historical decompositions for each of the three sub-sample estimation results.

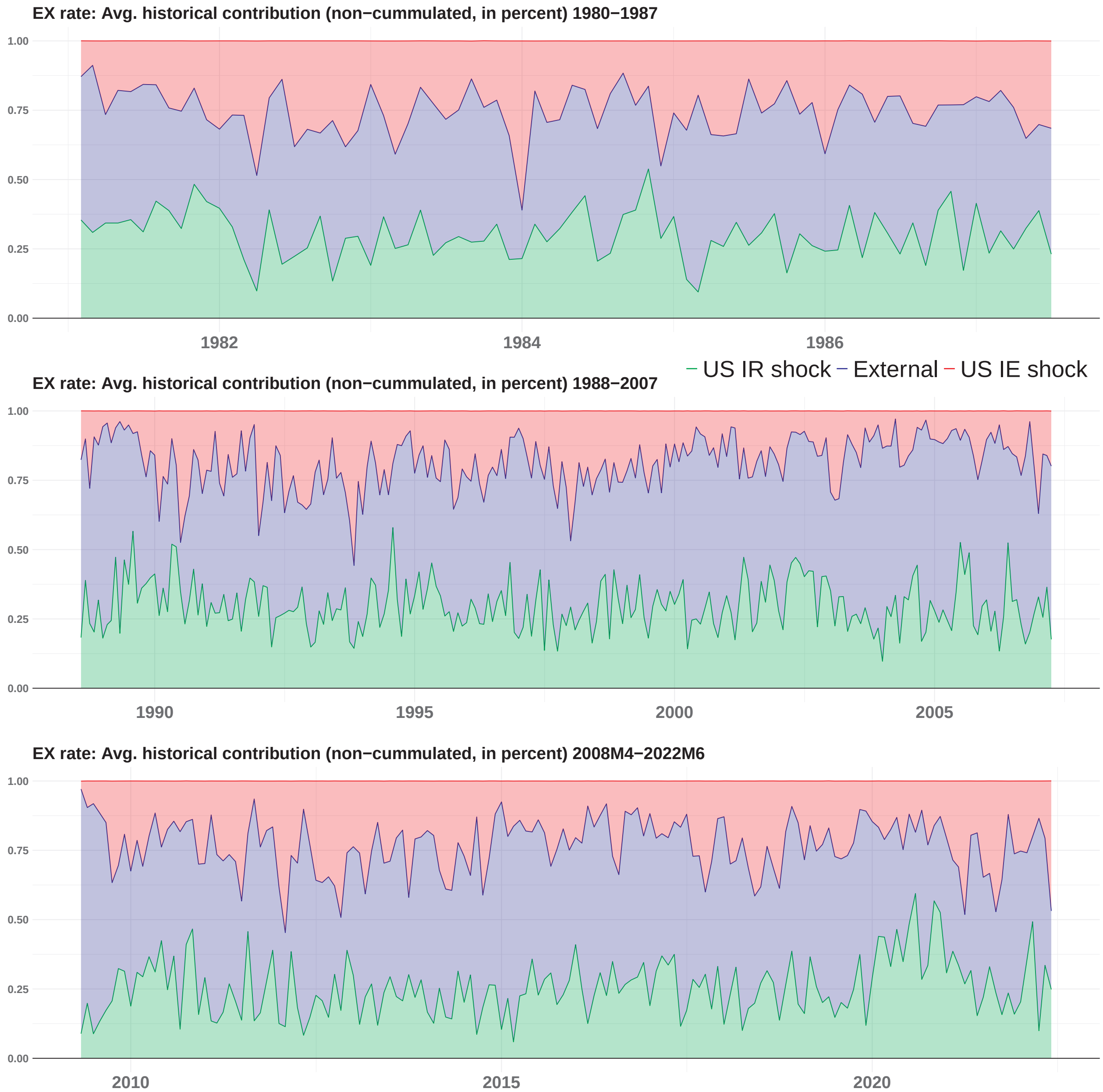

Figure 5: Sub-samples avg. historical decomposition of exchange rate changes, 1980M1-2022M6

During the Volcker period, all three shocks considered are roughly equally important in explaining the development of US dollar exchange rates, even if there are slight variations over time (panel (a)). In the pre-crisis period (panel b), the impact of external shocks is observed to have risen in comparison to the Volcker period, with a continued increase over the pre-crisis period. This shock that we consider to be closely related to global risk accounts for approximately 50% of the variation in US dollar exchange rates. This may be indicative of the growing influence of the US dollar in global financial markets and the increased demand for secure US dollar assets, as evidenced by references (Krishnamurthy & Vissing-Jorgensen, 2012; Engel & Wu, 2018; Krishnamurthy & Lustig, 2019). The second most significant shock in this pre-crisis period is the US interest rate shock, which explains, on average, approximately 30% of exchange rate movements, while shocks to long-run inflation expectations account for about 20% of exchange rate movements.

On average, external shocks were also the most important factor in explaining exchange rate dynamics in the post-crisis period. However, their relative importance has declined since 2020. Moreover, there were also shorter phases in which shocks to long-term inflation expectations had the greatest impact on the value of the US dollar. This was the case, for example, in the period between 2012 and 2014, when uncertainty about the duration of the zero interest rate phase increased in most advanced economies, heightening concerns about the long-term sustainability of public finances. Or in the period after 2022, when there was a significant increase in public deficits and debt, mainly in response to the energy crisis. Between 2008 and 2020, the importance of US interest rate shocks decreased somewhat compared to the previous sub-samples and only explains around 20% of exchange rate fluctuations. Since 2020, however, US interest rate shocks have become more pronounced again, which is due to the rapid rise in official central bank interest rates in response to the rise in inflation in the countries analysed.

7 Conclusion

Using a monthly data for the period 1980M1 to 2022M12 and a cross-section of eight advanced economies, i.e. Australia, Canada, Germany, Japan, New Zealand, Sweden, Switzerland and the United Kingdom, we analyse the exogenous drivers of US dollar exchange rates by means of agnostically identified structural VARs.

We find that in response to a tightening of US monetary policy, the US dollar appreciates. In response to a sustained rise in long-run inflation expectations, the US dollar depreciates. We demonstrate that unexpected rises in inflation expectations are significantly related to a deterioration in the fiscal authority's credibility to repay high budget debt. In this sense, also fiscal policy matters for US dollar exchange rates. An external shock, which is measured as an unexpected appreciation of the US dollar, leads to a depreciation of the US dollar in the following months. We show that the identified external shock is strongly related to global risk aversion and the convenience yield that investors are willing to pay for holding US dollar assets. Thus, lower global risk appetite and greater demand for safe US dollar assets are associated with a US dollar appreciation that cannot be explained by US interest rate shocks.

We find that all three identified shocks, the US interest rate shock, the external shock and the long-run US inflation expectations shock, are important determinants of US Dollar exchange rate dynamics. However, on average, the external shock appears to be the most important driver.

There is evidence of time dependence in the response of US short-term interest rates and the US dollar exchange rate to shocks to inflation expectations, indicating that the monetary reaction function has alternated over time. During the Volcker era, US short-term interest rates increased and the US Dollar on average appreciated in response to an unexpected rise in long-run inflation expectations, which indicates an active monetary policy stance. However, between the late 1980s and the early 2000s, US interest rates significantly declined and the US dollar exchange rate significantly depreciated in response to positive shocks to US long-run inflation expectations. We interpret this as an indication that US monetary policy became more passive in the pre-crisis period.

Our findings add to the understanding of the properties of exchange rates, and interest rate fluctuations. The interplay between monetary and fiscal policies as well as shocks to the demand for safe dollar assets and global risk aversion explain part of the variation in the US dollar exchange rate. This information could help solve the exchange rate disconnect puzzle and shed light on the optimal design of (fiscal and) monetary policy.

References

Barro, R. J. & Bianchi, F. (2023). Fiscal Influences on Inflation in OECD Countries, 2020-2022. Working Paper 31838, National Bureau of Economic Research.

Bassetto, M. (2002). A game-theoretic view of the fiscal theory of the price level. Econometrica, 70(6), 2167–2195.

Baumeister, C. & Hamilton, J. D. (2019). Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks. American Economic Review, 109(5), 1873–1910.

Beechey, M. J., Johannsen, B. K., & Levin, A. T. (2011). Are long-run inflation expectations anchored more firmly in the euro area than in the united states? American Economic Journal: Macroeconomics, 3(2), 104â29.

Bernanke, B. S. (2003). Constrained discretion and monetary policy. Remarks before the Money Marketeers of New York University, New York.

Bernoth, K., de Vries, C. G., & von Hagen, J. (2022). The term structure of currency futures' risk premia. Journal of Money, Credit and Banking, 54(1), 5–38.

Bernoth, K. & Herwartz, H. (2021). Exchange rates, foreign currency exposure and sovereign risk. Journal of International Money and Finance, 117.

Bianchi, F., Faccini, R., & Melosi, L. (2023a). A fiscal theory of persistent inflation*. The Quarterly Journal of Economics, 138(4), 2127–2179.

Bianchi, F., Gómez-Cram, R., Kind, T., & Kung, H. (2023b). Threats to central bank independence: High-frequency identification with twitter. Journal of Monetary Economics, 135, 37–54.

Bianchi, F. & Ilut, C. (2017). Monetary/Fiscal policy mix and agents' beliefs,. Review of Economic Dynamics, 26, 113–139.

Bianchi, F. & Melosi, L. (2017). Escaping the great recession. American Economic Review, 107(4), 1030–58.

Bianchi, F. & Melosi, L. (2022). Inflation as a fiscal limit. Working Paper Series WP 2022-37, Federal Reserve Bank of Chicago.

Bilbiie, F. O. (2022). Neo-fisherian policies and liquidity traps. American Economic Journal: Macroeconomics, 14(4), 378–403.

Brüggemann, R., Jentsch, C., & Trenkler, C. (2016). Inference in VARs with conditional heteroskedasticity of unknown form. Journal of Econometrics, 191(1), 69–85.

Bruno, V. & Shin, H. S. (2015). Capital flows and the risk-taking channel of monetary policy. Journal of Monetary Economics, 71, 119–132.

Caldara, D. & Herbst, E. (2019). Monetary policy, real activity, and credit spreads: Evidence from bayesian proxy svars. American Economic Journal: Macroeconomics, 11(1), 157–92.

Cieslak, A., Hansen, S., McMahon, M., & Xiao, S. (2023). Policymakers' uncertainty. SSRN Electronic Journal.

Cochrane, J. (2022a). A fiscal theory of monetary policy with partially repaid long-term debt. Review of Economic Dynamics, 45, 1–21.

Cochrane, J. H. (2001). Long-term debt and optimal policy in the fiscal theory of the price level. Econometrica, 69(1), 69–116.

Cochrane, J. H. (2022b). Fiscal histories. Journal of Economic Perspectives, 36(4), 125–46.

Cochrane, J. H. (2022c). Inflation past, present and future: Fiscal shocks, Fed response, and fiscal limits. Working Paper 30096, National Bureau of Economic Research.

Cochrane, J. H. (2023). The Fiscal Theory of the Price Level. Princeton University Press.

Comon, P. (1994). Independent component analysis. A new concept? Signal Processing, 36(3), 287–314.

Corbo, V. & Di Casola, P. (2022). Drivers of consumer prices and exchange rates in small open economies. Journal of International Money and Finance, 122(102553).

Cormun, V. & De Leo, P. (2022). Shocks and exchange rates in small open economies.

De Michelis, A. & Iacoviello, M. (2016). Raising an inflation target: The japanese experience with abenomics. European Economic Review, 88, 67–87. SI: The Post-Crisis Slump.

Dornbusch, R. (2017). Expectations and Exchange Rate Dynamics. Journal of Political Economy, 84(6), 1161–1176.

Dupor, B. (2000). Exchange rates and the fiscal theory of the price level. Journal of Monetary Economics, 45(3), 613–630.

Eichenbaum, M. & Evans, C. (1995). Some empirical evidence on the effects of shocks to monetary policy on exchange rates. The Quarterly Journal of Economics, 110(4), 975–1009.

Engel, C. & Wu, S. P. Y. (2018). Liquidity and exchange rates: An empirical investigation. Working Paper 25397, National Bureau of Economic Research.

Evans, G. W. & McGough, B. (2018). Interest-rate pegs in New-Keynesian models. Journal of Money, Credit and Banking, 50(5), 939–965.

Faust, J. & Rogers, J. H. (2003). Monetary policy's role in exchange rate behavior. Journal of Monetary Economics, 50(7), 1403–1424.

Friedman, M. (1963). Inflation: Causes and Consequences. A publication of the Council for Economic Education, Bombay. Asia Publishing House.

Garcia-Schmidt, M. & Woodford, M. (2019). Are low interest rates deflationary? A paradox of perfect-foresight analysis. The American Economic Review, 109(1), 86–120.

Garin, J., Lester, R., & Sims, E. (2018). Raise rates to raise inflation? Neo-Fisheriansim in the New-Keynesian Model. Journal of Money, Credit and Banking, 50(1), 243–259.

Genest, C., Quessy, J.-F., & Rémillard, B. (2007). Asymptotic local efficiency of Cramér von Mises tests for multivariate independence. The Annals of Statistics, 35(1), 166–191.

Georgiadis, G., Müller, G. J., & Schumann, B. (2021). Global risk and the dollar. Working Paper Series 2628, European Central Bank.

Gertler, M. & Karadi, P. (2015). Monetary policy surprises, credit costs, and economic activity. American Economic Journal: Macroeconomics, 7(1), 44–76.

Gouriéroux, C., Monfort, A., & Renne, J. (2017). Statistical inference for independent component analysis: Application to structural VAR models. Journal of Econometrics, 196(1), 111–126.

Gourinchas, P.-O., Rey, H., & Govillot, N. (2010). Exorbitant privilege and exorbitant duty. Working Paper 10-E-20, Institute for Monetary and Economic Studies.

Gürkaynak, R. S., Kara, A. H., Kisacikoglu, B., & Lee, S. S. (2021). Monetary policy surprises and exchange rate behavior. Journal of International Economics, 130(103443).

Gürkaynak, R. S., Levin, A., & Swanson, E. (2010). Does inflation targeting anchor long-run inflation expectations? evidence from the u.s., uk, and sweden. Journal of the European Economic Association, 8(6), 1208–1242.

Hamidi Sahneh, M. (2016). Testing for non-fundamentalness. Mpra paper, University Library of Munich, Germany.

Herwartz, H., Lange, A., & Maxand, S. (2022a). Data-driven identification in SVARs - when and how can statistical characteristics be used to unravel causal relationships? Economic Inquiry, 60(2), 668–693.

Herwartz, H. & Lütkepohl, H. (2014). Structural vector autoregressions with Markov switching: Combining conventional with statistical identification of shocks. Journal of Econometrics, 183(1), 104–116.

Herwartz, H., Maxand, S., & Rohloff, H. (2022b). The link between monetary policy, stock prices, and house prices - evidence from a statistical identification approach. International Journal of Central Banking, 76.

Herwartz, H., Rohloff, H., & Wang, S. (2022c). Proxy SVAR identification of monetary policy shocks - Monte Carlo evidence and insights for the US. Journal of Economic Dynamics and Control, 139(104457).

Herwartz, H. & Trienens, L. (2024). Fiscal theory, persistent monetary shocks, and state-dependent neo-Fisherian effects.

Herwartz, H. & Wang, S. (2023). Point estimation in sign-restricted SVARs based on independence criteria with an application to rational bubbles. Journal of Economic Dynamics and Control, forthcoming(104630).

Hnatkovska, V., Lahiri, A., & Vegh, C. A. (2016). The exchange rate response to monetary policy innovations. American Economic Journal: Macroeconomics, 8(2), 137–81.

Ilzetzki, E. & Jin, K. (2021). The puzzling change in the international transmission of U.S. macroeconomic policy shocks. Discussion Paper DP15740, Center for Economic Policy Research.

Inoue, A. & Rossi, B. (2019). The effects of conventional and unconventional monetary policy on exchange rates. Journal of International Economics, 118, 419–447.

Jarociński, M. (2022). Estimating the Fed's unconventional policy shocks. Working Paper Series 2585, European Central Bank.

Jarociński, M. & Karadi, P. (2020). Deconstructing monetary policy surprises - The role of information shocks. American Economic Journal: Macroeconomics, 12(2), 1–43.

Jiang, Z. (2021a). Fiscal cyclicality and currency risk premia. The Review of Financial Studies, 35(3), 1527–1552.

Jiang, Z. (2021b). US fiscal cycle and the dollar. Journal of Monetary Economics, 124, 91–106.

Jiang, Z., Krishnamurthy, A., & Lustig, H. (2021). Foreign safe asset demand and the dollar exchange rate. The Journal of Finance, 76(3), 1049–1089.

Kalemli-Özcan, S. (2019). U.S. monetary policy and international risk spillovers. NBER Working Paper Series w26297, National Bureau of Economic Research.

Kalemli-Özcan, S. & Varela, L. (2021). Five facts about the UIP premium. Working Paper 28923, National Bureau of Economic Research.

Kilian, L. & Lütkepohl, H. (2017). Structural vector autoregressive analysis. Cambridge University Press.

Kim, S. & Roubini, N. (2000). Exchange rate anomalies in the industrial countries: A solution with a structural var approach. Journal of Monetary Economics, 45(3), 561–586.

Kim, S.-H., Moon, S., & Velasco, C. (2017). Delayed overshooting: Is it an 80s puzzle? Journal of Political Economy, 125(5), 1570–1598.

Krishnamurthy, A. & Lustig, H. N. (2019). Mind the gap in sovereign debt markets: The U.S. treasury basis and the Dollar risk factor. Working Paper 3443231, 2019 Jackson Hole Economic Symposium.

Krishnamurthy, A. & Vissing-Jorgensen, A. (2012). The aggregate demand for treasury debt. Journal of Political Economy, 120(2), 233–267.

Lange, A., Dalheimer, B., Herwartz, H., & Maxand, S. (2017). SVARs: Data-driven identification of SVAR models. R package version 1.3.11.

Lanne, M. & Lütkepohl, H. (2008). Identifying monetary policy shocks via changes in volatility. Journal of Money, Credit and Banking, 40(09), 1131–1149.

Lanne, M., Meitz, M., & Saikkonen, P. (2017). Identification and estimation of non-Gaussian structural vector autoregressions. Journal of Econometrics, 196, 288–304.

Leeper, E. (1991). Equilibria under 'active' and 'passive' monetary and fiscal policies. Journal of Monetary Economics, 27(1), 129–147.

Leeper, E. (2013). Fiscal limits and monetary policy. Central Bank Review, 13(2), 33–58.

Leeper, E. & Leith, C. (2016). Chapter 30 - understanding inflation as a joint monetaryâfiscal phenomenon. volume 2 of Handbook of Macroeconomics (pp. 2305–2415). Elsevier.

Lilley, A., Maggiori, M., Neiman, B., & Schreger, J. (2022). Exchange rate reconnect. The Review of Economics and Statistics, 104(4), 845–855.

Lukmanova, E. & Rabitsch, K. (2020). New evidence on monetary transmission: Interest rate versus inflation target shocks. Mimeo.

Lukmanova, E. & Wouters, R. (2022). Inflation expectations and term premium.

Lütkepohl, H. & Netšunajev, A. (2017). Structural vector autoregressions with smooth transition in variances: The interaction between US monetary policy and the stock market. DIW Discussion Paper 1388.

Maggiori, M. (2017). Financial intermediation, international risk sharing, and reserve currencies. American Economic Review, 107(10), 3038–71.

Matteson, D. S. & Tsay, R. S. (2017). Independent component analysis via distance covariance. Journal of the American Statistical Association, 112(529), 623–637.

Miranda-Agrippino, S. & Rey, H. (2020). U.S. monetary policy and the global financial cycle. The Review of Economic Studies, 87(6), 2754–2776.

Miranda-Agrippino, S. & Rey, H. (2022). Chapter 1 - the global financial cycle. In G. Gopinath, E. Helpman, & K. Rogoff (Eds.), Handbook of International Economics: International Macroeconomics, volume 6 of Handbook of International Economics (pp. 1–43). Elsevier.

Moneta, A., Entner, D., Hoyer, P. O., & Coad, A. (2013). Causal inference by independent component analysis: Theory and applications. Oxford Bulletin of Economics and Statistics, 75(5), 705–730.

Müller, G. J., Wolf, M., & Hettig, T. (2024). Delayed overshooting: The case for information rigidities. American Economic Journal: Macroeconomics, 16(3), 310â42.

Mumtaz, H. & Theodoridis, K. (2018). The Federal Reserve's implicit inflation target and macroeconomic dynamics: A SVAR analysis. Cardiff Economics Working Papers E2018/1, Cardiff.

Nakamura, E. & Steinsson, J. (2018). High-frequency identification of monetary non-neutrality: The information effect. The Quarterly Journal of Economics, 133(3), 1283–1330.

Nautz, D., Strohsal, T., & Netsunajev, A. (2019). The anchoring of inflation expectations in the short and in the long run. Macroeconomic Dynamics, 23(5), 1959â1977.

Netsunajev, A. & Winkelmann, L. (2014). Inflation expectations spillovers between the United States and euro area. Discussion Paper 2014-023, Humboldt University of Berlin.

Orlowski, L. T. & Soper, C. (2019). Market risk and market-implied inflation expectations. International Review of Financial Analysis, 66, 101389.

Pesaran, H. & Smith, R. (1995). Estimating long run relations from dynamic heterogeneous panels. Journal of Econometrics, 68(1), 79–113.

Rey, H. (2015). Dilemma not trilemma: The global financial cycle and monetary policy independence. CEPR Discussion Paper 10591, Centre for Economic Policy Research.

Rigobon, R. (2003). Identification through heteroskedasticity. The Review of Economics and Statistics, 85, 777–792.

Romer, C. D. & Romer, D. H. (2004). A new measure of monetary shocks: Derivation and implications. American Economic Review, 94(4), 1055–1084.

Romer, C. D. & Romer, D. H. (2023). Presidential address: Does monetary policy matter? the narrative approach after 35 years. American Economic Review, 113(6), 1395–1423.

Rüth, S. K. (2020). Shifts in monetary policy and exchange rate dynamics: Is Dornbusch's overshooting hypothesis intact, after all? Journal of International Economics, 126(103344).

Sargent, T. J. (2013). Rational Expectations and Inflation (Third Edition). Princeton University Press.

Sargent, T. J. & Wallace, N. (1981). Some unpleasant monetarist arithmetic. Quarterly Review, 5(Fall).

Schmitt-Grohé, S. & Uribe, M. (2022). The effects of permanent monetary shocks on exchange rates and uncovered interest rate differentials. Journal of International Economics, 135(103560).

Scholl, A. & Uhlig, H. (2008). New evidence on the puzzles: Results from agnostic identification on monetary policy and exchange rates. Journal of International Economics, 76(1), 1–13.

Sims, C. A. (1980). Macroeconomics and reality. Econometrica, 48(1), 1–48.

Sims, C. A. (1994). A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy. Economic Theory, 4(3), 381–399.

Sims, C. A. (2011). Stepping on a rake: The role of fiscal policy in the inflation of the 1970s. European Economic Review, 55(1), 48–56.

Smets, F. & Wouters, R. (2024). Fiscal backing, inflation and us business cycles. Forthcoming.

Stavrakeva, V. & Tang, J. (2019). The Dollar during the Great Recession: US monetary policy signaling and the flight to safety. Discussion Paper 14034, Center for Economic Policy Research.

Uribe, M. (2022). The neo-Fisher effect: Econometric evidence from empirical and optimizing models. American Economic Journal: Macroeconomics, 14(3), 133–62.

Williamson, S. (2016). Neo-fisherism: A radical idea, or the most obvious solution to the low-inflation problem? Federal Reserve Bank of St. Louis Regional Economist, (24), 5–9.

Woodford, M. (1995). Price-level determinacy without control of a monetary aggregate. Carnegie-Rochester Conference Series on Public Policy, 43, 1–46.

Woodford, M. (2001). Fiscal requirements for price stability. Journal of Money, Credit and Banking, 33(3), 669–728.

Appendices

A - Estimation of structural model parameters

Building upon the result of Comon (1994), a variety of approaches to ICA-based point estimation of the structural parameter matrix D in (2) have been suggested (e.g., Moneta et al., 2013; Matteson & Tsay, 2017; Lanne et al., 2017; Gouriéroux et al., 2017).[15] In this study, we estimate D by means of an approach that can be considered as a modification of the estimator in Matteson & Tsay (2017), which has been successfully employed, for instance, by Bernoth & Herwartz (2021). Avoiding an explicit distributional assumption, the estimator of D is obtained by selecting the particular structural matrix that obtains implied shocks with weakest dependence in terms of the Cramér-von-Mises (CvM) distance (Genest et al., 2007),

$$\mathcal{B} = \int_{(0,1)^K} \left[\sqrt{T} \left(C(\tilde{\epsilon}) - \prod_{k=1}^{K} U(\tilde{\epsilon}_k) \right) \right]^2 d\tilde{\epsilon}, \tag{4}$$

where C and U denote the empirical copula of orthogonalized model disturbances and the implied copula under independence, respectively. Since the CvM-distance is constructed from (joint) ranks, it is scale free. Genest et al. (2007) consider it an 'ideal' choice for nonparametric dependence diagnosis unless sufficient support for a local dependence alternative is available. As we are not aware of such an alternative in the analysis of heterogeneous economies, we determine an estimator for D by solving the minimization problem

$$\widehat{D} = \widetilde{D}_{\hat{\theta}}, \text{with } \hat{\theta} = \text{argmin}_{\theta}\{\mathcal{B}|\tilde{\epsilon}_t = \widetilde{D}_{\theta}^{-1} u_t\}. \tag{5}$$

To implement (5), we use rotation matrices that structure the space of potential decompositions of the reduced form residual covariance estimates $\widehat{\Sigma}_u = GR_{\theta}R_{\theta}'G' = \widetilde{D}_{\theta}\widetilde{D}_{\theta}'$, where G is a lower triangular Cholesky factor of $\widehat{\Sigma}_u$ and $R_{\theta}R_{\theta}'$ is the identity matrix. Hence, $\widehat{D} = GR_{\hat{\theta}}$. Random vectors $\tilde{\epsilon}$ are determined from orthogonalized reduced form model disturbances ($\tilde{\epsilon}_t = \widetilde{D}_{\theta}^{-1}\hat{u}_t$), and

[15] Kilian & Lütkepohl (2017) review alternative ICA approaches and embed these variants of data-based identification into the SVAR literature. Assuming independence of shocks is more strict than the typical orthogonality assumption. However, this restriction is also implicit in the stylized construction of impulse response functions tracing the effects of isolated unit shocks (by setting $E[\epsilon_{jt}|\epsilon_{it} = 1] = 0$, $i \neq j$).

the rotation matrices are specified as the product of three Givens rotation matrices, i.e.

$$R_\theta = \begin{pmatrix} \cos\theta_1 & -\sin\theta_1 & 0 \\ \sin\theta_1 & \cos\theta_1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\theta_2 & 0 & -\sin\theta_2 \\ 0 & 1 & 0 \\ \sin\theta_2 & 0 & \cos\theta_2 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_3 & -\sin\theta_3 \\ 0 & \sin\theta_3 & \cos\theta_3 \end{pmatrix}.$$

The minimization outlined in (5) can be achieved by means of nonlinear optimization.[16]

It is worth noting that the point estimate $\widehat{D}$ that solves (5) is unique up to the signs and ordering of its columns, since changing the column ordering or multiplying single columns with minus unity does not change $\widehat{D}\widehat{D}'$. To establish uniqueness of column signs and ordering (and hence comparability of economy-specific estimates $\widehat{D}_i$), we opt for the particular ordering that yields a maximum sum of (absolute) diagonal elements. Following, for instance, Lütkepohl & Netšunajev (2017) this ordering establishes that a particular shocks exerts its strongest effect on the variable to which it is primarily associated. If - given this column ordering - a particular diagonal element is negative, we multiply the respective column with minus unity. Thereby, sign uniqueness establishes that the analysis focuses on the effects of positive shocks.

B - Data sources and used samples

- **Interest rates,** i_t, i_t^*: Treasury yields with 12-month maturity (End Month). Source: For Australia, Germany, New Zealand, Japan, Sweden, Switzerland, the United Kingdom, and the United States: *Macrobond*. For Canada: *Refinitiv* from CANSIM - Statistics Canada.

- **US treasury basis with the G10 economies**: Treasury yields with 12-month maturity for the United States, United Kingdom, Japan, Canada, Sweden, Switzerland, Australia, New Zealand are taken from *Macrobond*. For Germany, we obtain data from *Refinitiv*. For observations prior to 1997, we construct implicit bond rates with 12-month maturity from German treasury yields with 10-years maturity.

- **US Inflation expectations,** π^e: Median of the estimate of the CPI inflation rate over the next 10 years in percentage points. Source: Survey of Professional Forecasters, Federal Reserve Bank of Philadelphia downloaded from *Macrobond*.

[16] Procedures are implemented in the R package 'svars' (`https://cran.r-project.org/package=svars`) as provided by Lange et al. (2017). To guard against the potential of a local optimum we try 100 alternative initializations with randomized seeds and extract a global optimum accordingly.

- **Nominal exchange rates,** s_t: Source: *Macrobond.* Exchange rates are listed in foreign currency per US dollar.
- **Forward points**: Source: *Macrobond.* We use the spot rates from Macrobond to transform the forward points into forward rates.
- **VXO**: CBOE S&P 100 Volatility Index. Source: *FRED Economic Data, St. Louis Fed.*

The time series and sample periods used for the calculations and estimates are as follows:

- To estimate the three-dimensional VARs, we use data from 1980M1 to 2022M6 for all eight economies. The time series used are 12-month US Treasury yields, bilateral spot exchange rates, and 10-year US inflation expectations.
- We restrict the end of the *pre-crisis* sub-sample for all economies to 2007M4. The *Volcker* (*post-crisis*) sub-sample is homogeneous for all economies from 1980M1 to 1987M7 (2008M4 to 2022M6).
- To calculate the average US Treasury basis against the G10 economies, we use time series from 1995M2 to 2022M6 of 12-month US and foreign Treasury yields, spot exchange rates, and 12-month forward rates.
- To estimate the rolling regressions, we use data on the US Treasury basis and the VXO from 1995M2 to 2022M6.

C - Tests of normality and fundamentalness

The structural analysis pursued in this work relies on the identifying assumption of non-Gaussianity of structural shocks and the existence of the Wold representation for the vector valued VAR process y_t. Diagnostic results displayed in Table 3 indicate highly significant deviations from the Gaussian distribution for all identified shocks in all considered economies. In addition, the shocks deviate from moment conditions that are typical for the joint normal. We detect both significant skewness and excess kurtosis. Table 4 documents test outcomes for the null hypothesis that the data are in line with the existence of a Wold representation. With 5% significance, we cannot reject the null hypothesis of fundamentalness for all economies except New Zealand and all implementations of the test statistic. Undocumented results show that (i) extending the lag-order to $p = 12$ results in p-values of at least 35% and (ii) Johansen trace tests of the null hypothesis of a zero cointegration rank are throughout insignificant. From these diagnostics we conclude that a Wold representation exists for the considered economies.

Table 3: Univariate and multivariate normality tests for the structural shocks.

		Univariate			**Multivariate**		
Country		US IR	External	US IE	Multi JB	Skewness	Kurtosis
AUS	stat.	1442.268	145.461	10235.963	11823.692	655.055	11168.636
	p-value	0	0	0	0	0	0
CAN	stat.	1447.641	656.965	9860.256	11964.86	627.306	11337.56
	p-value	0	0	0	0	0	0
CHE	stat.	1446.906	29.643	10475.759	11952.308	621.369	11330.939
	p-value	0	0	0	0	0	0
DEU	stat.	1421.707	19.952	10221.973	11663.631	611.411	11052.221
	p-value	0	0	0	0	0	0
GBR	stat.	1345.264	74.195	9880.962	11300.42	598.874	10701.55
	p-value	0	0	0	0	0	0
JPN	stat.	1309.574	73.714	10504.484	11887.77	645.159	11242.61
	p-value	0	0	0	0	0	0
NZL	stat.	1317.945	632.87	10084.081	12034.895	684.759	11350.136
	p-value	0	0	0	0	0	0
SWE	stat.	1329.727	151.513	10322.531	11803.77	643.722	11160.048
	p-value	0	0	0	0	0	0

Notes: Univariate Jarque-Bera tests for the single structural shocks (US interest rate shock, external shock and US inflation expectations shock) are documented in the left hand side. Tests for joint normality, symmetry, and no excess kurtosis of all structural shocks are shown in the right hand side panel. Diagnostics refer to structural innovations identified in three dimensional VARs of lag order 12.

Table 4: Testing fundamentalness of VAR residuals (olf

p-max	1	2	3	4	5	6	7	8
AUS	0.62	0.59	0.55	0.52	0.50	0.48	0.46	0.45
CAN	0.82	0.79	0.77	0.75	0.73	0.72	0.71	0.69
CHE	0.38	0.35	0.32	0.29	0.27	0.26	0.25	0.25
DEU	0.71	0.68	0.65	0.63	0.61	0.6	0.59	0.59
GBR	0.34	0.32	0.30	0.27	0.26	0.25	0.24	0.24
JPN	0.45	0.41	0.37	0.35	0.33	0.31	0.31	0.30
NZL	0.60	0.60	0.59	0.59	0.58	0.58	0.58	0.58
SWE	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79

Notes: The test conducted by Hamidi Sahneh (2016) examines the null hypothesis of fundamentalness, which implies the non-predictability of the VAR residuals. The table presents the p-values for alternative maximum lags used to predict future innovation. The diagnostics are based on VARs of lag order 12 using the Parzen Kernel. Results for alternative kernels and residuals from VAR(12) models are similar and available upon request. We express our gratitude to Mehdi Hamidi Sahneh for providing the relevant codes for this test.

D - Estimated structural parametermatrices

With the values in parentheses $(a;b)$ denoting the bootstrap means (a) and t-ratios (b) the estimated structural impact multipliers $\widehat{D}$ read for full sample information as follows:[17]

$$\widehat{D}_{AUS} = \begin{bmatrix} \underset{(0.325;5.204)}{0.379} & \underset{(0.005;0.046)}{0.002} & \underset{(0.018;1.758)}{0.045} \\ \underset{(-0.243;-0.088)}{-0.051} & \underset{(3.177;13.153)}{3.278} & \underset{(-0.072;-0.02)}{-0.002} \\ \underset{(-0.043;-1.4)}{-0.119} & \underset{(0.009;-0.479)}{-0.024} & \underset{(2.335;8.224)}{2.424} \end{bmatrix}, \widehat{D}_{CAN} = \begin{bmatrix} \underset{(0.329;5.187)}{0.381} & \underset{(-0.011;-0.847)}{-0.034} & \underset{(0.018;1.556)}{0.04} \\ \underset{(0.106;0.922)}{0.291} & \underset{(1.996;9.619)}{2.031} & \underset{(-0.136;-1.358)}{-0.112} \\ \underset{(-0.039;-1.035)}{-0.081} & \underset{(0.02;0.354)}{0.019} & \underset{(2.329;8.273)}{2.421} \end{bmatrix}$$

$$\widehat{D}_{CHE} = \begin{bmatrix} \underset{(0.33;5.244)}{0.384} & \underset{(0.003;-0.024)}{-0.001} & \underset{(0.017;1.397)}{0.036} \\ \underset{(0.662;1.764)}{0.851} & \underset{(3.045;17.767)}{3.091} & \underset{(-0.185;-0.814)}{-0.13} \\ \underset{(-0.019;-0.6)}{-0.047} & \underset{(-0.021;-0.052)}{-0.002} & \underset{(2.34;8.27)}{2.429} \end{bmatrix}, \widehat{D}_{DEU} = \begin{bmatrix} \underset{(0.33;5.213)}{0.384} & \underset{(0.01;-0.214)}{-0.009} & \underset{(0.02;1.386)}{0.036} \\ \underset{(0.431;1.618)}{0.695} & \underset{(2.884;17.521)}{2.909} & \underset{(-0.105;-0.278)}{-0.044} \\ \underset{(-0.03;-0.575)}{-0.043} & \underset{(-0.005;0.025)}{0.001} & \underset{(2.342;8.286)}{2.431} \end{bmatrix}$$

[17] For inferential purposes we use a Moving Block Bootstrap as suggested by Brüggemann et al. (2016). According to their recommendation the block length is set to 25 ($\approx 5.03\ T^{1/4}$). To improve the scaling of documented estimation results structural parameter estimates and bootstrap means are multiplied by 100.

$$\widehat{D}_{GBR} = \begin{bmatrix} \underset{(0.327;5.304)}{0.38} & \underset{(0.008;-0.518)}{-0.024} & \underset{(0.019;1.671)}{0.041} \\ \underset{(0.255;1.327)}{0.632} & \underset{(2.773;15.067)}{2.82} & \underset{(-0.114;-0.596)}{-0.084} \\ \underset{(-0.042;-1.115)}{-0.084} & \underset{(-0.052;-1.088)}{-0.052} & \underset{(2.338;8.379)}{2.43} \end{bmatrix}, \widehat{D}_{JPN} = \begin{bmatrix} \underset{(0.328;5.281)}{0.381} & \underset{(0.028;-0.199)}{-0.008} & \underset{(0.023;1.854)}{0.047} \\ \underset{(0.239;1.607)}{0.677} & \underset{(3.022;16.842)}{3.064} & \underset{(-0.056;0.152)}{0.018} \\ \underset{(-0.055;-1.422)}{-0.108} & \underset{(-0.035;-0.513)}{-0.022} & \underset{(2.347;8.184)}{2.439} \end{bmatrix},$$

$$\widehat{D}_{NZL} = \begin{bmatrix} \underset{(0.322;4.883)}{0.38} & \underset{(0.018;0.453)}{0.031} & \underset{(0.015;1.741)}{0.044} \\ \underset{(-0.392;-0.325)}{-0.292} & \underset{(3.347;10.91)}{3.522} & \underset{(-0.076;-0.017)}{-0.002} \\ \underset{(-0.016;-1.159)}{-0.101} & \underset{(0.022;-0.178)}{-0.01} & \underset{(2.328;8.371)}{2.42} \end{bmatrix}, \widehat{D}_{SWE} = \begin{bmatrix} \underset{(0.329;5.376)}{0.381} & \underset{(0.018;-0.516)}{-0.018} & \underset{(0.022;1.673)}{0.042} \\ \underset{(0.122;1.479)}{0.543} & \underset{(3.113;17.186)}{3.131} & \underset{(-0.069;-0.33)}{-0.062} \\ \underset{(-0.037;-1.106)}{-0.077} & \underset{(-0.035;-0.111)}{-0.005} & \underset{(2.346;8.289)}{2.438} \end{bmatrix}$$