Central banks and the absorption of international shocks (1891-2019)

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October 28, 2024

Abstract

We study how central banks have used their balance sheet to absorb international monetary shocks since the late 19th century, thereby regaining some monetary policy autonomy in a context of financial openness. If the uncovered interest rate parity does not hold, an increase in the leading international interest rate may push up domestic interest rates in both fixed and floating exchange rate regimes. Central banks can partially insulate domestic short-term interest rates from this increase by expanding domestic assets. With a fixed exchange rate, this is in addition to the sterilization of foreign exchange interventions. Accounting for the response of central bank balance sheets to an exogenous international shock sheds light on some puzzling behavior of interest rates and exchange rates across international monetary regimes in history. This study is based on a new monthly dataset of central bank balance sheets, macroeconomic, and financial variables for 23 countries since 1891.

Keywords: trilemma, central bank balance sheets, international monetary system, dilemma, global financial cycle, foreign exchange interventions
JEL Codes: N1, N2, E4, E5, F3, F4.

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Can countries have an autonomous monetary policy if they are financially open? The standard answer to this central question of international macroeconomics is that it is only possible under a floating exchange rate regime (Mundell (1963); Obstfeld and Taylor (2004); Ilzetzki, Reinhart, and Rogoff (2019)). Countries can choose freely two options out of the following three, but have to forgo the third one: fixed-exchange rates, financial openness and autonomous monetary policy. Over the years, two major - and very different - qualifications have been brought to the canonical macroeconomic trilemma model. First, as long as the peg is credible and uncovered interest rate parity (UIP) holds, central banks can keep their interest rate stable in a fixed exchange rate regime with exchange rate bands, as shown in so-called target zone models (Krugman (1991); Svensson (1994); Eichengreen (2000)). Second, even a floating exchange rate may not be sufficient to insulate a country from a global financial cycle. In this view, the trilemma collapses onto a dilemma, as the sharp distinction between floating and fixing largely vanishes (Rey (2015); Bruno and Shin (2015)).[1]

Contributions to this literature measure the autonomy of national monetary policy by the ability of the central bank to maintain its interest rate unchanged following an exogenous movement in the so-called international interest rate (typically represented by the interest rate of the dominant central bank, such as the US Fed today). It is argued that the reaction of the central bank's interest rate by and large reflects a country's exchange rate regime and the level of its financial openness. We contend that such an approach misses an important dimension by ignoring actions of the central bank to influence the domestic interest rate. If there are no imperfections in international financial markets (i.e. if the UIP does hold), there is no reason for the central bank domestic assets to react to a change in the international rate. But failures of the UIP change everything. The target zone model is no longer valid with a fixed exchange rate. And a floating exchange rate is not enough to absorb the effect of

[1]We would like to thank the following research assistants for their essential work in building the dataset. Elie Boisivon and Raphaël Wargon made the most substantial contributions, together with Félix Berte, Laura Bonino, Gautier Davy, Thomas Duvillier, Alessandro Ferrante, Beth Finlayson, Théodore Humann, Elie Malhaire, Oriane Pichon, Emma Sarhdaoui. We owe special gratitude to Victor Degorce for sharing some data on exchange rates and money market rates, Antonin Chenard for sharing some primary sources and Jules Baleyte for help with interwar data. We also thank Marianna Astore, Jane Boyko, Anna Grodecka-Messi, Clemens Jobst and Masato Shizume for providing help with some parts of the Italian, Canadian, Swedish, Austrian and Japanese data respectively, as well as Fabrice Reuzé, Patrice Denis, and Frederik Grelard on the Bank of France's sources. Research funds were provided by Labex OSE - EUR grant ANR-17-EURE-0001, Institut Louis Bachelier, Université Paris 8, York University and Wissenschaftskolleg zu Berlin. For discussions and comments on previous versions of the paper, we thank Katrin Assenmacher, Olivier Blanchard, Paul Bouscasse, Emmanuel Carré, James Cloyne, Lawrence Christiano, Victor Degorce, Oscar Jorda, David Guerreiro, Chris Meissner, Silvia Miranda-Agrippino, Dirk Niepelt, Maurice Obstfeld, Ugo Panizza, Hélène Rey, Moritz Schularick, Maria Sole Pagliari, Jon Steinsson, Antoine Terracol, Cédric Tille, Miklos Vari, as well as seminar participants at the Bank of Spain, the Universities of Neuchâtel, Bordeaux, York, Paris, Aix-Marseille, Paris Saclay, Geneva, Northwestern and UC Davis.

an international shock on domestic interest rates. The central bank may thus have to act in order to help stabilize the domestic interest rate in response to a rise in the international rate. Rather than being merely passive, the central bank can in fact be active: as it does for usual monetary policy operations (e.g. Hamilton (1997); Arce, Nuno, Thaler, and Thomas (2020)), the central bank injects liquidity to avoid a too large increase in the interbank rate. The central bank will buy domestic assets to stabilize the domestic money market rate, instead of increasing its policy interest rate to follow the market.

The recent literature has shown convincingly that central banks can conduct foreign exchange (FX) interventions to keep the exchange rate within the bands in a fixed exchange rate regime, and that such interventions can be sterilized - i.e., they do not cause an impact on the interest rate and the money base - if UIP fails (e.g. Blanchard, Adler, and de Carvalho Filho (2015); Gabaix and Maggiori (2015); Fratzscher et al. (2019); Naef and Weber (2023). We contend that it is equally important to consider how the purchases of domestic assets and the extending of domestic loans by a central bank contribute to monetary policy autonomy in a financially globalized world by acting on interest rates. Crucial for our argument, such actions do not aim only at sterilizing FX interventions, but go beyond them.

The aim of this article is therefore to test whether central banks use their domestic portfolio - open market and loans - to stabilize the money market rate after a rise in the main international interest rate. For fixed exchange rate, we also study the joint reaction of the domestic portfolio and of foreign exchange (FX) reserves. Finally, we want to establish whether the greater use of the central bank's balance sheet is associated with greater monetary policy autonomy, as we surmise.

Following the well-established tradition in international macroeconomics of examining long-run data to compare different regimes of exchange rates and financial globalization (Mauro, Sussman, and Yafeh (2002); Obstfeld and Taylor (2004); Schularick and Taylor (2012); Bordo and Meissner (2016); Ilzetzki, Reinhart, and Rogoff (2019); Meyer, Reinhart, and Trebesch (2022)), we have built a new monthly dataset of central bank balance sheets covering 23 countries from 1891 to 2019 to answer our questions. Our estimates end before the COVID-19 pandemic. We examine, by means of local projections, the short-term fluctuations in central bank assets, both domestic and international, and liabilities in response to exogenous international interest rate shocks, drawing comparisons between different exchange rate regimes, degree of capital account openness and stages of financial globalization. For that purpose, our dataset also includes historical monthly series of production, prices, central bank interest rates, exchange rates, money market interest rates, equity prices and long-term bond yields on government debt.

Such a database is essential for several reasons. First, while Ferguson, Kornejew, Schmelzing, and Schularick (2023) have built a dataset of *annual* central bank balance sheets to study the long-term impact of lender of last resort policies, *monthly* data are crucial for our exercise as the central banks absorb international interest rate shocks within months and not years. Consequently, the balance sheet movements we are interested in is unlikely to register in yearly data. As a matter of fact, the recent literature on the global transmission of US monetary policy shocks finds that the effect on financial variables and exchange rates usually vanishes within 6 months (Miranda-Agrippino and Rey (2020); Degasperi, Hong, and Ricco (2023)). Our previous investigations on the pre-1914 gold standard led to similar results (Bazot, Bordo, and Monnet (2016); Bazot, Monnet, and Morys (2022)). Second, the central bank data need to be sufficiently disaggregated. We not only distinguish between international reserves and domestic assets but also isolate the operations that were specifically used for liquidity provision to banks rather than long-term investments by the central bank or loans to the Treasury. Given the extremely wide spectrum of central bank operations since 1891 which came to our attention as part of this research, focusing solely on total domestic assets (or on total international assets, for that matter) would result in large measurement errors. In most cases, the need for detailed asset categories required relying on historical sources rather than retrospective balance sheets reconstructed and published ex post by central banks or historians (which are typically confined to annual series anyway). Except for three countries (France, the UK and the USA), we had to hand-collect historical data from previously unused primary sources.

The second data contribution of our work relates to the construction of exogenous monetary policy shocks. Monetary policy decisions in the dominant country may be endogenous to macroeconomic and financial variables in other countries, either because they react to the exchange rate, or because they react to domestic fluctuations that are correlated to international business cycles. For some periods, we can rely on series of exogenous monetary policy shocks constructed by other scholars. Starting in 1989, we can rely on US monetary policy surprises data based on market investors' expectations, as extracted from intraday futures interest rates (e.g. Gürkaynak, Sack, and Swanson (2005); Nakamura and Steinsson (2018)), and purged from the information contained in macroeconomic and financial data available at the time of the monetary policy decisions (Miranda-Agrippino and Rey (2020); Bauer and Swanson (2023b)). A monetary policy shock constructed in this way is exogenous to economic fluctuations because it was neither anticipated by markets nor could it predicted by observable economic variables. For earlier periods, we can rely on Lennard (2018), who constructed a series of exogenous monthly interest rate changes for the Bank of England prior to 1913, and Romer and Romer (2004) who build an exogenous series for the US from 1969 to the early 2000s. For all other periods we construct our own exogenous shocks; to which we add 1891-1913 in order to obtain a more precisely estimated series thanks to daily data. We build these shocks by using, in a first step, daily (instead of intraday) exchange rates, money market rates and stock market indices to account for market expectations. In a second step, we regress the daily surprise on observable macroeconomic variables. Our methodology is close to that of Cloyne, Hürtgen, and Taylor (2022) in their recent paper on the Bundesbank from 1974 to 1998.

Our investigation yields important new insights. First, in financially open economies, the domestic portfolio of central banks responds positively to a rise in the exogenous international rate in both fixed and floating exchange-rate regimes. The central bank injects liquidity in order to stabilize the money market rate and maintain it in line with its target policy rate. In a fixed exchange-rate regime, this liquidty injection comes *in addition* to sterilized foreign interventions. Under floating exchange-rate, only domestic assets react as there is no need for FX interventions. In financially closed economies and during episodes of low financial globalization (e.g, the early Bretton Woods era), CB balance sheets generally do not react significantly, as the *trilemma* predicts. Nevertheless, we also find evidence that capital controls are not always binding and do not completely insulate an economy from international shocks. To provide further support to our main argument, we revisit the whole history of the international monetary system since the late 19th century. We point out, for each sub-period, how considering the movements in the balance sheets of central banks sheds light on monetary policy autonomy and the mechanisms behind international finance.

Second, the large response of domestic CB assets helps explain why there has often been more monetary policy autonomy (as measured by the difference between the changes in the domestic and the international rates) than what international macroeconomists would predict. In particular, the standard *trilemma* framework explains well the difference of interest rate reaction between floating and fixed exchange rates but has been unable to explain the low pass through of interest rate during fixed exchange regimes with capital account openness such as the gold standard. The only possible explanation was the one provided by the target zone model (Bordo and MacDonald (2005)), relying on the strong twin assumption that UIP hold and pegs were perfectly credible. We show that the reaction of domestic assets combined with sterilized foreign exchange interventions sheds light on why central banks increased their interest rate by only about 20-30bp on average after a 100bp rise of the Bank of England rate during the classical and interwar gold standards, whereas the trilemma predicts an almost perfect pass through, and the target zone model predicts that the interest rate remains stable without any central bank intervention whatsoever.[2] Likewise, studies that emphasize the presence of a *dilemma* in recent decades have struggled to explain why the short-term money market rates do not increase (or even decrease) in advanced economies with floating exchange rates while other asset returns move up with the US interest rate (Miranda-Agrippino and Rey (2020); Degasperi, Hong, and Ricco (2023)). The positive response of CB domestic assets in today's advanced economies -despite floating exchange rate – provides an explanation.

Our findings underscore the need to take into account the response of central bank balance sheets when interpreting how central bank interest rates, money market rates, and exchange rates respond to an international monetary policy shock. In line with the recent literature on the global financial cycle (e.g., Rey (2015); Bruno and Shin (2015)), they also highlight that the new era of financial globalization has not made central bank policy any simpler. And this is not only due to the well-documented persistence of managed float regimes that rely on foreign exchange interventions (Ilzetzki, Reinhart, and Rogoff (2019)). Even with floating exchange rates, central banks have to use their balance sheet to absorb the effects of international shocks.

Contributions to the literature

Our paper contributes to several strands of literature. It speaks directly to scholars that have studied the trilemma in historical perspective (Obstfeld and Taylor (2004); Obstfeld, Shambaugh, and Taylor (2005); Bordo and James (2015); Jordà, Schularick, and Taylor (2020)). We confirm the main predictions of this framework in history. Yet while previous studies had noted that the pass-through of interest rates was far from perfect in fixed exchange-rate regimes without capital controls, they had not investigated the role of central bank balance sheet in providing an explanation for their finding. Our study is therefore in line with analyses that have shown that the international monetary system has historically functioned differently from what simple theory predicts. Central banks have many tools at their disposal to round the corner of the *trilemma*. In this, our work builds on seminal arguments formulated decades ago by Nurkse (1944); Bloomfield (1959) who had noted that central banks during

[2] The limited response of interest rates in the paradigmatic historical regime of fixed-exchange rate with full capital account openness was already diagnosed in Obstfeld, Shambaugh, and Taylor (2005); Bordo and MacDonald (2005); Morys (2013); Bazot, Monnet, and Morys (2022).

the classical and interwar gold standards did not play the "rules of the games".[3] Other contributions that have provided important amendment to the conventional portrayal of the macroeconomic *trilemma* have usually focused on the flexibility of exchange arrangements (Eichengreen (2000); Bordo (2003); Ilzetzki, Reinhart, and Rogoff (2019)).

Second, we address issues in the literature on the current international monetary system and global financial cycle (following the seminal paper of Rey (2015)). We confirm the role of the global financial cycle and the emergence of a dilemma in recent years.[4] As highlighted in this literature (Gabaix and Maggiori (2015); Rey (2015); Miranda-Agrippino and Ricco (2021); Kalemli-Özcan (2019); Kalemli-Özcan and Varela (2021); Jeanne (2022)), the failure of the UIP is crucial to explain our empirical results. If UIP held, there would be no need for central bank balance sheets to react and to stabilize the exchange rates and/or money market rate. Moreover, sterilized foreign exchange interventions are known to be ineffective if UIP holds (e.g. Gabaix and Maggiori (2015)). Our conclusions for today's emerging economies are more limited since we have only five of them in our sample. Yet the absence of significant domestic assets expansion in these countries is consistent with Kalemli-Özcan (2019), which shows that - all else equal - the money market rate increases more than the central bank policy rate in emerging economies after a rise in the US interest rate.[5]

Third, we also contribute to the literature on central bank balance sheets. Much has been written on how central banks can rely on their balance sheet (through monetary finance, quantitative easing or lending of last resort) when facing major shocks, such as wars, economic or financial crises. Ferguson, Kornejew, Schmelzing, and Schularick (2023) provide a comprehensive overview of long-lasting balance sheet expansions of central banks over five centuries - based on annual data - and study the long-term consequences of lender of last resort policies on risk-taking.[6]. Yet short-term expansions of central bank balance sheets are,

[3]According to Nurkse (1944); Bloomfield (1959), central banks did not play the rules of the games of the gold standard because - contrary to theory - they did not follow the Bank of England by raising their interest rate and decreasing the money supply when the latter increased its discount rate.

[4]There is a dilemma in the sense that floating exchange rates are no longer enough to absorb all effect of international financial shocks. This does not mean that there is no longer a difference between fixed and floating exchange rates (Obstfeld, Ostry, and Qureshi (2019)).

[5]There could be several reasons why central banks in emerging economies have more difficulties to affect the money market rate through open market operations, including banks' foreign currency indebtedness or the segmentation of the money market Ivashina, Scharfstein, and Stein (2015); De Leo, Gopinath, and Kalemli-Özcan (2022); Vari (2020); Meneses-González, Lizarazo-Cuellar, Cuesta-Mora, and Osorio-Rodríguez (2022). Moreover, these countries may give priority to the stability of the exchange rate and have difficulties to maintain a credible peg, which increases the currency risk premium, in addition to the UIP wedge. We leave these questions to further research.

[6]The historical literature on lender of last resort during banking crises is enormous. See Rieder (2023) for a recent overview. As important is the literature on monetary financing, especially but not only during wars (see Morys (2020)). Investigations of earlier episodes of quantitative easing or unconventional monetary

at least, equally important and much more frequent, especially to smooth the fluctuations of the money market. Miron (1986) established that the US central bank eliminated the seasonality in nominal interest rates - and thus caused a decrease in the frequency of banking panics - by conducting seasonal asset purchases. A quantitative literature starting with Hamilton (1997) has studied the causal effect of liquidity injection on money market rates, confirming the ability of central banks to stabilize the later. This ability is at the core of our analysis. Indeed, central banks play an essential role for the economy and the financial system by expanding their balance sheet to smooth short-term liquidity shocks. The first paragraph of Federal Reserve act of 1913 announced that the purpose of the newly created central bank was to "furnish an *elastic currency*". More than once century later, the "elasticity" metaphor still appears in the European Central Bank's monetary policy strategy: "An elastic supply of central bank reserves based on banks' needs is therefore best suited [...] to contribute to flexibly absorbing liquidity shocks."[7] Little was known however about how central bank *elastic currency* can smooth short-term international financial shocks to which open-economy are frequently subject to. Our study thus sheds light on how the "elastic currency" furnished by central banks matters for the transmission of international monetary policy shocks.

The rest of the article is structured as follows. Section 1 provides a simple theoretical framework explaining how a central bank may use its international and domestic assets in response to an international financial shock, and how these reactions depend on the presence of financial market imperfections. Section 2 presents our new data set comprising monthly central bank balance sheets, exchange rates and other macroeconomic and financial variables for 23 countries since 1891. The section 3 explains how we constructed historical exogenous monetary policy shocks when there were none in the literature. In section 4 , we display the results over the whole sample - regardless of period - and compare between floating and fixed-exchange rates, and between financially open and closed economies.5 explores central bank reactions across other historical periods of the international monetary system and exchange rate regimes. We discuss how these new results bring coherence and robustness to our previous interpretations. Last, section 6 provide additional robustness checks, based on alternative estimation samples and exogenous monetary policy shocks, and further discussion of potential biases arising from central banks' international asset accounting rules ("valuation effects").

policy include Monnet (2014); Jaremski and Mathy (2018); Reis (2019).

[7] https://www.ecb.europa.eu/press/pr/date/2024/html/ecb.pr240313~807e240020.en.html

1 Theoretical Framework: deviations from UIP and the reactions of central bank balance sheets

We are interested in how a central bank uses its balance sheet in response to movements in the exchange rate and the domestic interest rate that are caused by a shock to the international interest rate. To guide our empirical investigation in the next sections, we first explain the objectives and instruments of the central bank. Against this background, we explain which financial market imperfections (i.e., deviations from the UIP) are necessary to trigger movements in central bank domestic assets in response to a rise of the international rate.

Our purpose is not to build a general equilibrium mode but simply to show why - in an open economy - deviations from the UIP is necessary to trigger a spread between the money market rate and the targeted rate of the central bank, a spread to which the central bank will respond by increasing its domestic assets (i.e.,injecting liquidity in the money market or extending loans). The intuition is simple. If UIP holds, in a floating exchange rate regime, all the adjustment works through the exchange rate, with no movement in the domestic money market rate. The latter only moves if the central bank decides to react to the international shock by lowering its target interest rate - which leads to a further depreciation of the domestic exchange rate. In a credible peg, if UIP holds, the target zone model applies: the deviation from the target exchange rate is expected to be temporary - within the exchange rate bands - and no movement in the domestic money market rate is required. If the peg is not fully credible, the central bank can implement foreign exchange (FX) interventions to prevent the exchange rate from going out of the target bands. If these FX interventions are not "sterilized" by an equivalent increase in domestic assets, they lead to a decrease in the money base and an increase in the central bank interest rate. The interest rate remains stable only if the foreign exchange interventions are "sterilized", in other words if the domestic assets increase. But, as a number of important papers have shown, sterilized FX interventions are only effective if and only if the UIP does not hold. Thus, without violation of the UIP conditions, there would be no reason to observe a rise in the domestic assets of the central bank.

1 .1 The (domestic) objectives and instruments of the central bank

Given our focus, it is important to define the central bank objective and its means of action. The central bank sets a target interest rate i^T following a specific rule, where this rate depends on a set of economic conditions Ω, so that:

$$i^T = f(\Omega)$$

Depending on the period, the variable in Ω can be the exchange rate only, or the output gap and the inflation rate (as with a Taylor rule). To be as general as possible, we do not specify Ω and we keep the possibility that it is affected by international conditions, including potentially the spillovers due to a shock to the international interest rate, so that the central bank may want to change its target rate in response to this shock (see Degasperi, Hong, and Ricco (2023) for a recent discussion of this issue).

More important for our purpose is that - once the target interest rate is set - the central bank wants to ensure that the money market rate is in line with the target rate:

$$i_t = i^T$$

where i_t is the short-term rate that prevails on the domestic money market (e.g. short-term Treasury bills or 3-month interbank rate). This is the condition that defines that monetary policy is fully effective.

There is an international rate, i^*, that is exogenously determined, and thus by construction is not influenced by domestic conditions.

The central bank balance sheet is described in the following stylized way:

$$D + I = L$$

D is the domestic portfolio of the central bank, that is loans to domestic institutions and holdings of domestic securities. I are international reserves (gold, foreign exchange, etc.). L are short-term liabilities (banknotes and bank reserves) created in counterpart to the holding of domestic and international assets. We abstract here from equity and other assets of the central bank. D and I are therefore only liquid assets that the central bank can use at will.

For the moment, we focus on domestic objectives and simply lay out that the central bank can use D to ensure that $i_t = i^T$. Money creation ($\Delta L > 0$) through domestic liquidity provision ($\Delta D > 0$) stabilizes the money market rate (as in Hamilton (1997)) and thus prevents a spread between i_t and i^T. In other words, there is a reaction function of the domestic assets of the central bank that depends on the spread between the target interest rate and the money market rate:

$$\Delta D_t = f(i_t - i^T)$$

, with $\Delta D_t > 0$ if

$$i_t > i^T$$

The central bank buys domestic assets, or lends to banks through a standing facility or tendering process (thus creating bank reserves), when the money market rate exceeds the target rate of the central bank. This simple rule captures the *elastic currency* principle, that is the ability of the central bank to smooth short-term fluctuations in the money market rate.[8]

1 .2 When UIP does not hold

To examine the different policy options in response to an increase in i_t^* , it is natural to start from the standard parity condition (the UIP in log-linear form):

$$i_t = i_t^* + E(e_{t+1} - e_t) + \sigma_t$$

where i is the domestic money market rate, i^* is the international rate and $E(e_{t+1} - e_t)$ is the expectation of the change in the future exchange rate (i.e. the expected rate of depreciation - or appreciation - of the domestic currency relative to the currency of the leading country that sets i^*).

In line with the recent literature on international finance and global dollar shocks (e.g. Miranda-Agrippino and Ricco (2021); Kalemli-Özcan (2019); Jeanne (2022)), we make two assumptions. First, i^* is exogenously determined by the monetary policy of the leading country (e.g. the US today). Second, we add a UIP wedge, σ_t, which captures the frequent deviations from the uncovered interest parity observed in the real world. The existence of such a premium has been documented in historical studies as well as for the current period.[9]

[8]That is the well-known rule of thumbs of central banks since the 19th century (e.g Sissoko (2016) on England and Bazot, Bordo, and Monnet (2016) on France) and which stands at the foundation of the US Federal Reserve (cf. introduction). Recent theoretical models and empirical studies also provide support and evidence on how an expansion of the central bank balance sheet decreases the money market rate to bring it back to the target rate of the central bank (Hamilton (1997); Boeckx, Dossche, and Peersman (2017); Arce, Nuno, Thaler, and Thomas (2020); Vari (2020); Copeland, Duffie, and Yang (2021)).This is a feature of both "conventional" monetary policy and "unconventional policy" measures (such as quantitative easing or full allotment at a fixed rate during crises).

[9]For the last three decades, including in floating exchange regimes, Kalemli-Özcan (2019) documents that the interest rate differential can increase after a tightening of US monetary policy. The domestic interest rate increases more than what it predicted by the UIP, a phenomenon that she attributes to a change in risk perception. As argued and demonstrated by Bruno and Shin (2015); Gabaix and Maggiori (2015); Ivashina, Scharfstein, and Stein (2015); Miranda-Agrippino and Ricco (2021), this does not need to be country specific however. As international investors borrow from the international money market in dollar, a tightening of US monetary policy increase further the value-at-risk constraint of intermediaries. Risk premium increases and

We thus implicitly consider that the nature of σ_t may have changed over the last century, but it causes similar issues for the central bank. In cases of fixed-exchange rate regime (see below), we will distinguish between a currency risk χ_t and the UIP wedge σ_t.

We have presented the objectives and instruments of the central bank. We can now distinguish the cases of floating vs. fixed exchange rates.

1 .3 Floating exchange rate with capital mobility.

What happens to i after an exogenous increase in i^*? In the floating exchange rate case, all the adjustment can occur through the exchange rate after a rise in i^*. The spot exchange rate of the domestic currency depreciates and investors anticipate that there will be a future appreciation: the initial depreciation will lead to the case where it is no longer beneficial to invest with i^*. So $E(e_{t+1} - e_t)$ is negative and can fully offset the interest rate differential between i_t and i_t^*. If UIP holds and the country floats, the central bank does not have to care about the exchange rate (i.e. no intervention necessary to appreciate the domestic currency), nor about a rise in i_t.

On the contrary, a UIP wedge with $\sigma_t > 0$ generates an immediate increase in i_t after an initial rise in i_t^*. The central bank thus faces $i_t > i^T$ and responds by expanding its domestic portfolio (i.e. $\Delta D > 0$), as explained previously. In other words the reaction function of the domestic assets of the central bank depends on the UIP wedge σ_t:

$$\Delta D_t = f(i_t - i^T) = g(\sigma_t)$$

, with $\Delta D_t > 0$ if $i_t > i^T$ that is if $\sigma_t > 0$

An increase in central bank domestic assets (ΔD) offsets the effect of σ on $i_t - i^T$ so that the central bank stop increasing D when $i_t = i^T$. This can lead to the paradoxical empirical result that UIP may seem to hold ex post because of the immediate liquidity expansion of the central bank, which offsets the effect of σ_t on i_t. In practice however, the central bank liquidity expansion may not be fully effective or may respond with a lag.[10]

leverage decreases when US monetary policy tightens. For the same amount of risk, investors thus demand a higher interest rate. Following recent empirical works on UIP deviations and international financial shocks by Jeanne (2022); Kalemli-Özcan and Varela (2021) among others, we remain agnostic about the exact nature of this excess return or premium.

[10] This imperfect transmission of central bank liquidity provision to the money market can be due to market segmentation caused by banking and interest regulation (Monnet (2014); Koch (2015)), financial development (Bazot, Monnet, and Morys (2022); Meneses-González, Lizarazo-Cuellar, Cuesta-Mora, and Osorio-Rodríguez (2022)), substantial borrowing in foreign currency (De Leo, Gopinath, and Kalemli-Özcan (2022)), or a too strong asymmetry between the borrowing demand of banks (Vari (2020)).

As discussed in Miranda-Agrippino and Rey (2020); Degasperi, Hong, and Ricco (2023), the central bank may decide to counteract the contractionary effect of a rise in i_t^* on the domestic economy (i.e. fall in production) by lowering i^T. This corresponds to the case described at the beginning of this section, when i^T reacts because of a change in Ω. In a world without financial frictions, i_t follows i^T and decreases as well (i.e. no spread between the two rates) while the exchange rate depreciates further, without the need for an increase in D.

1 .4 Fixed-exchange rate with capital mobility.

The standard literature in international macroeconomics had usually assumed that $i_t = i_t^*$ for a country with a fixed-exchange rate and full capital mobility. However, the target zone models developed by Krugman (1991); Svensson (1994) - see Bordo and MacDonald (2005) for an application to economic history - had noticed that the UIP gives more flexibility. If the exchange rate target is credible (so that it remains within announced exchange rate bands), investors also anticipate a reversion to parity so that they anticipate an appreciation of the exchange rate following the initial depreciation caused by a rise in i^*. In theory, it is thus possible that the UIP and reversion to mean parity allow the central bank to keep an interest rate differential between i_t and i_t^* in a fixed exchange rate regime: "exchange rate bands, counter to the textbook result, give central banks some monetary independence, even with free international capital mobility" (Svensson (1994)).

Following the target zone literature, we simply decompose $E(e_{t+1} - e_t)$ in two terms so that: $E(e_{t+1} - e_t) = E(c_{t+1} - c_t) + E(b_{t+1} - b_t)$, where $E(c_{t+1} - c_t)$ is the expected rate of realignment of the central parity (we also rewrite this term as χ_t), and $E(b_{t+1} - b_t)$ is the expected exchange rate change within the exchange rate band. Thus, the UIP condition rewrites as:

$$i_t = i_t^* + E(b_{t+1} - b_t) + \chi_t + \sigma_t$$

where b is the exchange rate within the band and χ expresses the currency risk, that is risk of a change in the fixed-parity.

If the peg is fully credible, we have $\chi_t = 0$. Then, $E(b_{t+1} - b_t)$ can be negative, which allows the central bank to keep the domestic rate below the international rate. This is the case described by the target zone literature to explain a greater monetary policy autonomy.[11] By

[11] If there are no exchange rate bands (i.e. no target zone), we have $E(b_{t+1} - b_t) = 0$, which implies that i_t has to increase with i_t^*. It has to increase more if χ_t and σ_t are positive.

contrast, if investors anticipate a devaluation of the domestic currency, then χ_t is positive, and the domestic interest rises above the international one since investors ask to be compensated for their risk (see Mitchener and Weidenmier (2015) for evidence of currency risk under the gold standard).

Foreign exchange interventions and the central bank domestic portfolio.

The central bank can act on χ_t through foreign exchange interventions to increase the credibility of its peg (that is maintains the exchange rate within the bands, see Krugman (1991); Flood and Garber (1991); Froot and Obstfeld (1991); Svensson (1994)) if the latter is not sufficiently credible. The central bank intervenes on the foreign exchange market to appreciate the value of the domestic currency after an increase in i^*. This can be done through either "unsterilized" or "sterilized" foreign exchange interventions. In both cases, the central bank sells international assets so that $\Delta I_t < 0$. The extent of FX interventions depends on the credibility of the exchange rate band, so that:

$$\Delta I_t = l(\chi_t)$$

If they are "unsterilized", these operations lead to a fall in bank reserves ($\Delta L < 0$) akin to a restrictive monetary policy, so that $i_t > i^T$. If the central bank plays the "rule of the games", it has no choice but to increase i^T to match the increase in i_t. Unsterilized FX interventions are known to be effective but ultimately force the central bank to increase its target rate i^T and decrease money creation (L).

On the contrary, if the central bank wants to keep i^T and i_t stable, it needs to expand D, that is to "sterilize" the FX interventions. With "sterilized" FX interventions, the central bank maintains the same level of liquidity in the domestic banking system: its liability (L) remains stable. In a world with perfect capital market, sterilized FX interventions are not supposed to be effective since it's just a swap between foreign and domestic assets, but a substantial theoretical and empirical literature has shown that market imperfections can make them effective in practice (e.g. Gabaix and Maggiori (2015); see Villamizar-Villegas and Perez-Reyna (2017); Naef and Weber (2023) for surveys of this large literature).[12]

[12] The model of Gabaix and Maggiori (2015) is based on a limited commitment constraint of international investors, which practically limit their ability to hold foreign exchange positions. Consequently, assets denominated in different currencies are not perfect substitutes and the UIP does not hold. For example, there is an oversupply of the domestic currency compared to the foreign currency. To balance this out, international investors demand an extra return for holding onto domestic currency. FX interventions change the investors' financial situation and influences the exchange rate through the risk premium. The effect of FX interventions is stronger with a higher risk premium. Our empirical estimations will test whether FX interventions are

However, even if the central bank increases D to sterilize FX interventions ($\Delta I_t < 0$), there is still a UIP wedge σ_t that pushes the domestic interest rate up. In order to maintain $i_t = i^T$, the central bank thus has to expand D. So, in a fixed-exchange rate, the changes in the domestic portfolio of the central bank depend both on the UIP wedge (as in the floating exchange rate) and on FX interventions:

$$\Delta D_t = f(i_t - i^T) = g(\sigma_t, \Delta I_t)$$

, with $g'(\sigma_t) > 0$ and $g'(\Delta I_t) < 0$.

Thus, if χ_t and σ_t both exist, the central bank can combine sterilized FX interventions with an additional increase in its domestic assets.

1 .5 Capital controls.

Contrary to the cases discussed above, the case of capital controls (imperfect capital mobility) does not require a response of the central bank balance sheet after an increase in i^*. In this case, σ_t is the result of capital controls. It is negative - while it was positive in the previous cases - and allows for a differential between i and i^* even if the anticipations about the exchange rate equal zero. Arbitrage between countries are not possible. This is the standard prediction of the trilemma (Obstfeld and Taylor (2004); Rey (2015)): absent capital mobility, there is no need for the central bank to use either foreign exchange intervention (I) or its domestic portfolio (D) to tame the effect of a rise of i^* on the domestic economy.

However, in practice, the economy might not be fully closed financially, despite the presence of some form of capital controls. Countries with incomplete capital account convertibility may thus show patterns that resemble the two cases of full capital account openness described previously (consistent with the fact that several countries use both capital controls and FX interventions, see Obstfeld, Shambaugh, and Taylor (2010); Ilzetzki, Reinhart, and Rogoff (2019); Jeanne (2022); Cezar and Monnet (2023)). In other words, if capital controls do not prevent all arbitrage between currencies, they might be compatible with a positive σ_t. In this case, an increase in the domestic portfolio is needed to prevent the domestic rate to move up.

enough, or if domestic assets expansions are also required.

2 Central bank balance sheet data

2 .1 Data collection, sources and sample

Central banks record their balance sheet data at two frequencies: as annual data and at a frequency equal to or higher than monthly (weekly, twice or thrice per month). Like all public companies, central banks have always published an annual report for their shareholders, whether private (the most common case until the Second World War) or the state. They are legally obliged to do so, and the annual report always contains an annual balance sheet, as well as the profit and loss account, often translated into foreign languages so that they can be read by the international financial community. These data are accessible to the public, and time series have often been compiled retrospectively by the central banks themselves or by economic historians, thereby providing the statistical foundation for most subsequent compilations (see Ferguson, Kornejew, Schmelzing, and Schularick (2023) for a recent example).

2 .1.1 The specificity of monthly central bank data

Obtaining long-run monthly balance sheet data is more cumbersome. Legal requirements and reporting practices have varied enormously from one period to another and from one country to another. Higher frequency series can sometimes be found in central bank annual reports or bulletins, but this is far from common, especially in earlier periods. Where they are publicly available, they may be found in monthly or quarterly central bank publications which, unlike annual reports, have typically not been translated into foreign languages, or in the official gazette published by the government. The presentation of these balance sheets is also less standardized than that of annual reports. Sometimes, only the key series of central bank operations are published. The other accounts required for closing the annual accounts (reserves, provisions, other assets and liabilities), particularly those subject to valuation effects, are added once a year to the annual report. During our data reconstruction efforts, we often found cases where total assets and total liabilities had not been published on weekly or monthly frequency. Fortunately, all the key series of central bank interventions in the foreign exchange and the domestic money markets were published at these frequencies. This practice continues today at some central banks. For example, the Bank of England publishes online (since 2014) a weekly report that discloses around 90% of the total balance sheet; yet the total balance sheet is published only once per year. The ECB also distinguishes between weekly "financial statements" and the annual account. The weekly statement does not contain the assets and liabilities of investments in subsidiaries or companies in which the euro area national banks hold participating interests. They are also submitted to different valuation rules since the revaluation of assets and liabilities occur at the end of every quarter.

Stemming from these difficulties, only a tiny number of central banks – the US Federal Reserve, the Bank of France, and the Bank of England to the best of our knowledge – have made their entire historical weekly or monthly balance sheet data publicly available on their website.[13] For other countries, such data are confined to central bank archives and void of any translation into English, especially before the Second World War.

In addition to such practical challenges, balance sheet items are more detailed at monthly than at annual frequency. Categories change frequently over time and differ between countries. This means that a substantial amount of work had to be done to construct balance sheet categories that are continuous and consistent over time and across countries (see below).

2 .1.2 Sources and sample of countries

Our task was greatly eased by the discovery of an exceptional source at the Bank of France, which collected and standardized monthly balance sheets of all central banks operating at the time starting in 1891 (twelve). By adding the new foundations of Italy (1894), Japan (1899), Switzerland (1907) and the United States (1913), the number grew to 16 countries by 1914.[14] The Bank of France continued to record monthly data for these banks until the 1950s and in some cases even until the late 1960s. This unique source forms the backbone for the first seven decades of our work. The appendix C provides information on the coverage of this source ("Bank of France historical archive") by country, and lists all the other sources we used to build our dataset.

The French records are European in outlook but include the U.S. and Japan. This perspective was justified until the First World War, when the U.S. and Japan were the only countries outside of Europe to have a central bank. Yet the French records fail to incorporate the interwar foundations in Latin America (Chile and Mexico in 1926, Colombia in 1929 and Argentina in 1935) and in the British Dominions (South Africa: 1922; Canada and India in

[13]Original French data were published by Baubeau (2018). Baubeau provides both all items that appear in the original source (and are often not continuous over time) and his own aggregation of the main items (to build continuous series). The aggregated categories nevertheless contain mistakes and are too wide for our purpose. We thus had to classify all original items according to our own conventions.

[14]We abstract from the idiosyncrasies of the Italian case but explain them briefly here. The country had six banks of note issue following Italian unification in 1861. Three of these went into decline in a combination of money market consolidation and financial crises, not unlike the contemporary case of Germany's system of multiple banks of note issue. The Banks of Italy, Naples and Sicily began to dominate the market and we amalgamate their balance sheets into one unified "Italian" balance sheet for our econometric purposes.

1935).[15] We cover them based on archival sources located in the respective central bank, bringing the number of countries to 23.[16]

Table 1: Sample of countries

Countries covered in the Bank of France sources since 1891 (twelve)	**Year**
Austria	1891
Belgium	1891
Denmark	1891
Finland	1891
France	1891
Germany	1891
Netherlands	1891
Norway	1891
Portugal	1891
Spain	1891
Sweden	1891
United Kingdom	1891
Pre-World War I additions due to later foundation (four)	**Year**
Italy	1894
Japan	1899
Switzerland	1907
United States	1913
Interwar additions (seven)	**Year**
South Africa	1922
Chile	1926
Mexico	1926
Colombia	1929
Argentina	1935
Canada	1935
India	1935

[15] Other central banks were created during the interwar, for which we could not locate historical monthly series (Peru, Bolivia, Turkey, New Zealand).

[16] Our objective is to analyse all central banks with a continuous history of monetary policy operations since (at least) the interwar period. We therefore exclude Russia, Bulgaria, Romania and Serbia given their state socialist experience after the Second World War, when their central banks persisted as institutions but performed entirely different functions. Pre-1939 data for these four countries are recorded in the French sources and we analysed them in our work confined to the Classical Gold Standard (Bazot, Monnet, and Morys (2022)). A peculiar 5th case is Greece which, for reasons unclear to us, is covered in the French sources for the period before 1914 but not thereafter. If we included all five countries into our analysis, the number of countries with a central bank would stand at 21 by 1914 and not by 16 as listed in table 1.

2 .1.3 International Reserves

Not all international reserves are managed by central banks. In the late 1930s, some countries set up a special institution to hold international reserves in an account separate from that of the central bank. This has two advantages: it ensures that foreign exchange losses are borne by the Treasury rather than the central bank, and it ensures greater secrecy in the publication of data on international reserves.

In our sample, this is the case in the USA (Exchange Stabilization Fund), the UK (Exchange Equalization Fund), and Belgium and France (*Fonds de stabilisation des changes*) until 1998. This did not apply to these four countries before 1936. Please note that international reserves in such cases are managed by central bank staff for all practical purposes, but they are kept in a separate account for the two reasons indicated above. The Belgian and French central banks could lend to the Stabilization Fund, or hold gold separately from the fund, so that both institutions (the Fund and the central bank) held international reserves on their asset side.

Because of the difficulties in obtaining complete data and consolidating the accounts of the Stabilization Fund and the central bank, we turn in such cases to an alternative source: the International Monetary Fund (IMF). Since 1956, the IMF has published monthly data on gold, foreign exchange reserves and other international reserves in its International Financial Statistics (IFS). IMF membership requires submitting these data at monthly frequency. We therefore use the IMF data as soon as they are available to integrate a comprehensive definition of international reserves. Using a complete definition of international reserves is necessary for our purpose, since we want to assess whether the domestic portfolio is growing solely to sterilize foreign intervention, or independently of it. In addition, as we shall see in detail in section 6 , the use of IMF data, expressed in USD or SDR - and their comparison with central bank data in local currency - also makes it possible to address the question of the valuation effects of international reserves. From 1956 onwards, we have systematically compared the results obtained using different sources and currencies for international reserves (see section 6).

2 .2 Relevant central bank balance sheets items

2 .2.1 Focus on monetary policy operations

Building long-run series of central bank balance sheets encounters considerable difficulties, partly because the functions performed by these institutions and the monetary policy implementation have changed a great deal since the 1890s. Central banks used to perform (and in some cases still do) a variety of functions which are not related to monetary policy and the refinancing of banks. For this reason, looking at total assets is not very instructive.

As explained in our theoretical framework (Section 1), we are interested in the short-term liquidity injections of the central bank, that is loans and asset operations that can either influence the exchange rate or the money market rate. In other words, we are interested in what is today called “foreign exchange interventions” and “monetary policy operations”. We call the sum of these specific assets the *liquid assets* of the central bank, because they can be used immediately by the central bank to affect the money market and exchange rates. These *liquid assets* represent financial transactions through which the central bank can provide an *elastic currency* - to use the jargon of central banks.

Our focus on ”liquid assets” implies to exclude three types of domestic assets (the second and the third being sometimes very large). First, we exclude the assets managed by the central banks for its own investment, that is mainly the pension funds of its employees as well as real estate. Second, we leave aside the assets managed on behalf of other institutions, in particular the Treasury, state-owned credit institutions (e.g., postal savings) or Sovereign Wealth Funds (Norway). In these cases, we find a separate account on the asset and the liability sides that indicates that this account was managed on behalf of another institution. Third, we exclude direct loans or investments that aimed at supporting the finance of a specific institution (which could be a financial or non-financial company) or the government. This category especially includes direct loans to a public bank or a nationalized company (often at a subsidized interest rate), the purchase of equity of a state-owned (or developmental) bank, or direct loans to the government. They also feature long-term loans that are akin to commercial bank loans rather than to regular central bank operations. Typical examples are mortgage loans that central bank refinanced to foster the development of the mortgage sector in the late 19th century and reconstruction loans granted to specific branches of industry after the Second World War. The reason for excluding assets in this third category - which are often very large in size - is that none of these investments or loans affect the money market rate, as they were not intermediated by banks participating in the interbank market. [17]

We have thus focused on the main operations, which we reframe in a typical modern

[17] On occasions, comparing the balance sheets compiled by the economists of the Bank of France and country-specific sources was instructive. The Bank of France had a razor-sharp focus on monetary policy operations (in today’s terminology), whereas the national central banks published information on the multitude of tasks performed under their roof. The large *conti d’ordine* of the Bank of Italy (accounts managed on behalf of others) are a case in point. They were not recorded by the economists of the Bank of France.

central bank balance sheet (Table 2). This standardized central bank balance sheet excludes equity (on the liability side) as well as assets managed on behalf of other institutions. The asset side distinguishes between the international portfolio and the domestic portfolio, for which we provide a further three and five sub-categories, respectively. The chosen level of disaggregation leads to economically meaningful concepts and distinctions (e.g., metallic reserves are different from foreign exchange reserves) while ensuring consistent time series over time. For example, the category "foreign exchange reserves (1.2)" is often split between deposits and securities, but not systematically enough to build continuous series over a long period.

Table 2: **Standardized central bank balance sheet**

ASSET	**LIABILITY**
1. International portfolio	3. Circulation (banknotes)
1.1 Metallic reserves: gold and silver	
	4. Deposits
1.2 Foreign exchange reserves	4.1 Deposits of financial institutions
1.3 Other international reserves	4.2 Deposits of non-financial institutions
2. Domestic portfolio	4.3 Deposits of the government
2.1 Discount loans	
2.2 Advances and other collateralized lending	
2.3 Open market operations	
2.4 Special loans	
2.5 Direct loans to the government	

Note: 1.3 mainly includes reserve positions at the IMF or European monetary fund.

2 .2.2 Assets and liabilities

We explain the domestic portfolio in more detail given its central role in our analysis. We also use it to explain a key feature of our data set, namely that some categories remain void of entries for prolonged periods of time, as the central bank activity in question did not yet exist or, conversely, was no longer relevant. The most important example relates to categories 2.1, 2.2 and 2.3 in table 2, the sum of which is referred to as monetary policy operations in this paper. With the exception of the Bank of England, central banks before World War I did not embark on Open Market Operations (category 2.3). Instead, they offered standing facilities to market participants in the form of discounting bills of exchange (category 2.1) and lending against collateral (category 2.2). Yet with the rise of open market operations after the Second World War, we see a reversal, often to the point the categories 2.1 and 2.2 drop out altogether. Further cases of void entries are 1.3 (no entries before the foundation of the IMF), 2.5 (direct loans to the government are prohibited in many countries today) and 4.2 (central banks deal exclusively with financial institutions today).

Our focus in the domestic portfolio is on the monetary policy operations (or "liquid assets"), the "bread and butter" of central banking. To understand categories 2.1, 2.2 and 2.3 better, it is helpful to distinguish them from 2.4 and 2.5. Category 2.4 "special loans" includes all targeted loans that were intended to foster the development of a particular sector or (financial or non-financial) institution (we provide some examples for such special loans above under 2.2.1).[18]

An important distinction relates to the classification of government debt. The purchase of government bonds on the secondary market is included in the open market category because they are primarily a tool of monetary policy and of the refinancing of financial institutions. By contrast, category 2.5 captures transactions directly between the government and the central bank: a loan to the government, typically granted upon request of the Treasury (often based on parliamentary approval and the passing of a law which appears as such in the original balance sheet). Because a direct loan to the Treasury has a different legal basis than a purchase of government securities on the secondary market, the two have always been clearly distinguished in central bank balance sheets. Both time series look very differently: asset purchases of government debt show standard random features of time series; direct loans, by contrast, reach a specific level upon issuance and subsequently stay flat (until possibly increased again at a well-defined point in time).

Extending on the previous paragraph, please note that asset purchases related to quantitative easing are classified as open market operations. While such purchases might be bigger in size today than in the past and differ in that they target explicitly long-term yields in some instances (as opposed to the money market rate which we are interest in), they reflect transactions in which the central bank acquires securities on the open market; which is the key difference to the other four sub-categories of the domestic portfolio.

Turning to the liability side, we distinguish between banknotes in circulation and deposits. While the former category dominated the liability side in the past (ca. 90% under the

[18]Please note that we do not include in this category the current Targeted Long-Term Refinancing Operations (TLTRO) of the ECB because, even though long-term and targeted, these loans are mostly aimed at refinancing banks rather than developing a specific industrial sector. TLTRO are considered as collateralized loans in category 2.2. By contrast, special loans to non-financial corporations during the covid (such as the Bank of England's Covid Corporate Financing Facility) are recorded as 2.4 since they were not granted upon the request of banks.

Classical Gold Standard), deposits dominate today. Bank notes in circulation is typically the time series easiest to reconstruct given the unambiguous classification in all balance sheets we encountered. The certainty introduced by this particular series often helped better understand other series, especially in inflation prone countries such as Argentina where taking off repeatedly zeros or issuing entirely new currencies made accounting often difficult.

Given the complexity and the variety of central bank operations, classifying original series in each of the categories of Table 2 required substantial institutional knowledge that we gathered from central bank annual reports or monographs. In some cases, we also relied on the work of historians or economists that had built annual data of central bank balance sheets and checked how they had categorized each series. These various annual datasets are compiled and listed in the work of Ferguson, Kornejew, Schmelzing, and Schularick (2023). Their objectives were not always similar to ours however, so that their classification can be different. For example, we have noticed that they did not always separate the discount of foreign paper from the discount of domestic paper, making it impossible to build a consistent series of foreign exchange assets. They usually do not distinguish between government debt purchased on the secondary market and direct loans to the government (or government debt purchased on the primary market). Items in our category 2.4 are also often classified as "other" or are not separated from monetary policy operations. For the three countries whose weekly balance sheets were available online (England, USA and France), we also had to build consistent series over time, especially for the USA and France where categories are not continuous in the published balance sheets.

In the quantitative analysis in sections 4 , 5 , 6 , we will use the sum of categories 1.1, 1.2 and 1.3 for the international portfolio, and the categories 2.1, 2.2 and 2.3 for the *domestic portfolio*. We exclude items 2.4 and 2.5 from the domestic assets (which, for this reason, are in light grey in Table 2) because these operations are different from providing short-term liquidity to the financial sector.

3 Identification of exogenous international monetary policy shocks

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Examining the international transmission of a shock to the central country's interest rate requires the construction of an exogenous measure of that shock. Otherwise, the variation in the international interest rate could simply be an endogenous reaction to domestic and global economic fluctuations. Several exogenous monetary policy shocks have been constructed for the postwar period, starting in the late 1960s (Romer and Romer (2004)) with "narrative identification" and, in the late 1980s with high-frequency identification (Bauer and Swanson (2023b)).

One major issue for the analysis for other historical periods is the lack of available measure of exogenous monetary policy shocks in the literature. One exception is Lennard (2018) who built an exogenous shock to the Bank of England interest rate before 1914, following the "narrative approach" of Romer and Romer (2004). However, there was no attempt to construct exogenous high-frequency monetary policy shocks for England and the USA before the late 1980s. High-frequency identification is all the more relevant for our purpose as it is designed to take into account market expectations, and thus identify the shock as a surprise for market participants (e.g. Gürkaynak, Sack, and Swanson (2005); Nakamura and Steinsson (2018); Miranda-Agrippino and Rey (2020)). Given the importance of money markets and exchange rates to our argument, we need to capture shocks that were not anticipated by domestic and international markets. We also need to ensure sure that these shocks were not a response to macroeconomic fluctuations (as in Romer and Romer (2004); Lennard (2018) and Bauer and Swanson (2023b)).

We thus make an attempt to construct historical exogenous monetary policy shocks by using state-of-the-art methodology based on high-frequency identification while coping with the constraints of data availability in historical periods. Since intraday data on interest rate futures are not available before the late 1980s, we collect daily interest rate, stock market and exchange rate data since the late 19th century in order to build a series of changes in the leading central bank interest rate that were not anticipated in these financial markets.[19] Our approach (high-frequency identification with historical daily data) is in the same spirit as the recent article of Cloyne, Hürtgen, and Taylor (2022) that identifies exogenous monetary policy shocks of the Bundesbank.

We build such new exogenous monetary policy shocks for the Bank of England in the interwar period (1925-1931), the Federal Reserve under the Bretton Woods era (1946-1971), and the Bundesbank during the European Monetary System (1980-1991). In addition, we also apply our method to the Bank of England during the classical gold standard (1891-1913) and compare our results with the ones relying on the shock constructed by Lennard (2018).

We build the shock as follows. We proceed in two steps. First, we use insights from the literature on high-frequency identification. The idea is to capture the market surprise using

[19] Also coping with the limitations of historical data, Weiss (2020); Bouscasse (2022) have used daily exchange rate data to build a measure of unexpected (exogenous) devaluations.

market variation in a very short window around policy meetings. The literature uses data on intraday futures contracts. Absent such financial instrument and intraday data for the specific historical period, we use daily data on the exchange rate, stock market and the money market rate. Our identification relies on the idea that changes in the policy rate which are not driven by exchange rate, stock market and interest rate movements in the day before the decision of the central bank are truly exogenous to conditions in these markets. In this first step (see equation (1)), we explain the daily policy rate of the reference country by lagged values of daily market interest rate and exchange rate.

In a second step, we follow Bauer and Swanson (2023b) and also consider a narrative approach *à la* Romer and Romer (2004); Lennard (2018); Cloyne, Hürtgen, and Taylor (2022) to purge the series of movement taken in response to information about the state of the economy. This step is justified by Bauer and Swanson (2023a)'s finding that monetary surprises identified from market data are in fact predictable by macroeconomic variables. Although we lack data on the forecasts produced by the central bank at the time and distributed internally before the central bank meeting (as in Romer and Romer (2004)), we can have access to historical data (production, price indices, reserves, money supply, exchange rates, etc.) that were available to policy makers at the monthly frequency when they took their decision. In this second step, we sum up the residual of the first regression (equation 1) with daily data to produce a monthly index. Then we regress this monthly index on macroeconomic monthly variables influencing the central bank decision (equation (2)). We thus obtain a monthly residual, which is the exogenous policy shock that we will use in our analysis.

Therefore, our two estimations are the following:

$$\Delta r_d^{\text{ref}} = \beta_0 + \beta_1 r_{d-1}^{\text{ref}} + \beta_2 \Delta r_{d-1}^{\text{ref}} + \sum_j \gamma_{j,p} y_{d-1}^j + \sum_j \phi_j \Delta_{d-1\rightarrow d-T} y^j + \epsilon_d \tag{1}$$

$$\Delta r_m^{\text{ref}} = \sum_k \sum_{p=1}^{p=P} \theta_{k,p} x_{m-p}^k + \sum_k \sum_{p=1}^{p=P} \mu_{k,p} \Delta x_{m-p}^k + \epsilon_m \tag{2}$$

With r_d^{ref} as the policy rate of the reference country (the UK or the US according to each period); j is the subscript corresponding to variables available at daily frequency; P is the number of lags, so y_{d-p}^j is the value of variable j p days before; $\Delta_{t\rightarrow t-T} y^j$ is the variation of variable j from T days before to one day before the observation; ϵ_d is the daily error term; Δr_m^{ref} is the residual of regression (1), that is ϵ_{d-}; k is the subscript corresponding to the set of variables x for which values are available at monthly frequency; ϵ_m is the monthly error term. The residual ϵ_m of regression (2) is thus used as the monetary policy shock. Of course, endogenous changes in the central bank rates can themselves have an impact, but we cannot estimate it precisely. So, we focus on changes that could not be anticipated, either based on available (i.e. real-time) monthly macroeconomic indicators or on daily market movements. For each period, we carefully select the set of variables influencing the decisions of the leading central bank. This includes taking into account the exchange rate when the currency of leading country has itself a fixed-parity. The list of all the variables used in these estimations appears in appendix B.

Two charges might be leveled at the construction of our shocks: (i) it does not use central bank forecast as in Romer and Romer (2004); (ii) it is not a monetary policy surprise per se. We however think that these problems are not of large importance, especially for the 1890-1970 period. First, as documented in Bauer and Swanson (2023a), a large proportion of the Fed response to the news is not due to forecast but to market prices, which we take into account at a daily frequency. In addition, as exemplified by the Bundesbank case during the EMS (Cloyne, Hürtgen, and Taylor (2022)), forecasts were neither used outside the US nor before 1969. It should also be noted that stock market prices (that we also use with daily frequency in the first step for the US) are supposed to capture all information at the disposal of market participants. Second, one aim of the recent literature relying on high-frequency identification is to account for forward guidance and simultaneity between Fed targeted rate change and financial variables. However, forward guidance was not explicitly used before the 1990s. Besides, our measure directly deals with the simultaneity issue thanks to high-frequency identification on daily market rate and exchange rate. It is also worth pointing out that the reason we do not have intraday data prior to the 1980s is that they did not exist, which also reflects the fact that financial market information was transmitted less rapidly, so daily data is more reliable for capturing market reactions in the past than it is today.

As a first step to test the quality of our shock we ran local projection analysis to see the response of the leading country main macro variables, namely price, production, and unemployment. As shown in the figures in appendix B (figures B.1, B.6, B.8, B.10, B.12) our shock produces conventional responses of both production and prices.

Last, it is important to note that the main conclusions in the next sections do not rely on the use of the exogenous monetary shocks we constructed as part of our research. Our baseline results rely on the shocks of Lennard (2018) before 1914, and the ones of Romer and Romer (2004) and Bauer and Swanson (2023b) for the more recent periods. Exogenous shocks were not available for the 1924-1931 and for the 1947-1971 periods; in which case we were left with no choice other than using our shock also for the baseline results. Yet excluding these two periods altogether would leave our main results unchanged. We document clearly in the notes of each table which shocks we use.

4 Average Responses of Central Bank Balance Sheets over 130 years

Our theoretical discussion in section 1 has highlighted that the central bank's domestic portfolio can react to a shock to the international interest rate for two different reasons: (i) as a counterpart to sterilized foreign exchange interventions; (ii) as a means of stabilizing the domestic money market. (i) is specific to a fixed exchange rate regime, while (ii) also applies to floating exchange rates. We begin by testing these simple predictions on our sample of 23 countries since the late 19th century.

4 .1 Econometric model

We estimate the impact of an interest rate change on other variables through local projections. Our econometric model is as follows:

$$y^k_{i\in g,t+h} = \alpha_{i\in g} + \Phi_h(L)Y_{t-1,i\in g} + \beta_h\Delta r^*_t + \Psi_h(L)X_{t,i\in g} + \nu_h(L)W_t + month + trend + \epsilon_{h,i\in g,t} \quad (3)$$

For $h = 0, 1, 2, ..., H$, with H the time horizon for which we want to measure the response to a shock. $y^k_{i\in g,t+h}$ is the value of variable $k = 1, ..., K$ for country $i = 1, ..., M$ belonging to group $g = 1, ..., G$. Note that $y^k_{i\in g}$ is part of a vector of endogenous variables Y_t for which the local projection is run. α_i is a country fixed effect $\Phi_h(L)$ is the polynomial set of lag operator for endogenous variables, Δr^*_t is the shock on the policy rate of the world leading central bank, and β_h is the estimated parameter which we focus on to see the effect of the shock on the endogenous variables. Our equation also includes a vector of time-varying control variables specific to each country $X_{i\in g,t}$ (exchange rate, interest rates, price index and industrial production index), and a vector of panel-invariant control variables (W_t) that intends to capture a world cycle that may influence jointly the leading economy and other countries. Starting 1973, W_t includes the index of global real economic activity built by Kilian (2019). Before this date, we simply proxy the world cycle by using the industrial production (or output) index of the leading country. All estimations also include the leading country consumer price and stock market indices, monthly dummies, and a time trend.

As such we calculate the response to a shock on the policy rate of the leading central bank for different group of countries. The group definition depends here on two binary variables: the exchange rate regime and the use of capital control.

4 .2 Definitions of exchange rate regime, financial openness and monetary policy shocks

To distinguish between different regimes of exchange rate (float vs. peg), we use the most common classifications in the academic literature for various periods.[20].

Who set the international interest rate for each period? Consistent with conventional accounts of the international monetary system, we hold the United Kingdom to be the leading country until 1939, and the United States after the Second World War (see also Jordà, Schularick, and Taylor (2020)).

Measuring financial openness over the long run is more difficult. There were no formal capital controls in the first era of globalization, although some countries may have been less financially integrated in practice (Obstfeld and Taylor (2004); Bordo and MacDonald (2005); Bazot, Monnet, and Morys (2022); Meissner (2024)). We therefore consider all countries to be open before 1914. Various forms of capital control were put in place during the First World War, and we consider countries to be financially closed during the two world wars. In line with the literature (e.g. Eichengreen (1992)), we consider that countries were financially open when they returned to the gold standard in the 1920s, and thus indirectly pegged to England, the leading financial center at the time. The Great Depression prompted some countries to reintroduce capital controls. The League of Nations recorded these controls, so we use this measure (from Mitchener and Wandschneider (2015)) to categorize financially closed economies in the 1930s. For the post-World War II period, we have two alternative measures of financial openness: either an index of capital controls that measures the extent of regulatory tools limiting free financial flows (Quinn and Toyoda (2008); Chinn and Ito (2008)), or a binary variable (from Ilzetzki, Reinhart, and Rogoff (2019)) that proxies for restrictions on the trade of foreign currency - i.e. exchange controls. The widely used datasets of Quinn and Toyoda (2008); Chinn and Ito (2008) provide *de jure* indices of capital controls based on the Annual Report on Exchange Arrangements and Restrictions (AREAER) published

[20]For the classical and the interwar gold standard periods, we rely on Bazot, Monnet, and Morys (2022) and Morys (2020) respectively. These authors compiled information on exchange rate regimes from a wide range of primary and secondary sources. For the post 1945 period, we rely on Ilzetzki, Reinhart, and Rogoff (2019). We do not use their fine-grained measure (with 12 nuances of exchange rate regime) but their binary variable that states if a country pegs to the dollar, to pound sterling, the deutschmark or the euro.

by the International Monetary Fund. The former cover the period 1950-2017 and the latter start in 1971 but are updated to 2021. These authors code the information contained in AREAER in different ways, resulting in differences in their index, each of which takes on different values. For the purposes of this section, all we need is a binary index. We therefore define a binary variable equal to 0 when both data sets agree that there have been no capital controls in a given country. This definition of financial openness will be our reference, but we will also provide robustness checks using that of Ilzetzki, Reinhart, and Rogoff (2019). This is already a binary variable. Ilzetzki, Reinhart, and Rogoff (2019)'s definition of financial openness is much less restrictive than those of Quinn and Toyoda (2008); Chinn and Ito (2008), and in fact corresponds to a measure of current account convertibility (i.e. the free flow of foreign currency). The absence of current account convertibility is generally associated with the presence of multiple exchange rates, which is what this variable measures. It does not capture capital controls that may apply to specific assets. As Jordà, Schularick, and Taylor (2020), we begin by using the Quinn and Toyoda (2008); Chinn and Ito (2008) indices as a benchmark, as capital controls can impede some key financial arbitrage, even in countries with full current account convertibility. [21]

Last, we construct a continuous series of monetary policy shocks for the whole period (1891-2019) by implementing sub-periods shocks normalized to obtain similar standard deviations for each sub-period. We then use this shock to instrument the main policy rate of each sub-periods: the BoE discount rate until WWII, the US discount rate during the Bretton-Woods period, the Fed funds rate until 2007, and the Fed shadow rate from 2008 until 2019.[22] In order to follow as closely as possible to the existing literature on the international transmission of monetary policy shocks, we first use shocks constructed by other researchers where available, i.e. we use those of Lennard (2018) for the Bank of England before 1914, and those of Romer and Romer (2004) for the US Fed from the end of Bretton Woods to 1988, and Bauer and Swanson (2023b) until 2019. We use our own shock for the remaining periods (where financially open economies were less frequent). In a a second step, and for the sake of robustness, we produced an "alternative" shock using our own shock

[21] So, for example, most Western European countries are considered financially open from the 1960s onwards in Ilzetzki, Reinhart, and Rogoff (2019), i.e. after the return to currency convertibility in 1959, whereas they become financially open in the Quinn and Toyoda (2008); Chinn and Ito (2008) datasets in the 1980s or early 1990s only, after the repeal of the last capital control measures - as documented in Bakker (2012).

[22] The shadow rate is estimated using Treasury forward rates out to a 10-year horizon and thus captures the stance of monetary policy when the targeted short-term rate of the Federal reserve is at the zero lower bound. When the target range is above 0 to 0.25 percent, the shadow rate is almost equal to the effective fed funds rate. We use the shadow rate series of Wu and Xia (2016) updated by the Federal Reserve Bank of Atlanta.

instead of Lennard (2018) before 1914 and those of Romer and Romer (2004) from 1972 to 1988.

4 .3 Main results

4 .3.1 Financially open economies

We focus first on financially open economies. In this first step, we sum up international assets (i.e. gold and foreign currencies) and domestic assets (loans and securities), that is $I + D$. We refer to this as "liquid assets", i.e., the assets that can be used to influence the money market and the exchange rates. Using the sum of "liquid assets" is to ensure that the reaction of domestic assets is not due solely to the sterilization of foreign exchange intervention. As explained in section 2 , we only use the relevant categories 2.1, 2.2, 2.3, as far as domestic assets are concerned. [23]

The impulse response functions in figure 1 show a positive response of central bank assets to an international monetary policy shock. In the left-hand panel, we combine all cases of financial openness irrespective of the exchange-rate regime. One month after the shock, the growth rate of liquid assets (international + domestic) is 4 pp higher than what it would have been without the shock. Consistent with the idea that pegged economies rely more heavily on foreign exchange intervention, which lowers their international reserves, we find that total assets increase less in pegged economies [right panel] than in floating economies [center panel]. Crucially, they are increasing in pegged economies (the response is significant 1 month after the shock), demonstrating that balance sheet fluctuations are not solely due to FX interventions. As shown in figure A.4 in the appendix, these results are also robust to the use of an alternative measure of exogenous monetary policy shocks, i.e. those we have constructed for the entire sample since 1891 (as explained in section 3 and appendix B).

Figure 2 shows the distinction between the reaction of international assets (I, in red) and domestic assets (D, in blue). In both floating and pegged economies, the domestic assets of the central banks respond significantly. The response is stronger with floating exchange rates (reaching a maximum of 7pp after 2 months) than with a peg (4pp). Importantly, we find a significant response of the domestic assets in pegged economies during months when the response of the international assets is not significant. Thus the rise of domestic assets is not only driven by the sterilization of FX interventions. The positive reaction of domestic

[23] When we sum up $I + D$, we have to use the series of foreign assets denominated in local currency (since the domestic assets are always denominated in local currency). When we distinguish between domestic and international assets, the latter are denominated in SDRs after the end of Bretton Woods for reasons explained in section **??**.

assets is also observed when the shock is the change in the policy rate of the leading central bank (see figure A.2), rather than an exogenous monetary policy shock. The increase is still significant but lower when we do not consider endogeneity issues. Importantly,

International assets fall only in pegged economies (where exchange rate interventions are likely to occur), although the reaction is not significant in this sample. The following sections will show that we observe a statistically significant decline in international assets only during specific sub-periods. Please note that some alternative econometric specifications reveal a more significant decline in international assets in the case of countries with fixed exchange rates for the whole sample. The response is just significant at the 10% level when international reserves are valued in domestic currency after the Second World War (see section 6) and is clearly significant after 2 months when we use an alternative definition of financial openness (based on current account convertibility, from Ilzetzki, Reinhart, and Rogoff (2019); see figure 3).

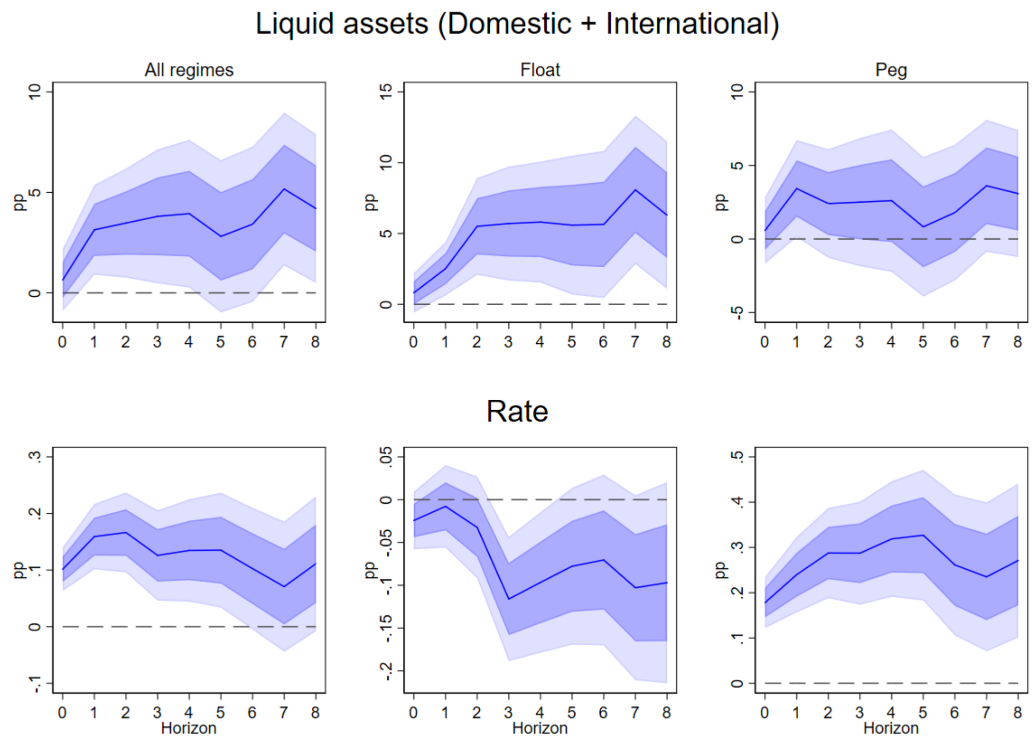
We find stronger and more significant responses of the domestic and international assets in pegged economies when we use Ilzetzki, Reinhart, and Rogoff (2019)'s classification of financial openness in figure 3. This is consistent with the fact that, as explained above, this classification only takes into account exchange controls - and not all types of capital controls. It therefore includes a larger number of observations for the case of open economies with a peg. We also find a significant negative reaction of international assets when we use the main central bank's actual policy rate instead of using different measures of monetary policy shocks (see figure A.2).

In sum, we demonstrate conclusively a positive response of total liquid assets, as well as of domestic liquid assets on their own, to an international monetary policy shock in financially open economies. Central banks have provided "elastic currency" over the past 130 years. We observe this reaction in both floating and fixed exchange rate regimes; in the latter case, the increase in total liquid assets goes beyond what is required by sterilized FX interventions.

4 .3.2 Central bank policy rates

We turn to the reaction of the domestic central bank policy rate in figures 1 and figure 3 (see also A.3 in the appendix), which is presented in the lower panels of these figures. First, the bottom left-hand panel of these figures tells us that financially open economies have enjoyed substantial monetary policy autonomy from the main international central bank over the past 130 years. Following a 100 basis point shock to the international policy rate, the typical central bank policy rate rose by only 15 basis points.

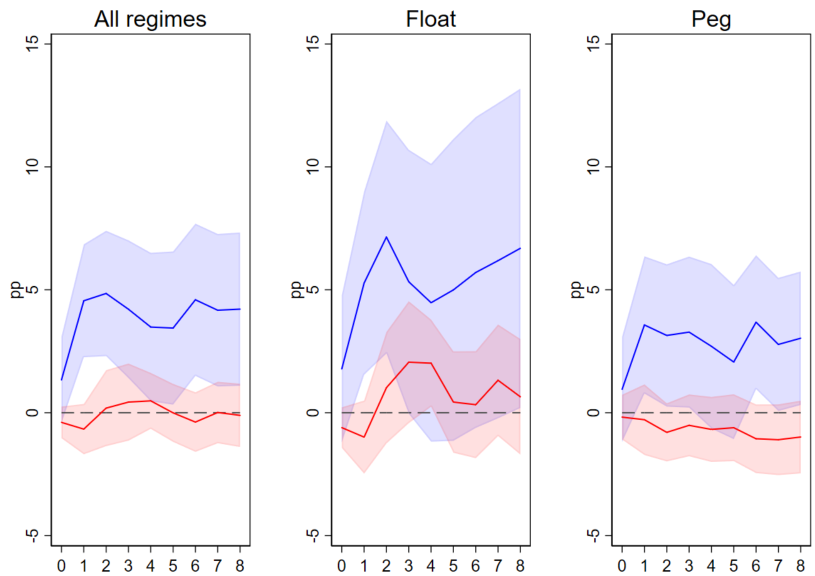
Figure 1: Responses of central bank total liquid assets and interest rate to an international shock. Financially open countries. Full sample



Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate for 1947-1971, Fed fund rate for 1973 to 2007, Fed shadow rate for 2007-2019) instrumented by a composite shock based on Lennard (2018) for 1891-1913, our own shock for 1924-1931 and 1947-1971, Romer and Romer (2004) for 1973-1987 and Bauer and Swanson (2023b) for 1988-2019. The capital control classification is based on the last update of the Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. The exchange rate classification is from Ilzetzki, Reinhart, and Rogoff (2019). The responses of liquid assets are in 12-month variation and valuated in local currency unit. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% and 90% confidence intervals.

Second, and as predicted by the *trilemma* (Obstfeld and Taylor (2004); Jordà, Schularick, and Taylor (2020)), the effect is stronger in pegged economies, averaging 30bp. Yet such a value is far lower than the 100bp predicted by the *trilemma*, but is also larger than the non-reaction predicted by target zone models. The fact that domestic assets react in floating and pegged economies alike means that the reaction of the domestic monetary policy rate would have been greater if the central bank had not injected liquidity. Movements in central bank balance sheets are essential to understand why the interest rate reaction falls between the

Figure 2: Responses of central bank domestic liquid assets (in blue) and international liquid assets (in red) to an international shock. Financially open countries. Full sample

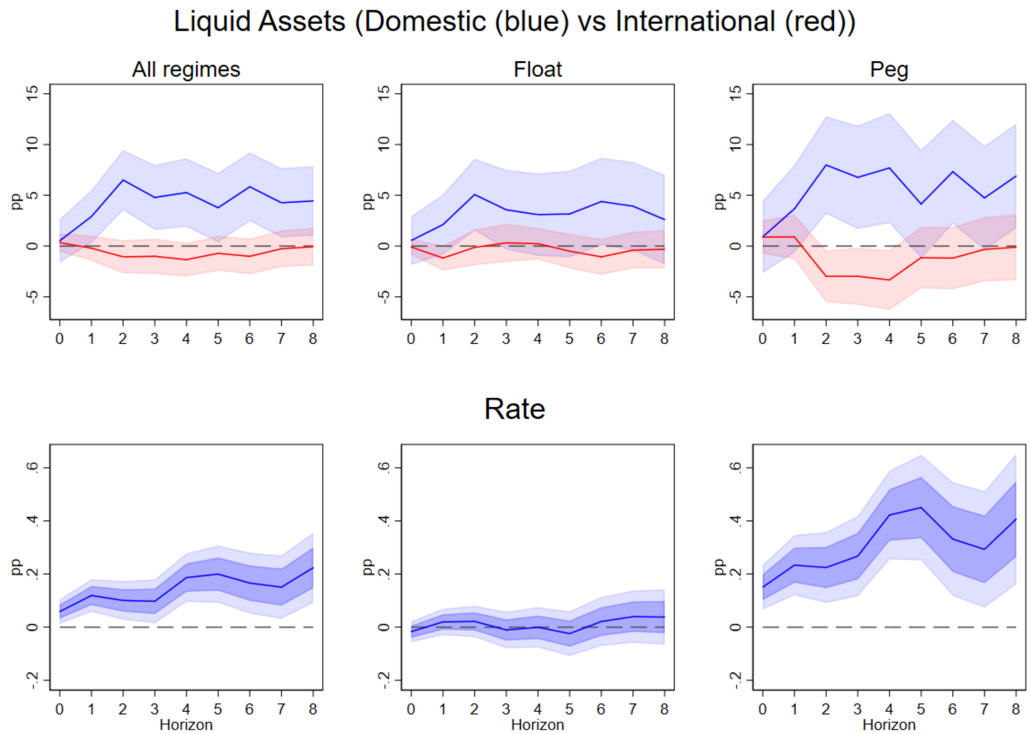


Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate for 1947-1971, Fed fund rate for 1973-2007, Fed shadow rate for 2007-2019) instrumented by a composite shock based on Lennard (2018) for 1891-1913, our own shock for 1924-1931 and 1947-1971, Romer and Romer (2004) for 1973-1987 and Bauer and Swanson (2023b) for 1988-2019. The capital control classification is based on the last update of Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. The exchange rate classification is from Ilzetzki, Reinhart, and Rogoff (2019). The responses of liquid assets are in 12-month variation. The international portfolio valuation is in local currency unit until 1956 and special drawing rights from 1957 onward. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 90% confidence intervals.

predictions of the two standard models in the literature.

Third, the central bank interest rate actually decreases in floating exchange rates in figure 1. This fall is not immediate, but it is visible 3 months after the shock, while the central bank's domestic assets react immediately. As revealed by figure 3 - using a wider definition of financial openness - the decline in interest rate is nevertheless not observed in all cases. It is not required to see an expansion of the domestic assets in floating exchange rates. Miranda-Agrippino and Rey (2020); Degasperi, Hong, and Ricco (2023) have also found a negative policy rate response, with recent data since the 1990s. It is driven by advanced economies (see also next section). This is because the rise in the US monetary policy rate has a negative impact on output in other countries, so central banks react by lowering their target policy rates (this corresponds to a reaction of i^T to a change in Ω in our theoretical discussion in

Figure 3: Responses of central bank domestic liquid assets (in blue) and international liquid assets (in red) to an international shock. Full sample. Alternative classification of financial openness



Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate for 1947-1971, Fed fund rate for 1973-2007, Fed shadow rate for 2007-2019) instrumented by a composite shock based on Lennard (2018) for 1891-1913, our own shock for 1924-1931 and 1947-1971, Romer and Romer (2004) for 1973-1987 and Bauer and Swanson (2023b) for 1988-2019. Capital control classification is based on the Ilzetzki, Reinhart, and Rogoff (2019) financial openness index post 1947. Exchange rate classification from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% confidence (lower panels) and 90% confidence (lower and upper panels) intervals.

section 1).

Examining the central bank's reaction helps us to understand this process, and how central banks manage to regain a degree of autonomy in monetary policy. The immediate reaction of the central bank's domestic assets can explain why there is no need to follow the international interest rate with a floating exchange rate despite the presence of a UIP wedge putting pressure on domestic money market rates (see the next section for a more detailed discussion). It also shows that a fall in the policy rate is accompanied by a sharp increase in central bank domestic assets. In other words, central banks would have trouble transmitting their rate changes to the domestic money market without injecting liquidity into the latter. Short-term expansions in central bank assets therefore explain how central banks manage to maintain the autonomy of their target monetary policy rate in a globalized world.

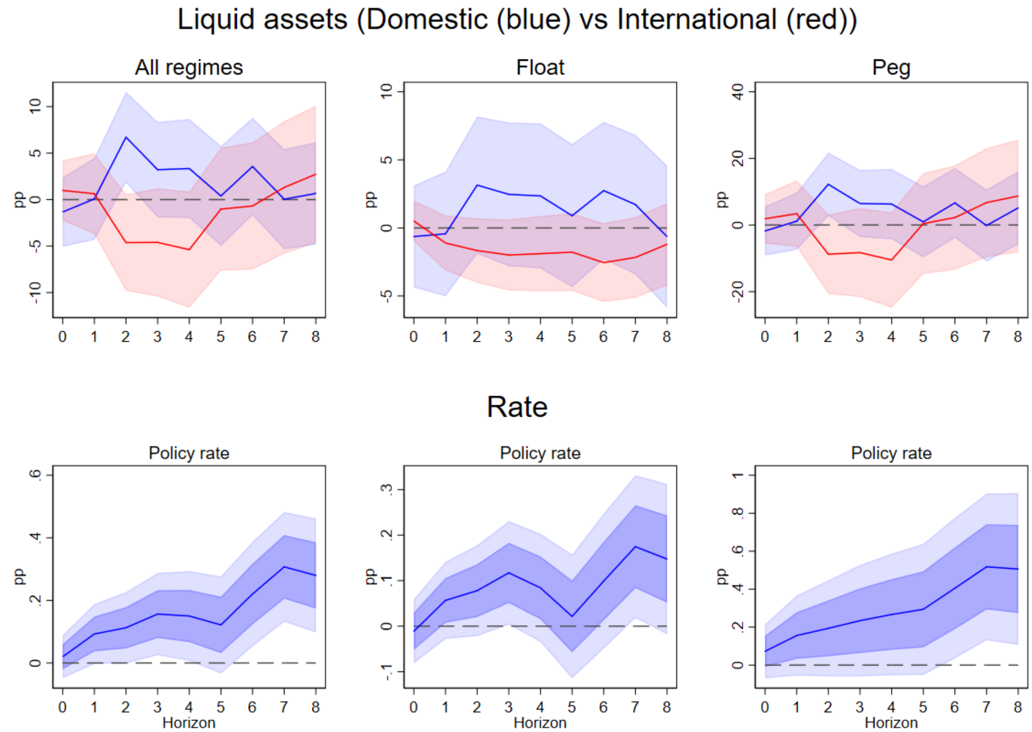
4 .3.3 Capital controls

If the predictions of the trilemma framework and our conjectures about the reaction of central bank balance sheets are correct, we should not observe any significant reaction in economies subject to capital controls. Yet capital controls are not always sufficient to insulate a country from international financial shocks. Figure 4 shows the results for the subset of countries with capital controls. We observe a short-lived positive response of the central bank's domestic portfolio, which is significant after two months only and comes back to zero in the fourth month. International assets reaction is not significant but the sign coincides with the one expected from financially open economies. The difference in the responses of domestic assets between financially open economies and those with capital controls is consistent with the trilemma. But there is also evidence that capital controls are often not binding.

Interest rate reactions also show important differences with financially open economies. They are never immediate, although they can become significant after a few months. When using a more restrictive definition of capital control (i.e. controls on the trade of foreign currency) from Ilzetzki, Reinhart, and Rogoff (2019), we do not find a significant reaction of interest rates (see figure A.5). In pegged economies with capital controls, we also find some significant positive reaction of the domestic assets, although much delayed compared to open economies (significance is visible 3 months after the shock). This again suggests that capital controls are not fully binding in the medium-long term.

In conclusion - as predicted in the discussion in section 1 - the response of central bank balance sheets and interest rates to an international shock is different in countries with capital controls. Responses are less immediate and generally insignificant. But in some cases, we nonetheless observe a delayed reaction of interest rates and domestic assets in our large and heterogeneous sample of pegged economies with capital controls. Thus, there is also evidence that capital controls are not always binding. This justifies the more detailed approach by historical sub-period in the next section.

Figure 4: Responses of central bank domestic liquid assets (in blue) and international liquid assets (in red) to an international shock. Economies with capital controls. Full sample



Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate for 1947-1971, Fed fund rate for 1973-2007, Fed shadow rate for 2007-2019) instrumented by a composite shock based on Lennard (2018) for 1891-1913, our own shock for 1924-1931 and 1947-1971, Romer and Romer (2004) for 1973-1987 and Bauer and Swanson (2023b) for 1988-2019. The capital control classification is based on the last update of Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. The exchange rate classification is from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The international portfolio valuation is in local currency unit until 1956 and special drawing rights from 1957 onward. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% confidence (lower panels) and 90% confidence (lower and upper panels) intervals.

5 From trilemma to dilemma: central bank balance sheet in history

The results of the previous section demonstrate the fundamental importance of the reaction of the domestic assets of central banks to international monetary shocks, but they mix highly diverse institutional configurations and monetary regimes over time. In this section, we apply the same methodology to different sub-periods since the end of the 19th century. This exercise has three main objectives. First, it adds robustness to our main arguments, by showing that our results are not driven by outliers, the specific identification of monetary policy shocks, or the definition of the exchange rate regime or capital controls. We show that, for each sub-period, central bank balance sheets react in a way that is consistent with historical knowledge of the period and the reaction of other financial variables. Second, examining each sub-period gives us the opportunity to discuss in more detail how the reaction of central bank balance sheets drives the reaction of several other key financial variables (not just the central bank interest rate), namely the money market rate, stock prices and the exchange rate. Finally, we contribute to the influential literature that has compared monetary policy and international financial markets across different eras of financial globalization and international monetary systems (e.g. Eichengreen (2000); Obstfeld and Taylor (2004); Bordo and Meissner (2016); Farhi and Maggiori (2018)).

Following the well-established chronology in this literature, we start by examining the First Era of Financial Globalization before World War I. The First Globalization is often considered to begin in the 1880s (our data start in 1891) and last until the First World War. During this period, financial development (market capitalization, banking assets) expanded rapidly alongside international capital flows (Mauro, Sussman, and Yafeh (2002); Bordo and Meissner (2016); Schularick and Steger (2010); Kuvshinov and Zimmermann (2022)). Sovereign debt, corporate bonds and shares were listed worldwide, and international investors arbitraged between several national money markets. Most - but not all - countries were pegged to gold (hence the name "classical gold standard") and there were no official restrictions on capital flows. The First World War considerably reduced the internationalization of capital. The Great Depression, the Second World War and the years of capital controls during the Bretton Woods era prevented financial globalization from catching up with its pre-1914 level (Meissner (2024)). It was not until the early 1990s that measures of financial openness and financial globalization reached levels similar to those of the first globalization. Yet the scale of the second globalization rapidly exceeded that of the first (Subramanian and Kessler (2013); Meissner (2024)). This has taken place in parallel to an also unprecedented rise of bank assets and stock market capitalization to GDP, in what financial historians have named the "hockey stick" pattern of finance (Jordà, Schularick, and Taylor (2019); Kuvshinov and Zimmermann (2022)). More importantly, the second globalization saw a much greater development of global banks and global investors relying on interbank markets for short-term dollar funding (Mauro, Sussman, and Yafeh (2002); Ivashina, Scharfstein, and Stein (2015); Aldasoro, Ehlers, McGuire, and von Peter (2020)). Another important difference between the first and second globalization is the exchange rate regime. Whereas the most financially developed economies had a fixed exchange rate regime (gold standard) prior to 1914 and floating was largely confined to countries suffering from fiscal dominance, the opposite situation holds true today: the major currencies (USD, EUR, YEN, GBP, CHF) float against each other, while other currencies often seek some form of peg vis-a-vis a major currency.

5 .1 The First Globalization

Most countries with central banks were on the gold standard before the First World War, but this did not mean that exchange rates never moved. Market exchange rates could fluctuate within bands around the central gold parity (mint parity). The upper and the lower limit of these bands were called the gold export point and the gold import point, respectively. Gold points existed because shipping gold from one country to another involved transaction costs. E.g., the gold export point was the exchange-rate at which it was cheaper to ship physical gold abroad rather than obtain a bill of exchange drawn on a foreign place despite the shipping and insurance costs involved. Between Europe's main financial centers, gold points deviated between 0.4% and 0.8% from gold parity.

If the peg was credible, and if the variation in the international interest rate was not too large, the exchange rate band could offer substantial flexibility, in line with the predictions of the target zone model (Bordo and MacDonald (2005)). However, as Figure 5 shows, this did not happen automatically. After an exogenous rise in the English interest rate, the central bank's international assets fell and domestic assets rose. In other words, the central bank let gold out of its vault and intervened on the foreign exchange market to prevent the exchange rate from depreciating too much. This intervention was offset by an increase in domestic loans to prevent the domestic money market rate from rising too sharply. These movements in the central bank's balance sheet were akin to sterilized intervention in the foreign exchange market. But this is only a part of the story. The rise of the domestic portfolio overcompensates the decline of international portfolio. The domestic portfolio increases by 2pp while the international portfolio decreases by 1pp, and the response of the former is still positive and significant 7 months after the shock while the response of the latter is indistinguishable from zero from the 2nd month after the shock.

Thanks to the flexibility offered by the exchange rate bands and the elasticity of the central bank's currency, the impact of the international rate on the central bank's average rate remains moderate. The pass through between the international and the domestic rate was less than 20%. This falls far short of the conventional wisdom about the gold standard, which associates this peg with a rigid system in which domestic rates systematically followed the international rate. By avoiding to increase their interest rate, and by using their balance sheets to circumvent partly the constraint of the trilemma, central banks breached what Keynes called the "rules of the game" of the gold standard, as previous authors, in particular Nurkse (1944); Bloomfield (1959), had already suggested relying on more basic statistics.

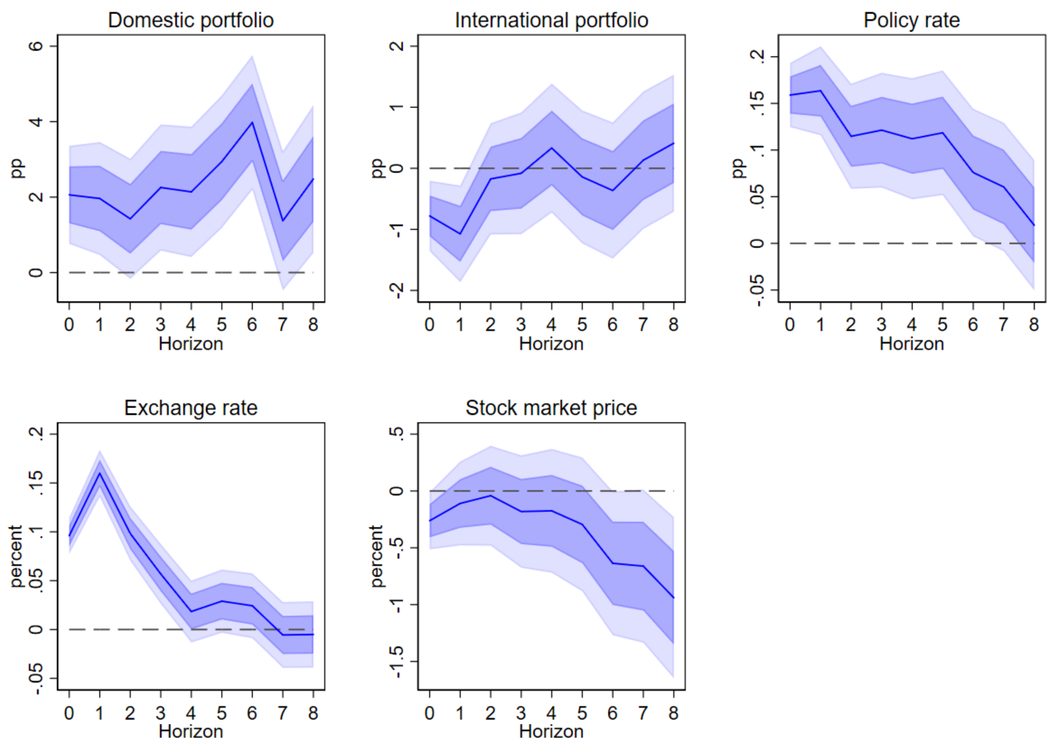
Please note that equity prices do not react significantly to the shock despite the strong integration of stock markets during this period. We interpret this as a sign that the moderate increase in the domestic interest rate following the international shock was not sufficient to have an impact on the stock market.

Figure 5 shows estimation results for all available countries in our sample, without including the money market rate. For a more limited set of countries, we also have data on the money market rate (Austria, Belgium, France, Germany, and the Netherlands - the "core" countries of the international financial system at that time). Results based on these countries only, including the money market rate, are presented on figure A.6 and lead to similar conclusions as before. This figure especially makes clear that the response of the money market exceeds the one of the central bank policy rate one month after the shock. The expansion of the domestic assets of the central bank helps to take the market rate back to the policy rate few months after the shock.[24]

Although fewer countries adopted a floating exchange rate during this period (this was the case for Italy before 1902, Spain and Portugal), it is interesting to examine how they reacted to an international shock. Results are displayed in Figure 6. The exchange rate reaction is significant and it is much stronger than for the gold-standard countries. After two months, a 100 basis point rise in the English rate is entirely absorbed by the depreciation in the exchange rate. No other variable reacts significantly. This suggests that floating countries during the first globalization reacted in a manner close to the textbook model of international macroeconomics. The floating exchange rate absorbed the shock, and central bank balance sheet fluctuations were not necessary for international adjustment. Yet, Italy, Spain and Portugal were less financially integrated to the rest of the world than core countries in the gold standard, despite the absence of formal capital controls (Bazot, Monnet, and Morys (2022)). This is likely to explain why the reaction of the exchange rate is not immediate.

[24] As previously shown by Bazot, Monnet, and Morys (2022), this was not the case in the USA, a country that had no central bank at the time. In this country, the reaction of the money market rate was around three times higher, and the stock market reacted significantly to a shock to the English rate.

Figure 5: Responses to a Bank of England shock. Classical gold standard, pegging countries. 1891-1913

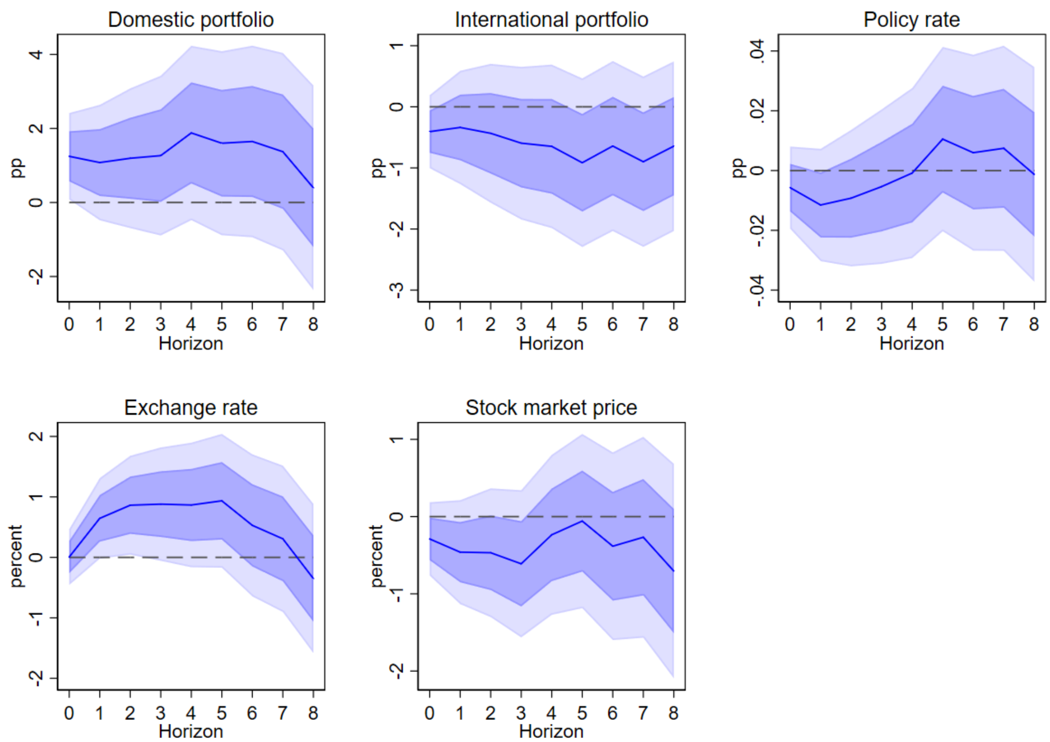


Note: Panel local projections including 3 lags. Responses to the exogenous BoE policy rate shock of Lennard (2018). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK business cycle, the UK stock market index, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

5 .2 The interwar gold standard

After the First World War, countries strove to rebuild the financial and monetary world that had prevailed prior to 1914. After England's return to the gold standard in 1925, this objective seemed within reach. Most other countries also rejoined gold, private financial flows resumed debt financing worldwide, and stock markets reached new heigts everywhere (Eichengreen (1992); Kuvshinov and Zimmermann (2022). The late 1920s boom was short-lived, however, and ended with the Great Depression and the devaluation of the British currency in September 1931. Not only did financial flows recede as the economic crisis spread around the world, but many countries actively imposed controls on trade, currency exchange and financial flows (Mitchener and Wandschneider (2015). Thus, although short-lived, the monetary regime of the interwar period, from 1925 to 1931, was expected to be quite similar

Figure 6: Responses to a Bank of England shock. Floating countries, 1891-1913



Note: Panel local projections including 3 lags. Responses to the exogenous BoE policy rate shock of Lennard (2018). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK business cycle, the UK stock market index, monthly dummies, a trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

to the pre-1914 gold standard, as far as central bank operations were concerned.

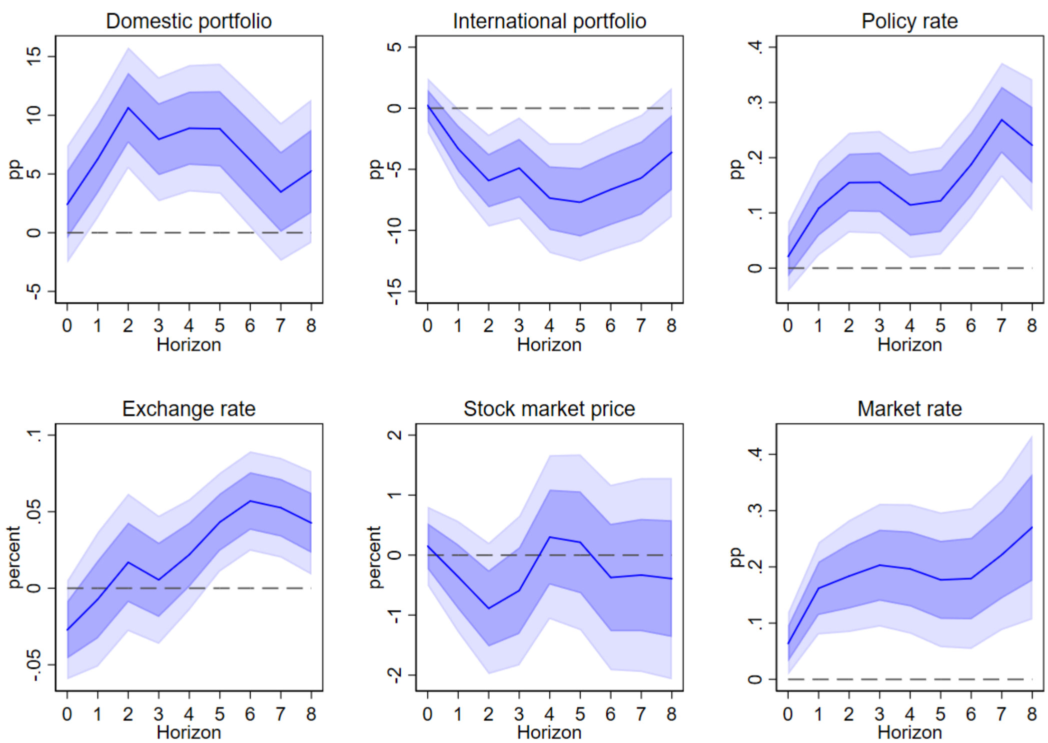
Figure 7 shows that domestic and international central bank portfolios reacted in similar ways to the pre-1914 patterns. The exchange rate constraint was stricter than before 1914, coupled with a higher interest rate reaction. Please note the interest rate response is - at approximateily 25 basis points - still far lower than the 100 basis point increase in the Bank of England rate. The reactions of the central bank's assets are far stronger than in the case of the gold standard, suggesting that more action was needed to make the peg credible. Indeed, countries rejoining the gold standard in the 1920s, typically after years of postwar inflation, struggled to rebuild a credible peg and regain the confidence of international markets (Eichengreen (1992); Bordo and MacDonald (2003)). For this reason, central banks relied substantially more on foreign exchange reserves than before 1914 (Eichengreen, Mehl, and Chitu (2018)). We complement this finding by showing that balance sheet policies in general were used far more widely in the interwar period.

5 .3 Bretton Woods

The Bretton Wood system lasted from the late 1940s to 1971. Its foundations were laid at an international conference held in June 1944 in Bretton Woods, New Hampshire (USA). The basic idea of the system was that only one country - namely, the United States - stood ready to convert currency into gold. All other countries maintained fixed exchange-rates vis-a-vis the United States. An important element of this period was the wide-spread use of capital controls that prevented international arbitrage (Obstfeld and Taylor (2004); Bordo and James (2015); Meissner (2024)).[25] As far as capital controls are concerned, economic historians draw a clear distinction between the years that preceded 1959 and the years that followed (Bordo (1993)). It was only in 1959 that most advanced economies returned to currency convertibility, that is their currency could be freely traded. Countries abandoned multiple exchange rates and gave up exchange controls on imports and exports (Ilzetzki, Reinhart, and Rogoff (2019); Monnet and Puy (2020)). With convertibility restored, speculators resumed arbitrage between different currencies (or gold) on the official international markets (Bordo, Monnet, and Naef (2019)). This does not mean that all restrictions on capital flows were lifted after 1959, but basic arbitrage between currencies was possible again. It is therefore important to distinguish between the 1947-1958 period (when economies were effectively

[25] Not only did capital controls block the transmission of international shocks, they were also associated with strong domestic banking regulation that allowed central banks to rely on quantity rationing (i.e. credit ceilings) rather than interest rates or *elastic money* (Monnet (2014, 2018)). So interest rates often played little role, internally and externally.

Figure 7: Responses to a Bank of England shock. Interwar gold standard. 1925m1-1931m8



Note: Panel local projections including 3 lags. Responses to our exogenous BoE policy rate shock (see section 3 and appendix B for details). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK industrial production index, the UK price index, the UK stock market index, the countries' industrial production indices, the countries' the price indices, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

financially closed, subject to strong foreign exchange control) and the 1959-1971 period (when some capital controls remained, but did not prevent all arbitrage between currencies). Please note that estimations on the Bretton Woods periods do not include money market rates and stock market prices because these data are far more limited during this period (especially before the 1960s), due to strong state regulation of the financial sector.

The main conclusion to draw from figure 8 (1947-1958) and figure 9 (1959-1971) is that central bank domestic assets were not required to tame international shocks before 1959, but they started to play a role again afterwards. Before 1959, the economies are fully closed financially and we do not observe a statistically significant reaction of any of the four variables (figure 8). Figure 9 (1959-1971) shows a different picture and provides evidence that capital controls are not able to fully insulate an economy once foreign exchange controls are lifted. The domestic portfolio reacts significantly during 6 months. We also see an increase in the central bank interest rate following the US shock. However, this increase is limited in size and gradual, as it takes 5 months to reach 10 basis points following a 100 basis point increase in the US rate. The positive reaction of the domestic assets and the existence of capital controls - whose effectiveness tends to loosen after some time - provide some explanations for this slow and weak reaction.

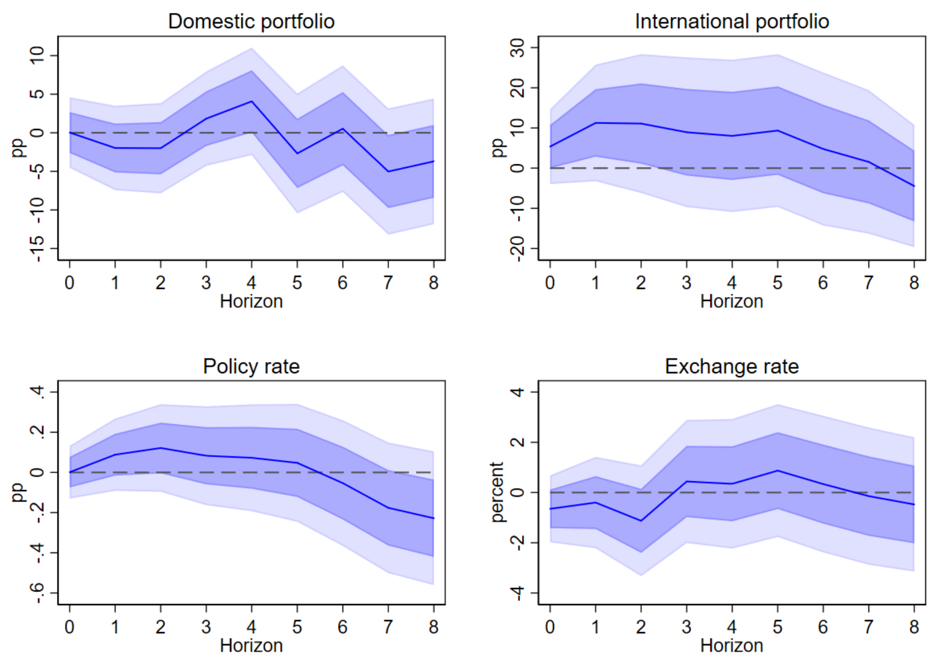
On the other hand, we do not observe a significant role for foreign exchange interventions both before and after 1959. This suggests that international monetary policy shocks did not threaten the credibility of the peg in other countries. [26]

5 .4 The Second Globalization

One of the main differences between the first and the second globalization is the predominance of floating exchange rates today. The adoption of floating exchange rates since the 1990s is itself strongly correlated with financial development and capital account openness (Bordo (2003); Ilzetzki, Reinhart, and Rogoff (2019). Our long-term sample, dominated by advanced economies, therefore contains mainly cases of open economies that have adopted floating exchange rates at some point since the end of the Bretton Woods system. The few emerging markets in our sample have rarely had a fully open capital account over the last thirty years. Consequently, we will deal with them in the next section.

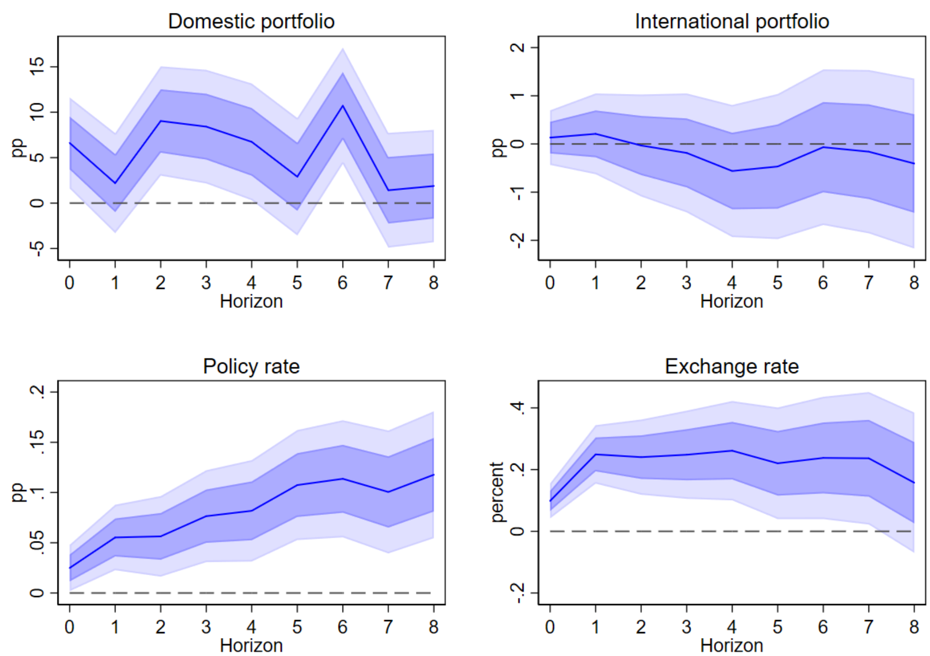
[26] Of course, this result does not imply that central banks did not resort to foreign exchange intervention during the Bretton Woods era. But they did do so when faced with current account imbalances - due to budget deficits or trade shocks - rather than in response to an international financial shock. For a recent overview of international reserve management and foreign exchange intervention in the Bretton Woods era, see Naef (2021); Monnet and Puy (2020).

Figure 8: Responses to a US Federal Reserve shock. Bretton Woods system. 1947-1958



Note: Panel local projections including 3 lags. Response to an exogenous Fed policy rate shock (see section 3 and appendix B for details). The responses of both domestic and international portfolios are in 12-month variation. The international portfolio valuation is set in local currency unit. The set of local projections also includes the US industrial production index, the US price index, the US stock market index, the countries' industrial production indices, the countries' the price indices, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

Figure 9: Responses to a US Federal Reserve shock. Bretton Woods system. 1959-1971



Note: Panel local projections including 3 lags. Response to an exogenous Fed policy rate shock (see section 3 and appendix B for details). The responses of both domestic and international portfolios are in 12-month variation. The international portfolio valuation is set in local currency unit. The set of local projections also includes the US industrial production index, the US price index, the US stock market index, the countries' industrial production indices, the countries' the price indices, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

Figure 10 shows the response of key variables to an exogenous US monetary policy shock (using the Bauer and Swanson (2023b) shock). We start the sample in 1994 to ensure that all economies in our sample are fully financially open.[27].

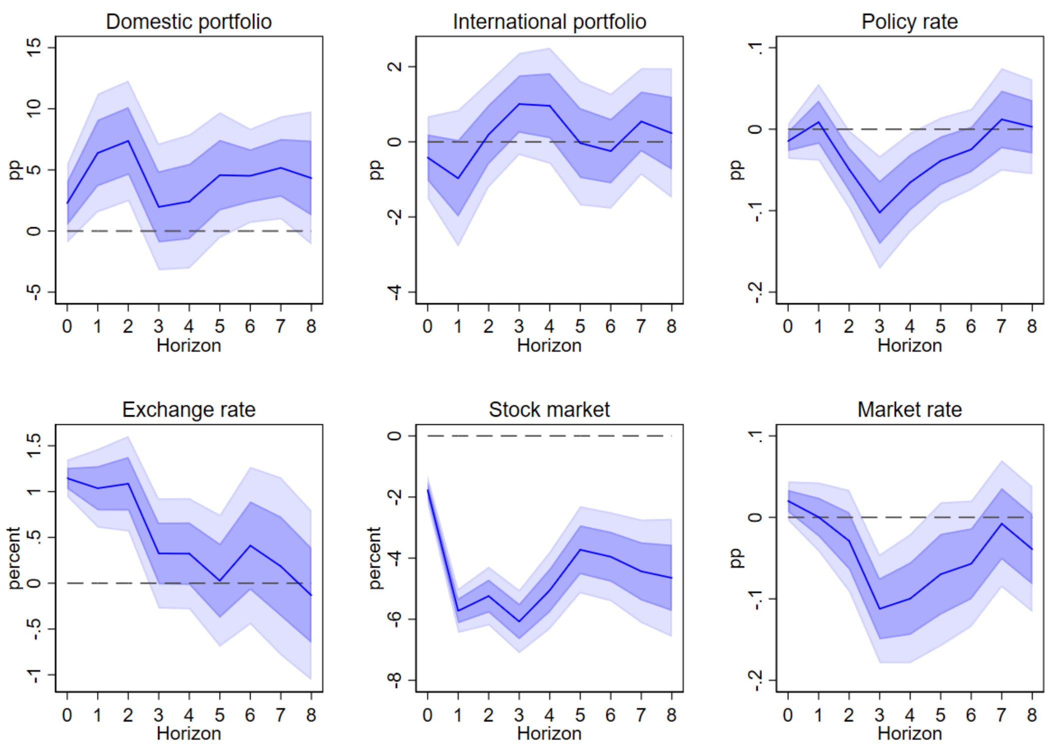
We comment on this figure bearing in mind the results of the first globalization. As in the case of floating countries prior to 1914 in figure 6, the exchange rate reacts strongly (the results in figure 10 are much moresignificant). However, the specificity of the second globalization lies in the fact that several other key variables also react. Crucially, the domestic portfolio also reacts strongly. The reaction is immediate and, one month after a US monetary policy shock, the central bank's domestic asset growth rate is 10 percentage points higher than usual. International reserves, by contrast, do not react. Taken together, these results suggest that the central bank is not trying to stabilize the exchange rate, but the money market rate. This hypothesis is confirmed by the positive reaction of the money market rate, which is immediate after the shock, but very weak (less than 10 basis points), and then quickly disappears. Expansion of the central bank's domestic portfolio therefore keeps the money market rate in line with the official interest rate. Moreover, as already shown in Miranda-Agrippino and Rey (2020); Degasperi, Hong, and Ricco (2023), the central banks decrease their policy interest rate few months after the shock. This is likely to be a reaction to falling output growth caused by the rise in the US interest rate. Our results demonstrate that this decrease in the target rate of central banks is accompanied by the expansion of the domestic assets. In contrast to the case of floating countries during the first wave of globalization, the exchange rate is not sufficient to absorb the international shock, and the central bank must increase domestic liquidity. In other words, the reactions of central bank balance sheets today are more important than ever before.

Figure 10 presents another important result. Before the First World War, exchange rate movements or interventions on the foreign exchange market were sufficient to control the effect of an international interest rate shock on the domestic stock market. This has no longer been the case since the 1990s. This result is consistent with those of Miranda-Agrippino and Ricco (2021); Degasperi, Hong, and Ricco (2023); Monnet and Puy (2021) who find a significant reaction of world asset prices to shocks from US monetary policy, even in countries with floating exchange rates. Our results rationalize this finding. Money market rates do not rise because the central bank's elastic currency provides liquidity to the interbank market. But this is not enough to stabilize asset prices.

[27] In Scandinavia and most European Union economies, full capital account liberalization was achieved in the early 1990s - rather than in the 1980s - and temporary capital controls were reinstated during the 1992-1993 exchange rate and banking crisis (Bakker (2012)).

What explains that we find equity prices to decrease today but not in the past? One main reason comes to mind. The risk-taking channel of monetary policy, i.e., the argument advanced by Bruno and Shin (2015); Miranda-Agrippino and Rey (2020) to explain why there is a global financial cycle today - irrespective of the exchange rate regime - depends on global financial intermediation. It relies on the idea that global banks and other financial intermediaries are forced to rebalance their portfolio as a result of higher financing costs resulting from a US monetary policy shock. Yet bonds and securities before 1914 were largely held by individual investors (Mauro, Sussman, and Yafeh (2002)). Consequently, in the past, we should not expect a portfolio rebalancing which is the driving force behind the reaction of today's equity prices to an international monetary policy shock. This explanation is consistent with the study of Mauro, Sussman, and Yafeh (2002) that found that bond yields across countries were much more correlated in the second globalization (the 1990s) than before World War I.

Figure 10: Second globalization, floating countries without capital control. Advanced economies (1994-2019)



Note: Panel local projections including 6 lags. Response to the exogenous Fed policy rate shock of Bauer and Swanson (2023b). The responses of both domestic and international portfolios are in 12-month variation. The international portfolio valuation is set in special drawing rights. The set of local projections also includes the global real activity index (Kilian (2019)), the countries' industrial production indices, the countries' price indices, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

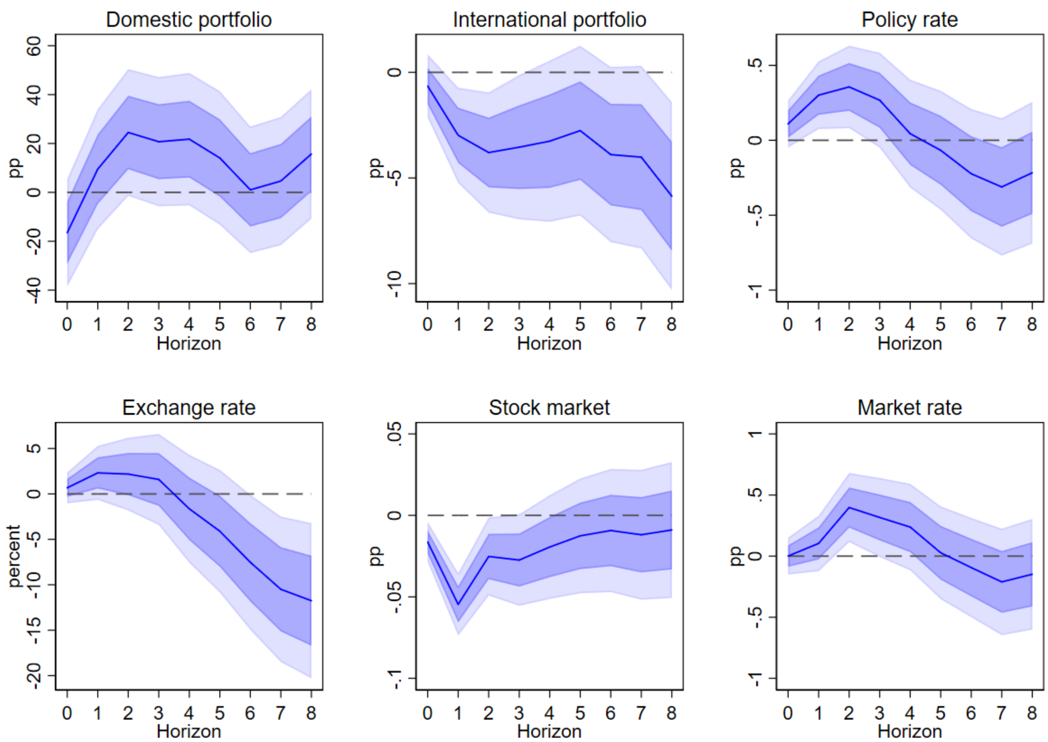
The comparison between the first and second globalization has highlighted the changing role of central banks in the international monetary system. In the past, short-term changes to the central bank's balance sheet rounded off the corners of the trilemma. They now play another role: that of managing the dilemma. Of course, this does not mean that the exchange rate regime no longer matters, and that sterilized intervention in the foreign exchange market is a thing of the past. Many countries are still in this situation. Yet our previous analysis underlines that the reaction of the central bank's domestic portfolio under a floating exchange rate regime is a new phenomenon in a long-term perspective, and characteristic of advanced economies in the second financial globalization.

5 .5 Today's emerging markets

Our dataset covers six countries that are today characterized as "emerging markets" and for which we could collect data since the 1930s: South Africa, Chile, Mexico, Colombia, Argentina, India. As a large literature has already emphasized, these countries are difficult to characterize today in terms of exchange rate regimes and capital account openness. They are partly open but sometimes apply temporary or even semi-permanent measures to control capital flows. Their exchange rate regime is more typical of a managed float (Ilzetzki, Reinhart, and Rogoff (2019)), especially since the early 2000s, after Mexico ended its hard peg and Argentina its currency board. Following the literature (e.g. Kalemli-Özcan (2019); De Leo, Gopinath, and Kalemli-Özcan (2022); Huertas (2022); Degasperi, Hong, and Ricco (2023), we consider them in a single group while acknowledging that their exchange rate regime and capital account openness do not correspond to a typical corner case of the macroeconomic trilemma.

The results we find on Figure 11 are in line with the recent literature on the transmission of US policy shocks to those countries. As previously, including the central bank balance sheet in the figure sheds light on the responses of other variables. The international portfolio reacts strongly and significantly, while the exchange-rate does not; a typical feature of a managed float regime. As highlighted in the literature on the global financial cycle and US monetary policy, asset prices fall sharply. Contrary to advanced economies during the same period (see Figure 10), the central bank and the money market rate increase strongly, by 30bp and 45bp respectively. As already noted by De Leo, Gopinath, and Kalemli-Özcan (2022), the money market rate increases more than the central bank rate. This is consistent with the lack of significant positive response of the domestic assets of the central bank that we observe on 11. Domestic assets actually decrease at the time of the shock, before increasing

Figure 11: Responses to a US Federal Reserve shock. Emerging markets. 2002-2019



Note: Panel local projections including 6 lags. Response to the exogenous Fed policy rate shock of Bauer and Swanson (2023b) The responses of both domestic and international portfolios are in 12-month variation. The international portfolio valuation is set in special drawing rights. The set of local projections also includes the global real activity index (Kilian (2019)), the US industrial production index, the countries' industrial production indices, the countries' the price indices, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

after 2 months, strongly but insignificantly.

Although De Leo, Gopinath, and Kalemli-Özcan (2022) cannot show empirically the absence of response of the CB domestic assets given their data, their theoretical argument is consistent with our findings. Central banks in emerging markets lack a proper way to fully affect banking conditions through open market operations, or/and they conduct unsterilized foreign exchange interventions that give priority to the stability of the exchange rate at the cost of a higher interest rate (Huertas (2022)). Lacking a significant reaction of the central bank domestic portfolio, and being less credible than historical exchange rate regimes such as the classical and interwar gold standard, these countries have to increase their interest rate strongly, at a higher level than pegged advanced economies before World War II.

6 Further discussion and robustness checks

We first consider whether our main empirical results could be due to a valuation effect, i.e. a change in the value of CB assets caused mechanically by the change in the international interest rate. We explain that this only concerns international assets (whose accounting rules differ from domestic assets) and countries with a *de jure* floating exchange rate in the more recent periods. Thus, none of our previous results on domestic CB assets are affected. To assess whether valuation effects can bias the response of the CB's international foreign exchange assets, we first discuss central bank accounting rules in detail, then compare response functions with three different valuations of foreign exchange assets: in SDR (our benchmark measure for the post-war period), in USD and in local currency.

A last subsection demonstrates that our main results are robust to different choices of sample periods and exogenous monetary policy shocks.

6 .1 Accounting rules and the revaluation of assets

6 .1.1 Domestic assets

Central bank domestic assets are always recorded at book value, i.e. at the price at which they were purchased. They are therefore not affected by valuation effects. Historically, there have been few cases when domestic assets have been suddenly revalued however. The main ones concern a few countries (e.g. Belgium in 1926, France and Italy in 1928) which revalued their gold reserves when they returned to the gold standard and took advantage of this opportunity to reduce the nominal volume of the public debt they held. Thus, the change in the value of the international assets had a mechanical effect on the value of domestic assets in such cases. Another important case in our sample concerns the eurozone countries. It was agreed that they would revalue their national assets at market value with entry into the Euro in January 1999. We apply the same caution to other types of accounting change, such as the 2006 reform at the Bank of England, which increased the balance sheet (both assets and liabilities) by extending the number of financial institutions that can hold deposits with the central bank. In these cases, we fix a missing value for the month in which the accounting change took place. In this way, we avoid calculating a monthly growth rate induced by this accounting change.

6 .1.2 International assets

Very different accounting rules apply to international assets, especially in floating exchange rate regime. In fixed-exchange regime, the international assets are valued at the fixed-parity (or cross-parity). This principle also applied to gold reserves under the Bretton Woods system. Therefore, in pegged economies, foreign exchange assets are only revalued when the currency is revalued. For this reason, central bank losses due to revaluations of FX reserves were very rare before the end of the Bretton Woods system (Humann, Mitchener, and Monnet (2024)). They only occurred when the reserve currency country devalued - England in 1931 and 1967 - which forced other countries to decrease the value of their foreign reserves denominated in local currency.

The difficulties are much greater when a country is floating. International assets can be revalued for two reasons: i) changes in the market price of the asset; ii) changes in the exchange rate. It is impossible to avoid the resulting biases entirely, but we can reduce them considerably by using alternative measures (see below). We also establish the direction of the bias.

Biases go in the following directions. i) If the market price of securities (or gold) is influenced by the international interest rate, the price - and therefore the value of international reserves - falls when the international interest rate rises. This is true regardless of the currency in which the reserves are denominated. Yet, as we discuss below, the accounting of such losses is not immediate, and the variations in the market price of securities are usually much lower than fluctuations of exchange rates. ii) If a central bank holds foreign exchange reserves in the dominant currency (e.g. the dollar today), the latter will appreciate after a rise in the international interest rate. As a result, the value of international reserves rises if they are denominated in local currency, but it does not change if international reserves are denominated in the dominant currency (USD). . If the central bank holds reserves in a currency other than the dominant currency (e.g. the yen or the euro today), the value of these currencies depreciates against the dominant currency (the dollar today). The value of international reserves held in other currencies but denominated in USD will fall. As we explain below, using reserves denominated in SDR can partially avoid this valuation effect since the SDR is a basket of reserve currencies.

Other important characteristics of FX reserves management and accounting rules must be considered. It is important to note that most central banks do not revalue their international assets on a monthly basis. In the past, they did so on an annual basis (Humann, Mitchener, and Monnet (2024)). Since the late 1990s, it has become standard practice to revalue them on a quarterly basis.[28]

When securities are revalued, the new valuation takes into account the new exchange rate and the new market price. It is important to note that valuation gains and losses are recorded in a separate account on the liabilities side, called the "revaluation account". Thus, sight liabilities (banknotes and bank reserves, i.e. time series 3 and 4.1 in our dataset) are not affected by revaluation.

Equally important, central banks - or other authorities managing foreign exchange reserves - now calculate their reserves both in local currency (as published in the central bank's balance sheet) and in dollars (as sometimes published on their website and always sent to the International Monetary Fund). The IMF also publishes the value of each country's international reserves in Special Drawing Rights (SDRs), i.e., in a basket of currencies. Currently, the weight of the US dollar in this basket is 43.38%. The IMF also publishes a series of gold reserves at constant prices, which is useful for our purpose.

Swap lines appear as international reserves on the balance sheet of the issuing central bank. This only concerns the US Fed in our sample (mainly since 2008), and is therefore not a problem. [29] They appear on the liabilities side of other central banks as non-resident deposits, which can be distinguished from the reserves of resident financial institutions (4.1).

Finally, central banks are known to invest their foreign portfolios in very safe assets. One consequence of this is that the market price of these assets varies much less than the standard share price. As a result, central bank documents clearly indicate that the bulk of revaluation variations are due to the exchange rate rather than to changes in the market prices of securities.[30] The literature on central bank losses - which are generally mainly due to exchange rate revaluations as a result of currency appreciation - also confirms this (Humann, Mitchener, and Monnet (2024)).

6 .1.3 Alternative specifications and robustness checks

These key institutional details and accounting rules allow us to account for potential biases in foreign exchange valuations as follows:

[28]See,for example, the clearly explained accounting rules of the Eurosystem central banks(https://www.ecb.europa.eu/pub/pdf/other/wfs-userguide.en.html) and those of the Swedish central bank (https://www.riksbank.se/en-gb/markets/riksbanks-balance-sheet/the-riksbanks-accounting-principles/).

[29]The ECB also offers swap lines, albeit to a lesser extent. But these lines appear on the balance sheet of the ECB itself, and not on the balance sheets of the national central banks in our sample

[30]See, for example, this ECB document, https://www.ecb.europa.eu/pub/pdf/scpops/ecbocp111.pdfp.5;15-16.

1. In all cases, we can isolate the revaluation account on the liability side and check that the expansion of domestic assets is indeed associated with money creation (expansion of liquid liabilities).

2. Given that foreign exchange reserves are generally revalued on a quarterly basis, the bias is unlikely to be immediately apparent when we use reserves denominated in domestic currency.

3. We use three alternative definitions of international reserves: in SDRs (published by the IMF), in USD (published by the IMF) and in domestic currency (as they appear on central bank balance sheets). It should be noted that (as explained in section 3) IMF data are more complete, as they include all reserves held by monetary authorities. Gold is valued at a constant price by the IMF. Reserves in domestic currency are subject to all the types of bias mentioned above (which can cancel each other out), including fluctuations in the price of gold. Reserves in USD have the advantage that their value is not affected by the exchange rate between the dollar and the domestic currency. However, they are affected by fluctuations in the exchange rate between other reserve currencies (e.g. yen, euro) and the dollar. Given that our sample includes Nordic countries that hold a substantial proportion of their reserves in euros, this bias may be non-negligible. For this reason, we prefer to use SDR reserves, since the SDR is a basket of all major international currencies.

Our robustness checks below focus on the recent period (post-1990) since biases are more likely to be strong today, both because gold reserves are less important in total international reserves and because central banks revalued their foreign assets more frequently.

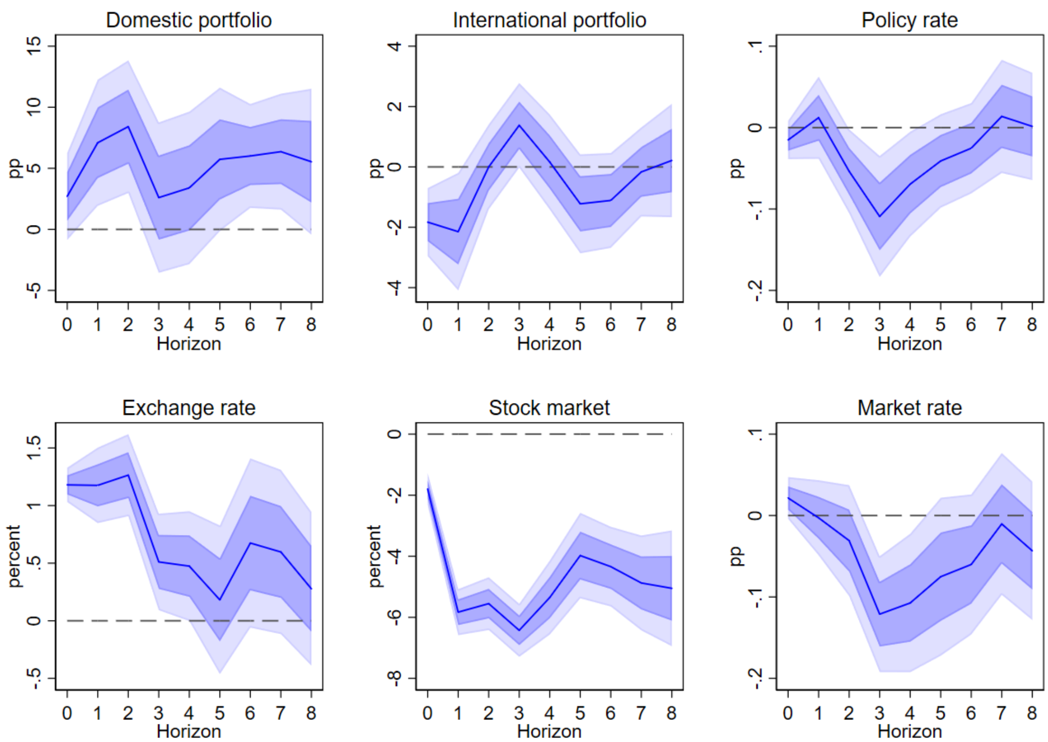
First, we check that the response of the liquid liabilities (banknotes + bank deposits) - excluding revaluation accounts - of the central bank is consistent with our interpretation of the response of the domestic assets. Figure A.7 in the appendix confirms the conclusion of the previous section: in the second globalization, central banks of advanced economies do inject liquidity (i.e. create money) to influence the money market rate, while it is not the case in emerging markets.

Second, the results presented in figure 13 show that our conclusions are similar over the period 1994-2019, in our panel of advanced economies, if we use reserves in local currency rather than in SDR (please note that the sample is slightly smaller in this case since it excludes countries whose foreign exchange reserves are managed by a special fund). As expected, the response of international reserves valued in local currency shows an upward bias, but it remains non significant. However, as displayed on figure 12, foreign exchange reserves expressed in USD react negatively to the shock. As explained above, this is due to the fact that reserves held in other currencies depreciate against the dollar after an increase of the US interest rate.

Figures A.9 and A.8 in the appendix show the same robustness checks for our sample of emerging markets. As before, we find a stronger and more significant negative reaction when foreign exchange reserves are in USD, and suspect a valuation bias in this case. As expected, the valuation bias goes in the opposite direction (i.e. is positive) when using international reserves in local currency, so that the decrease in international reserves is only observed 7 months after the shock. As in previous cases, these valuation effects affecting international reserves have no effect on the other variables.

These robustness checks have shown that none of our previous conclusions are called into question when we consider the effects of the valuation of foreign exchange reserves. However, they also show that valuation biases exist in countries that have adopted a floating exchange rate regime in recent periods. This has important implications for other studies. There is a downward bias after an international monetary shock if reserves are denominated in USD and an upward bias if they are denominated in domestic currency. Using SDR-denominated reserves offers a safer - albeit imperfect - option.

Figure 12: Responses to a US Federal Reserve shock. Floating countries without capital controls. Advanced economies, 1994-2019. Robustness check with international assets denominated in USD



Note: panel local projection identical to figure 10 but with foreign exchange reserve denominated in USD.

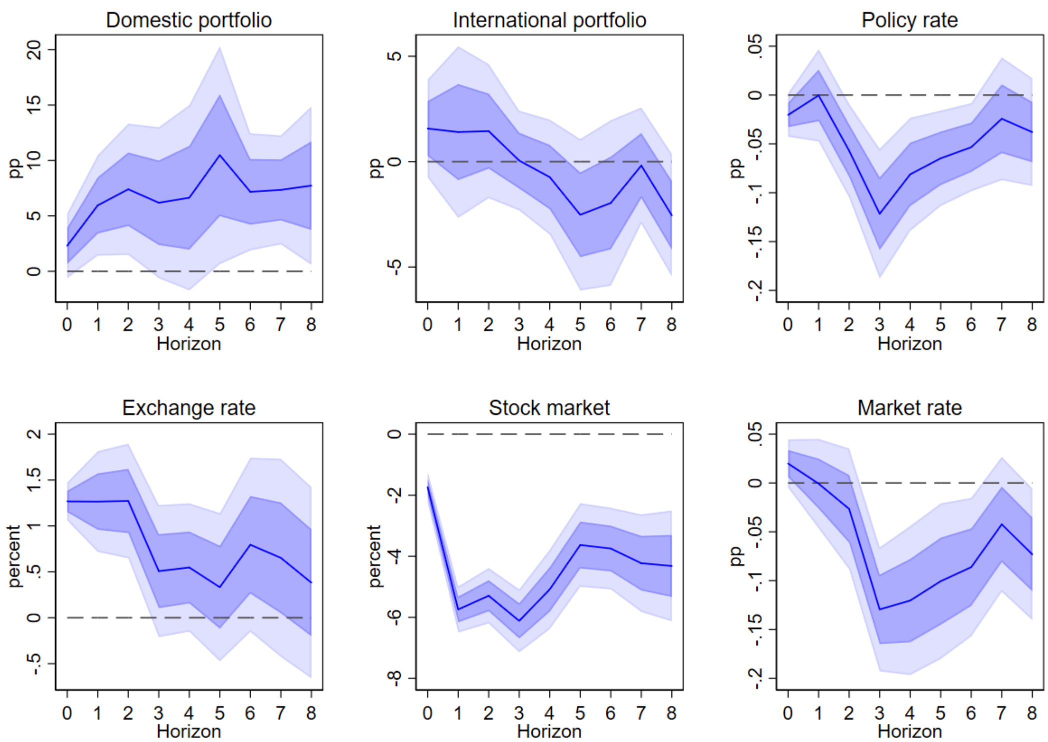
6 .2 Alternative samples and monetary policy shocks

In this section we discuss several robustness to our results. First, we build our own series for Bank of England monetary policy shocks during the gold standard. Instead of using the series of Lennard (2018), we use the same strategy as we did for other periods and apply it to England from 1891 to 1913. This allows to test both the quality of the results displayed in figures 5 and 6 but also the pertinence of the methodology used to produce our shock.

In fact, Lennard (2018) applied only the second step of the identification procedure we followed in section 3 , while also incorporating the monthly exchange rate in this second step. We thus complement this by our first step with daily data. For this reason, we expect our shock to be more exogenous since we account for market anticipations on a daily basis, rather than monthly.

Figures A.10 and A.11 show that the results are fully in line with our previous calculation

Figure 13: Responses to a US Federal Reserve shock. Floating countries without capital controls. Advanced economies, 1994-2019. Robustness check with international assets denominated in domestic currency



Note: panel local projection similar to figure 10 but with foreign exchange reserve valuation in domestic currency. Error bands correspond to the 68% and 90% confidence intervals.

based on Lennard's shock. We still observe a decline in the international portfolio and a rise in the domestic portfolio for pegging countries. This also coincides with the limited rise in the discount rate and a slight depreciation of the exchange rate. Our results for floating countries also displayed a full depreciation suggesting that the shock is fully absorbed through the exchange rate.

In a second robustness check, we extend the estimation sample for the second globalization period. So far, our analysis started when most advanced economies in our sample had fully opened their capital account in the early 1990s. But the shock produced by Bauer and Swanson (2023b) allows to extend the analysis back to 1988. Figure A.12 displays the results using this extended sample. This extension does not affect our conclusions. The domestic portfolio still reacts strongly while the stock market declines significantly. The only major change concerns the exchange rate, which tends to overshoot after 6 months. We interpret this as a consequence of including the 1992-1993 European exchange rate crisis in the estimation sample.

7 Conclusion

This paper explores the role of central bank balance sheets in taming the effect of international monetary policy shocks over the long run, i.e. since the late 19th century. We follow a well-established approach common to the literature on the macroeconomic trilemma and the global financial cycle, namely analysing the responses of domestic financial variables to a change in the leading international monetary policy rate. To do so, we have constructed a historical dataset of monthly exchange rates, (money market and policy) interest rates, and central bank balance sheets. It is supplemented with monthly data on industrial production, consumer prices and stock market indices. This is the first paper of its kind which relies on monthly data for the entire period 1891-2019.

Our main contribution is to add a dimension not previously considered in the literature, namely the role of central bank balance sheets, and in particular of domestic assets. First, we have documented a systematic expansion of central banks' domestic assets in the face of international monetary shocks in financially open economies since the late 19th century. This expansion can be observed in both floating and pegged economies; in the latter case, the expansions go over and above what is required in the context of the sterilization of foreign exchange interventions. We have explained that these results can be rationalized if we consider that international financial markets are imperfect, i.e. that the UIP does not hold.

Second, examining the reaction of central bank balance sheets helps us to understand how central banks manage to regain a degree of monetary policy autonomy in a financially globalized world. This sheds light on some of the puzzling behavior of interest rates and exchange rates across international monetary regimes throughout history, and in particular on the low pass-through of interest rate changes during the gold standard regimes. Today, the immediate reaction of the central bank's domestic assets help explain why advanced economies with a floating exchange rate do not need to follow a rise of the international interest rate (or even decrease their rate) despite the presence of a UIP wedge exerting pressure on domestic money market rates and other asset returns. In such a case, central banks would not be able to transmit their policy rate changes to the domestic money market - or to keep the policy rate unchanged - without injecting liquidity. In the past, short-term changes to the central bank's balance sheet rounded off the corners of the trilemma. They now play another role: that of managing the dilemma.

Our results pave the way for further research into why some central banks are more effective than others at stabilizing the money market - and possibly other markets - and the implications for the transmission of monetary policy and international financial shocks. From a more general point of view, our historical study has also shed light on the *raison d'être* of central banks, and may explain why these institutions have become ubiquitous. By providing "elastic currency" - to use an expression with a long history in central banking - central banks have demonstrated their ability to act as a cushion, or shock absorber, between the national economy and international financial markets.

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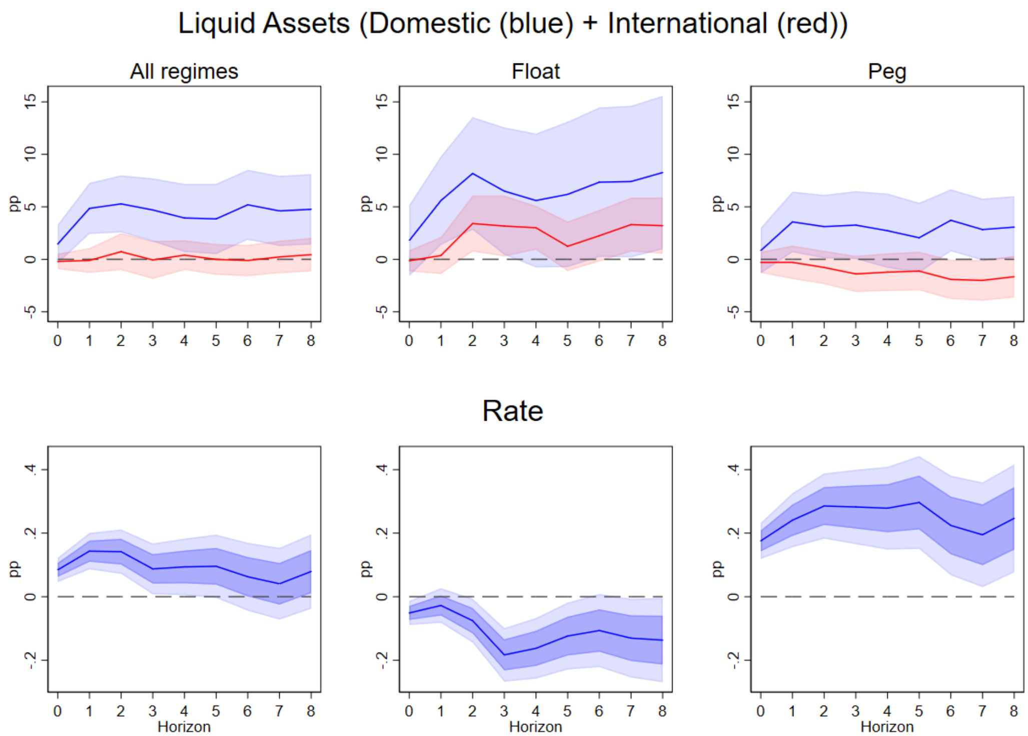
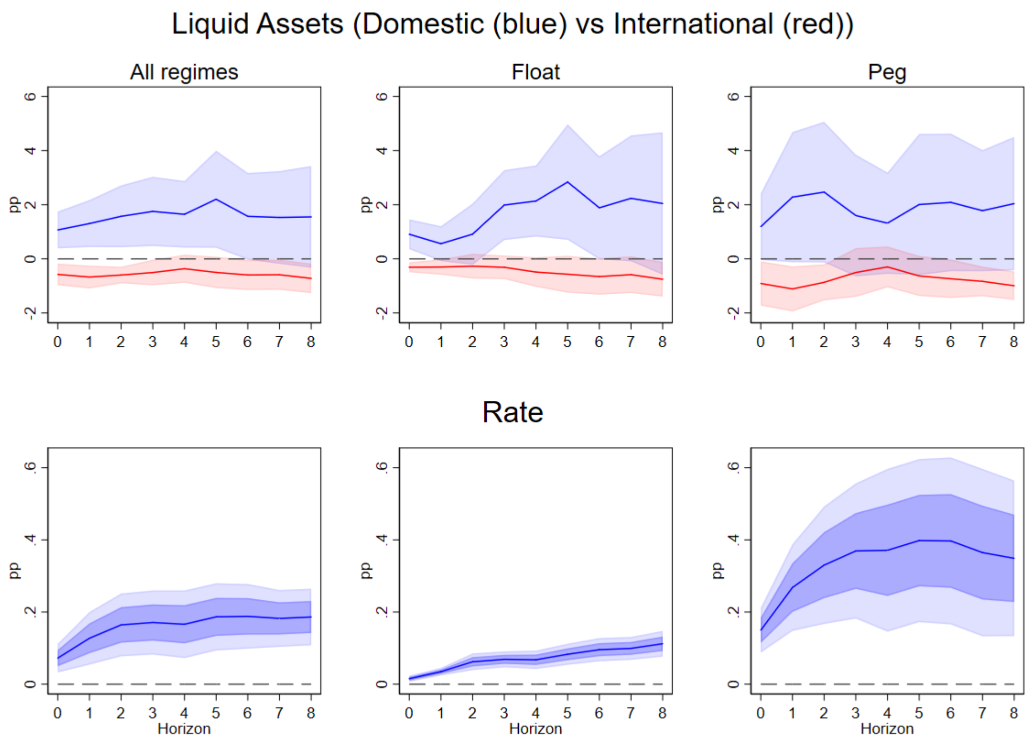
Appendix A Additional figures

Figure A.1: Responses of central bank liquid assets and interest rate to an international shock. Financially open countries. Full sample. International assets valued in domestic currency (LCU)



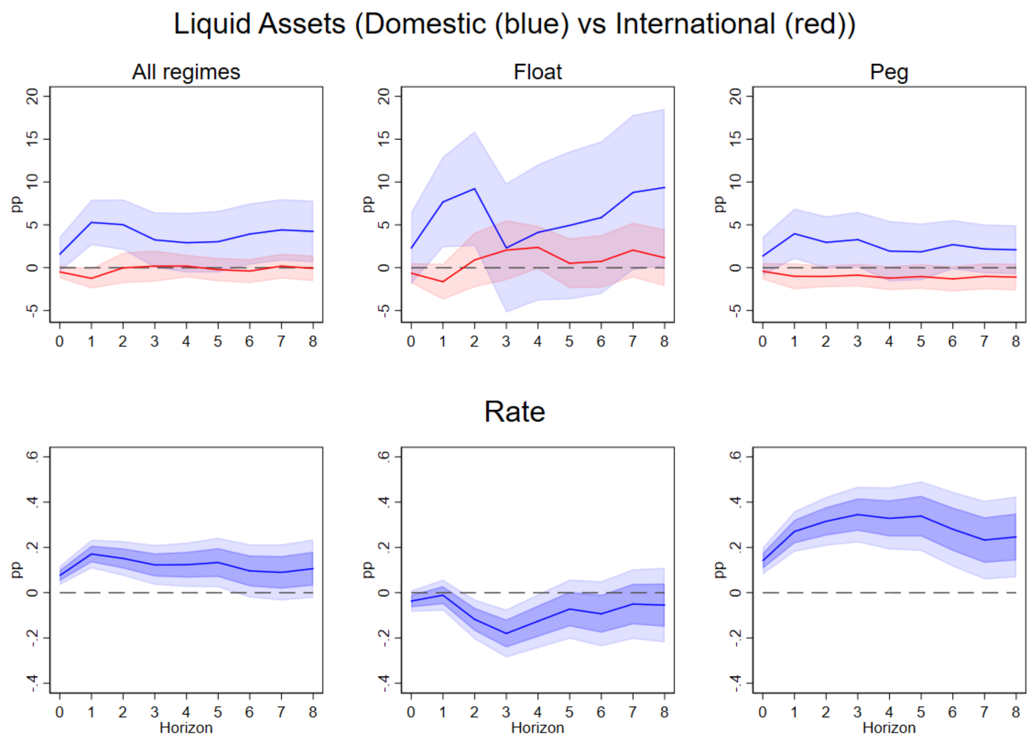
Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate from 1947 to 1971, Fed fund rate from 1973 to 2007, Fed shadow rate from 2007 to 2019) instrumented by a composite shock based on Lennard (2018) for 1891-1913, our own shock for 1924-1931 and 1947-1971, Romer and Romer (2004) for 1973-1987 and Bauer and Swanson (2023b) for 1988-2019. Capital control classification is based on the last update of Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. Exchange rate classification from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% confidence (lower panels) and 90% confidence (lower and upper panels) intervals.

Figure A.2: Responses of central bank liquid assets and interest rate to an international shock. Full sample. Shock to the (endogenous) policy interest rate of the leading central bank.



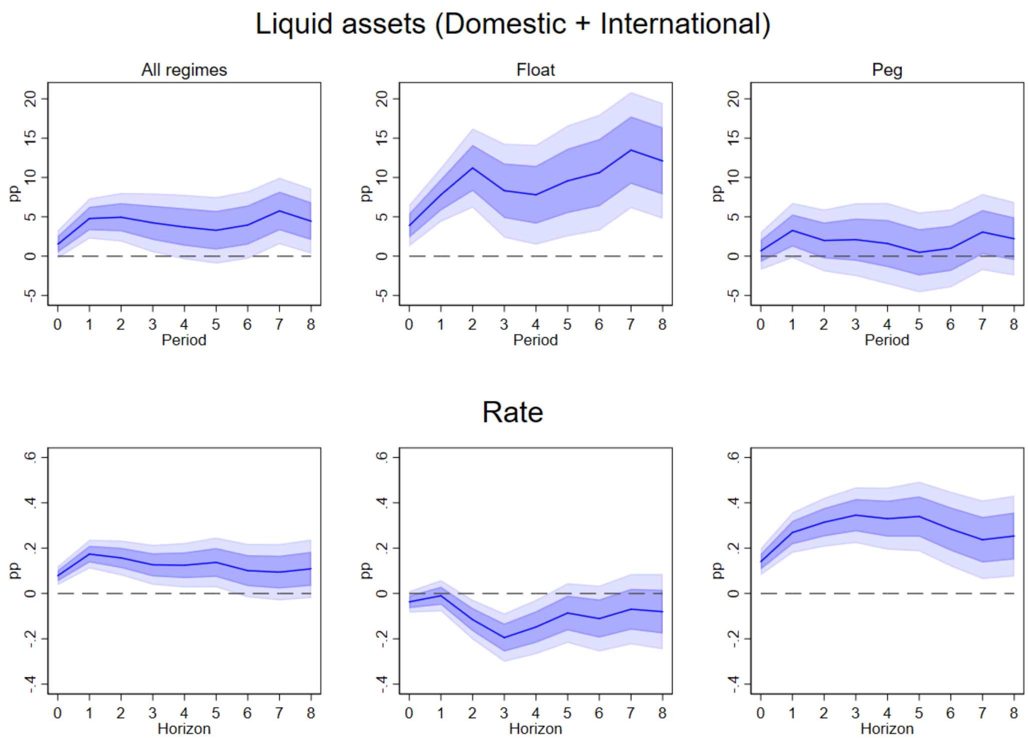
Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate from 1947 to 1971, Fed fund rate from 1973 to 2007, Fed shadow rate from 2007 to 2019). No exogenous monetary policy shock. Capital control classification is based on the last update of Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. Exchange rate classification from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% confidence (lower panels) and 90% confidence (lower and upper panels) intervals.

Figure A.3: Responses of central bank liquid assets (international assets versus domestic assets) and interest rate to an international shock. Financially open countries. Alternative monetary policy shocks. Full sample



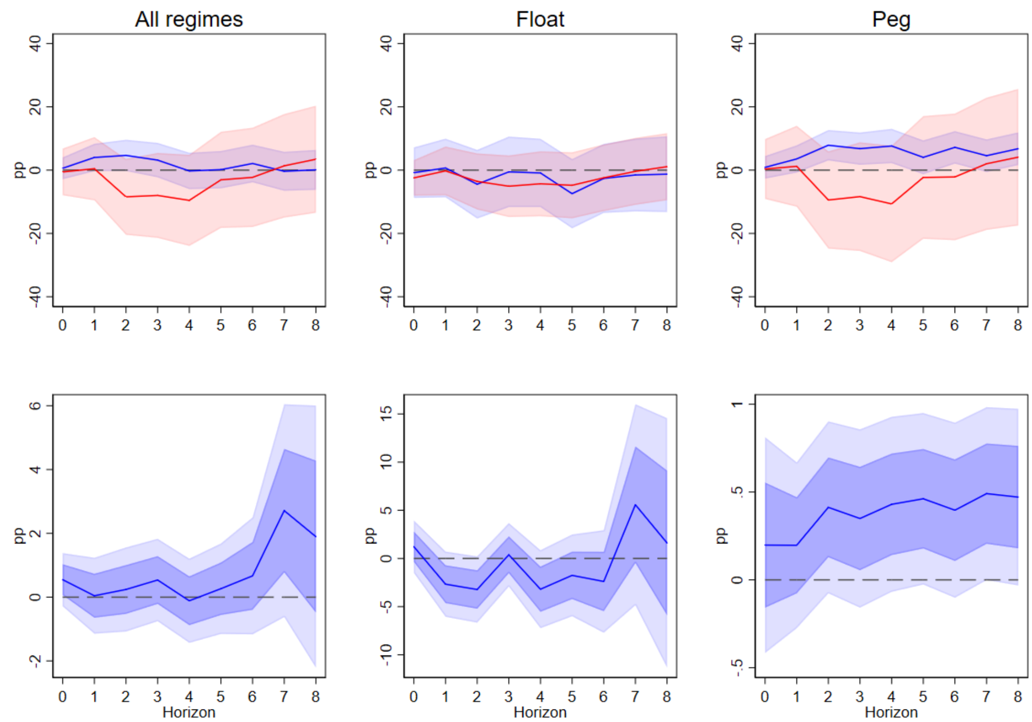
Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate from 1947 to 1971, Fed fund rate from 1973 to 2007, Fed shadow rate from 2007 to 2019) instrumented by a composite shock from our own shock (see section 3 and appendix B) for 1891-1913, 1924-1931, 1947-1971, 1973-1987) and Bauer and Swanson (2023b) for 1988-2019. The capital control classification is based on the last update of Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. The exchange rate classification is from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The international portfolio valuation is in local currency unit until 1956 and in special drawing rights from 1957 onward. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% confidence (lower panels) and 90% confidence (lower and upper panels) intervals.

Figure A.4: Responses of central bank liquid assets and interest rate to an international shock. Financially open countries. Full sample. Alternative exogenous monetary policy shocks.



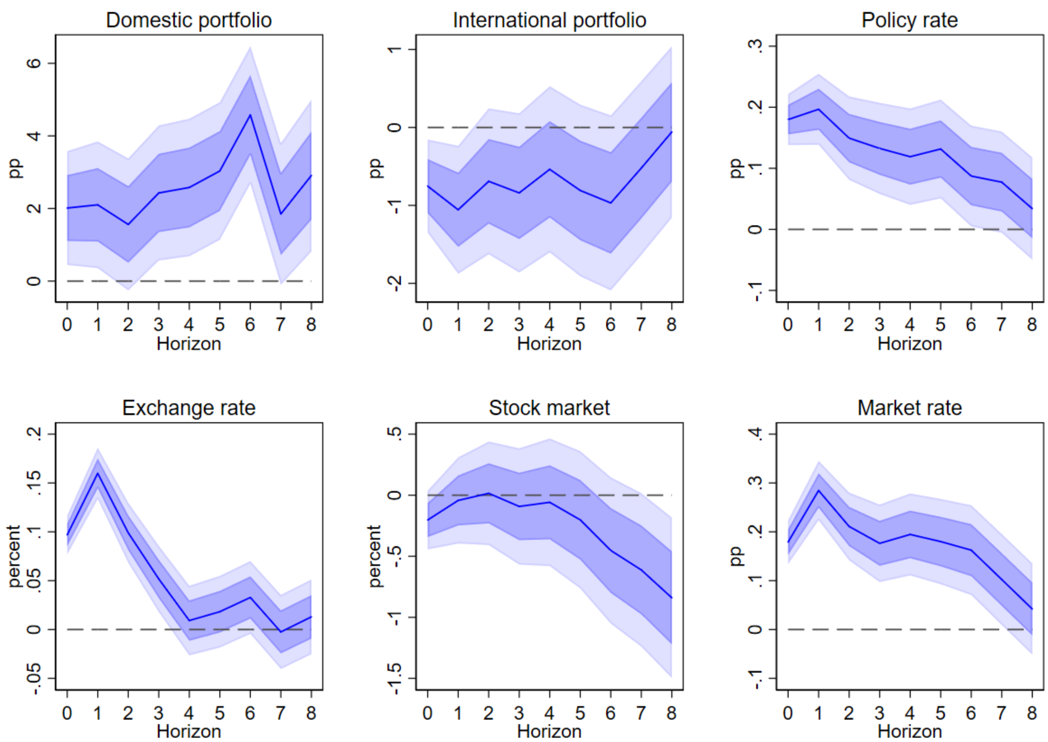
Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate from 1947 to 1971, Fed fund rate from 1973 to 2007, Fed shadow rate from 2007 to 2019) instrumented by a composite shock based on shock constructed in section 3 and appendix B until 1987 and Bauer and Swanson (2023b) for 1988-2019. Capital control classification is based on the last update of Quinn and Toyoda (2008); Chinn and Ito (2008) financial openness index post 1950. Exchange rate classification from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.5: Responses of central bank liquid assets and interest rate to an international shock. Economies with capital controls. Alternative classification of financial openness. Full sample



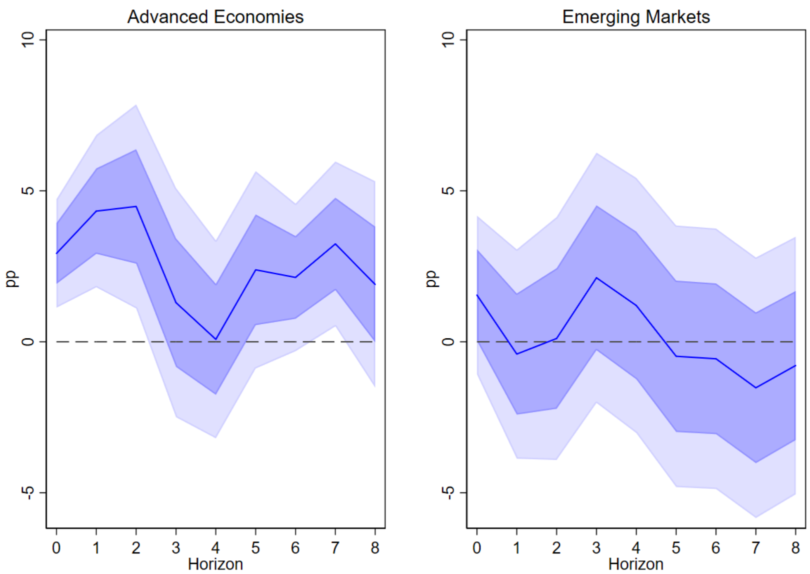
Note: Panel local projections using instrumental variable including 6 lags. Response to a change in the policy rate of the main central bank (BoE for 1891-1913 and 1924-1931, Fed discount rate from 1947 to 1971, Fed fund rate from 1973 to 2007, Fed shadow rate from 2007 to 2019) instrumented by a composite shock based on Lennard (2018) for 1891-1913, our own shock for 1924-1931 and 1947-1971, Romer and Romer (2004) for 1973-1987 and Bauer and Swanson (2023b) for 1988-2019. Capital control classification is from Ilzetzki, Reinhart, and Rogoff (2019) financial openness index post 1950. Exchange rate classification from Ilzetzki, Reinhart, and Rogoff (2019). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the domestic policy rate, the exchange rate, the world business cycle, monthly dummies, a time trend, and country fixed effects. Standard errors are clustered at country level. Error bands correspond to the 68% confidence (lower panels) and 90% confidence (lower and upper panels) intervals.

Figure A.6: Classical gold standard, pegging countries (1891-1913). Core countries with money market rates.



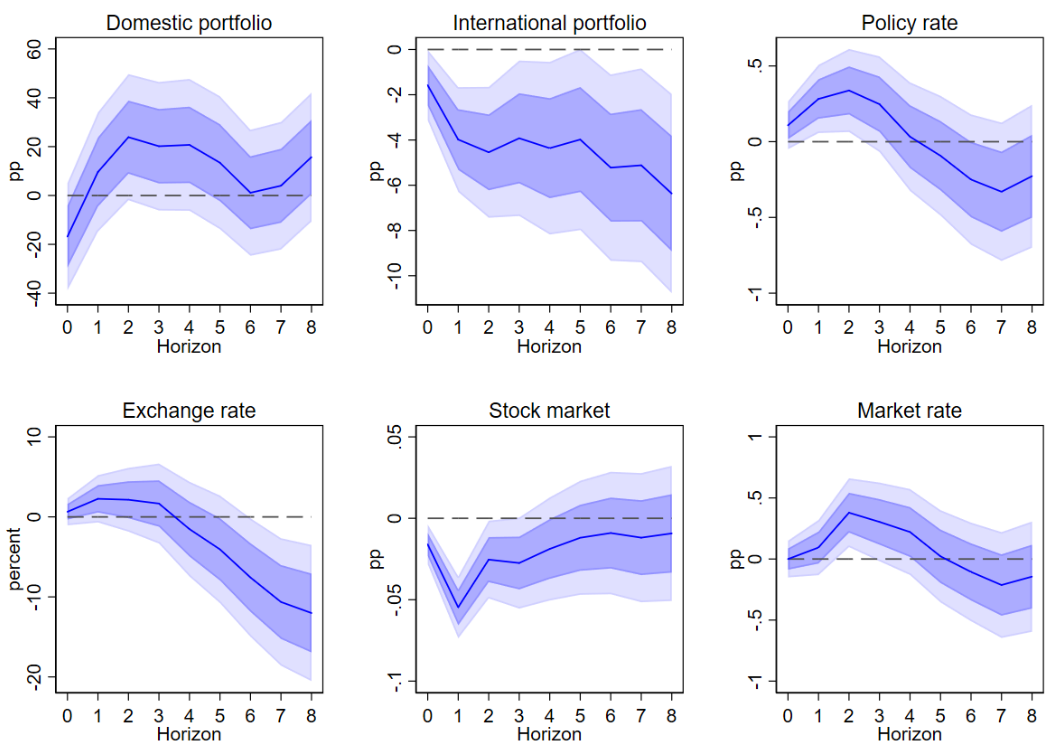
Note: Panel local projections including 3 lags. Response to the exogenous BoE policy rate shock of Lennard (2018). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK business cycle, the UK stock market index, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.7: Second globalization, advanced economies (floating, without capital controls) and emerging markets. Responses of liabilities



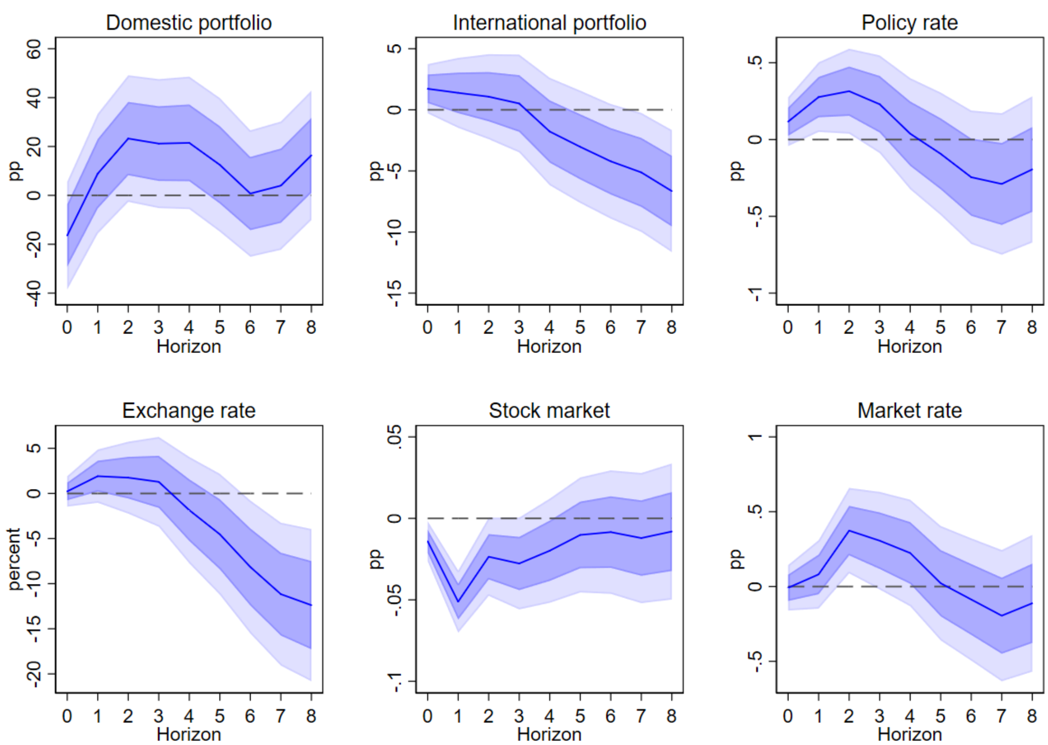
Note: panel local projection similar to figures 10 and 11. Responses of central bank liquid liabilities (excluding revaluation accounts): banknotes + bank deposits. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.8: Second globalization, emerging markets. International assets valued in USD



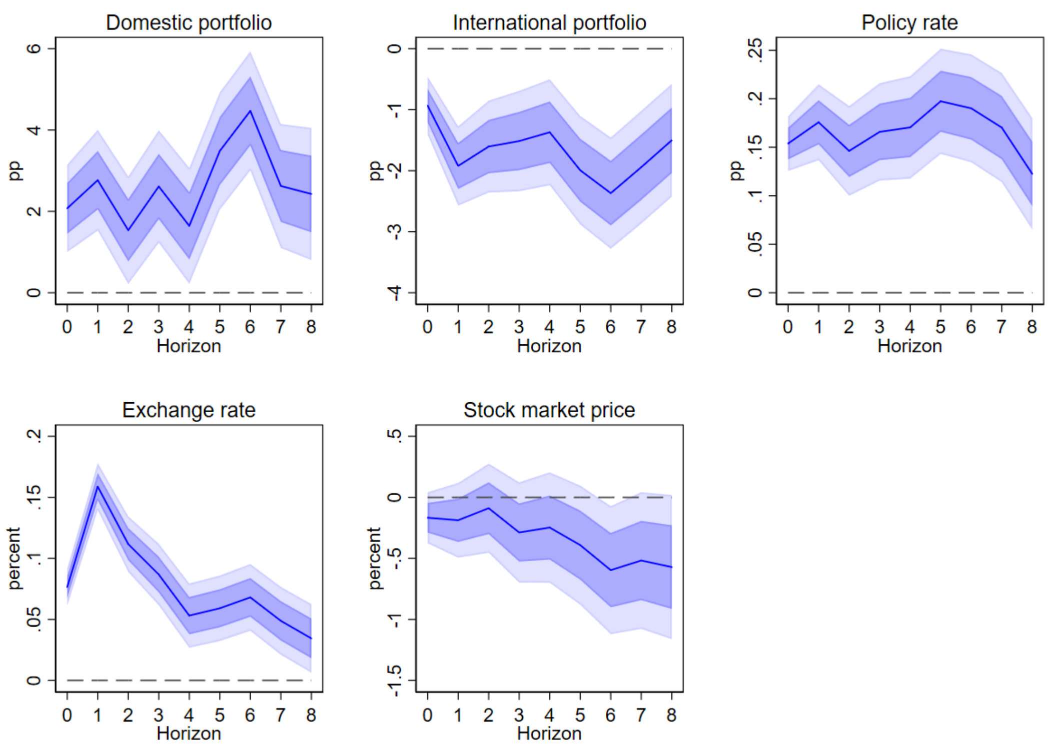
Note: panel local projection similar to figure 11 but with foreign exchange reserve valuation in USD. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.9: Second globalization, emerging markets. International assets valued in domestic currency



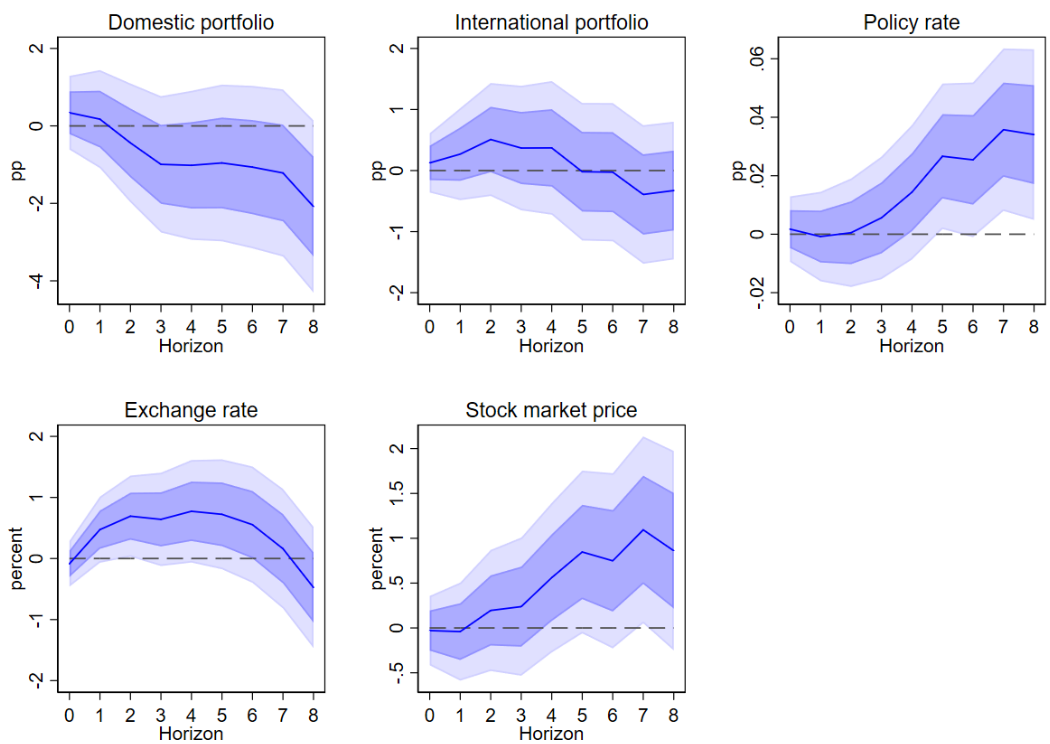
Note: panel local projection similar to figure 11 but with foreign exchange reserve valuation in domestic currency. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.10: Classical gold standard, pegging countries. Alternative monetary policy shock



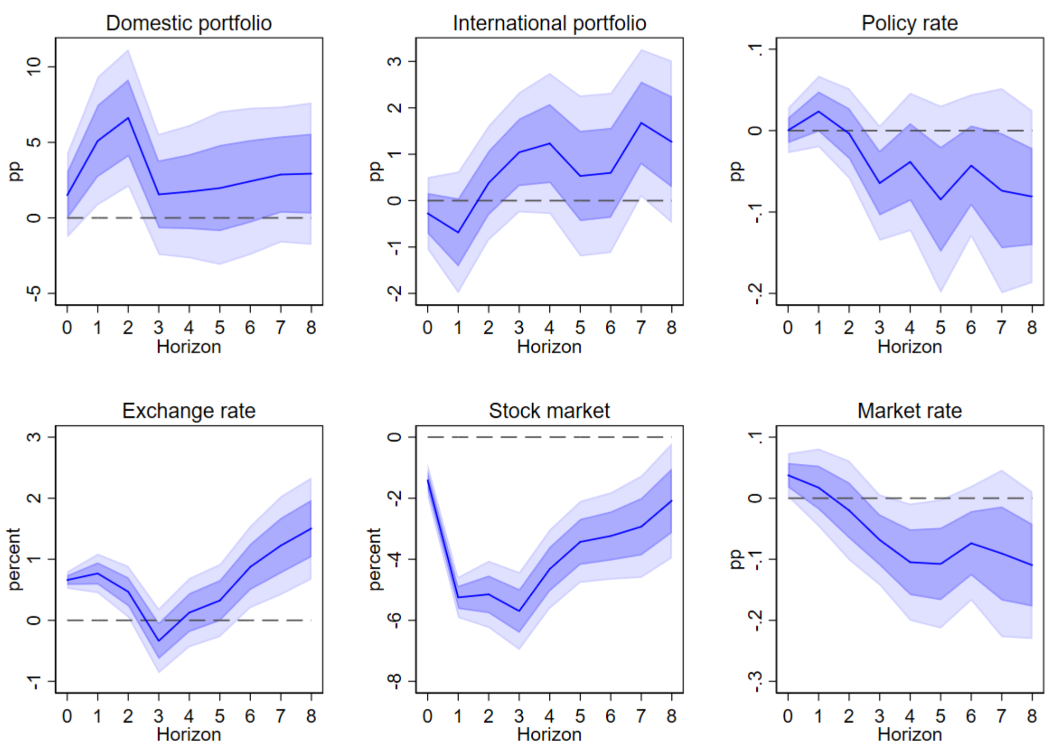
Note: Panel local projections including 3 lags. Response to BoE exogenous monetary policy shock (see section 3 and appendix B). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK business cycle, the UK stock market index, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.11: Floating countries, 1891-1913. Alternative monetary policy shock



Note: Panel local projections including 3 lags. Response to BoE exogenous monetary policy shock (see section 3 and appendix B). The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK business cycle, the UK stock market index, monthly dummies, a time trend, and country fixed effects. Error bands correspond to the 68% and 90% confidence intervals.

Figure A.12: Second globalization, extended sample (1988-2019)



Note: panel local projection similar to figure 10 but with sample starting in 1988. Error bands correspond to the 68% and 90% confidence intervals.

Appendix B Monetary Policy Shocks

This appendix provides information about the new monetary policy shocks that we have estimated and used in the empirical analysis of the paper. Namely, it: (i) lists the set of variables used to estimate a monetary policy shock for each historical period; (ii) compare the estimated monetary policy shock with the policy interest rate of each leading central bank; (iii) shows the responses of the main domestic variables (price, output, and unemployment) to the shock. This last step ensures that our monetary policy shocks leads to impulse response functions of macroeconomic variables which are consistent with the expected effects of an exogenous monetary policy shock.

B.1 Definition of an exogenous monetary policy shock

Building an exogenous monetary policy shock requires estimated the changes in the policy interest rate of the central bank that are neither predicted by the financial and macroeconomic variables that may influence the monetary policy decision nor correlated to the information set of central bankers at the time of the decision. This means to account for the set of confounding variables to ”purge” the policy rate from its endogenous component—that is the one explaining the policy rate and the variables of interest at the same time. In this respect, our methodology follows the ”narrative approach” that seeks to discard the endogenous factors behind central banks' decisions, following the methodology of Romer and Romer (2004) for recent periods, Lennard (2018) for the gold standard era, and Cloyne, Hürtgen, and Taylor (2022) for the European Monetary System. In addition, although we cannot use futures rate to assess monetary policy surprise as done in the most recent literature (Gertler and Karadi (2015), Jarociński and Karadi (2020), Miranda-Agrippino and Rey (2020), Bauer and Swanson (2023a), Bauer and Swanson (2023b)) due to data availability issue, we followed a ”second best” solution. So, we make use of daily frequency variables, primarily the exchange rate and interest rate, to capture the set of relevant market information which may affect the central bank decision in the very short run.

The purpose is to identify an exogenous monetary policy shock, defined as a change in the central bank target interest rate that was not predicted by daily fluctuations in financial markets (interbank, exchange rate and stock markets) and monthly values of macroeconomic and other financial variables. To achieve this, we identify the exact date of each monetary policy meeting (that is the day when the decision is taken to change the target interest rate). When possible, we also use “real time” (or vintage) data, that is statistics available to policymakers at the time of their decisions (i.e. different from revised statistics published ex post).

We thus proceed in two steps. First, we use insights from the literature on high-frequency identification. Our identification relies on the idea that changes in the policy rate which are not driven by exchange rate, stock market (from 1947 onward), and interest rate movements in the day before the decision of the central bank are genuinely exogenous to conditions in these markets. In other words, we assume that financial market prices just before the central bank decision captures the set of relevant information for expectation about this very decision. In this first step, we explain the daily policy rate of the reference country by lagged values of daily market interest rate and exchange rate.

In a second step, we follow the narrative approach to purge the series of movement taken in response to information about the state of the economy. As such we consult different primary and secondary sources to understand the objectives of the central bank and thereby select the set of pertinent variables to account for. Although we lack data on the forecasts produced by the central bank at the time and distributed internally before the central bank meeting (as in Romer and Romer (2004)), we can have access to historical data (production, price indices, reserves, money supply, exchange rates, etc.) that were available to policy makers at the monthly frequency when they took their decision. In this second step, we sum up the residual of the first regression with daily data to produce a monthly index. Then we regress this monthly index on macroeconomic monthly variables influencing the central bank decision. We thus obtain a monthly residual, which is the exogenous policy shock that we will use in our analysis.

We build such new exogenous monetary policy shocks for the Bank of England in the interwar period (1925-1931) and the Federal Reserve under the Bretton Woods era (1946-1971). In addition, we also apply our method to the Bank of England during the classical gold standard (1891-1913) and the Federal reserve after 1973 and compare our impulse response functions to the ones relying on the shock constructed by Lennard (2018), Romer and Romer (2004), and the literature on monetary policy surprises. For each period we propose to use a similar procedure of shock construction based on a similar set of variables. Small differences in the procedure occur due to data availability constraints.

The aim of this appendix is to provide comprehensive information on the construction of the shock, but also to show the response of domestic variables to the shock. As such the response of inflation production and unemployment is used to assess the quality of the shock based on comparisons with the results produced in the conventional literature on the effect of monetary policy.

B.2 Estimation method

This section provides information on the methodology and the set of variables used to build the monetary policy shocks. It distinguishes between daily and monthly frequencies. It also plots the related data and compare it with the raw policy rate change. Table B1 at the end of this document summarizes the variables and their frequency for each sub-period.

We note r_d^{ref} the reference policy rate, y^j the set j daily variables influencing the policy rate the day before each meeting day d, τ the time between two meetings, and x^k the set of k monthly variables influencing the policy rate over the P previous months $m-p$. Explanatory variables appear both in level and in growth rate (or first-difference). [31] The shock calculation is then obtained from a two stages regression as follow:

$$\Delta r_d^{\text{ref}} = \beta_0 + \beta_1 r_{d-1}^{\text{ref}} + \sum_j \gamma_{j,p} y_{d-1}^j + \sum_j \phi_j \Delta_{d-1\to d-\tau} y^j + \epsilon_d \tag{4}$$

$$\Delta r_m^{\text{ref}} = \sum_k \sum_{p=1}^{p=P} \theta_{k,p} x_{m-p}^k + \sum_k \sum_{p=1}^{p=P} \mu_{k,p} \Delta x_{m-p}^k + \epsilon_m \tag{5}$$

With d the meeting date and m the month index. $\Delta r_m^{\text{ref}} = \sum_d \epsilon_d$, that is the sum of ϵ_d within each month. The monetary policy shock is thus equal to ϵ_m.

B.3 Monetary policy shocks for each historical period

B.3.1 Gold Standard

At daily frequency: the dependent variable is the daily rate change of the BoE discount rate agreed upon at the discount committee meeting. Explaining variables are the BoE discount rate and the exchange rate vis-à-vis Paris and Berlin. This is justified by the fact that, in the gold standard, the central bank decision primarily reacts to the exchange rate. The frequency between two meetings is seven days ($\tau = 7$).

At monthly frequency: the dependent variable is the residual of the daily frequency regression summed up for each month. The explaining variables are: the year to year output change (proxied with railways revenues), the annual inflation rate, the unemployment rate,

[31] P has been set according to information criteria.

Gold Standard		Gold Ex. Standard		Bretton Woods		1973-2019	
variables	**Freq**	**variables**	**Freq**	**variables**	**Freq**	**variables**	**Freq**
BoE discount rate	daily	BoE discount rate	daily	Fed discount rate	daily	Fed targeted rate	daily
Exchange rate £/Ff and £/Mark	daily	Exchange rate £/F and £/$	daily	Exchange rate $/£, $/Ff., $/DM, $/Y	daily	Exchange rate $/£, $/Ff., $/DM, $/Y	daily
		Money market rate	daily	Fed funds rate	daily	Fed funds rate	daily
				Treasury Bills yields	daily	Treasury Bills yields	daily
				Dow Jones index	daily	Dow Jones index	daily
Production index (railway)	monthly	Production index	monthly	Production index	monthly	Production index	monthly
Inflation rate	monthly	Inflation rate	monthly	Inflation rate	monthly	Inflation rate	monthly
BoE international reserves	monthly	BoE international reserves	monthly	Fed international reserves	monthly	Fed international reserves	monthly
Unemp rate	monthly	Unemp rate	monthly	Unemp rate	monthly	Unemp rate	monthly
Money market rate	monthly			Bond yields	monthly	Bond yields	monthly
				Stock market index	monthly	Stock market index	monthly
						M3 growth	monthly

Table B1: List of Variables and Frequency across different monetary policy regimes

the money market rate, and the BoE gold reserves. We used four lags in the monthly calculation ($P = 4$).

B.3.2 Interwar (Gold Exchange Standard)

At daily frequency: the dependent variable is the daily rate change of the BoE discount rate agreed upon during discount committee meeting. Explaining variables are: the exchange rate vis-à-vis New York and Paris and the money market rate (3-month commercial paper)

Figure B.1: Monetary policy shock, classical gold standard

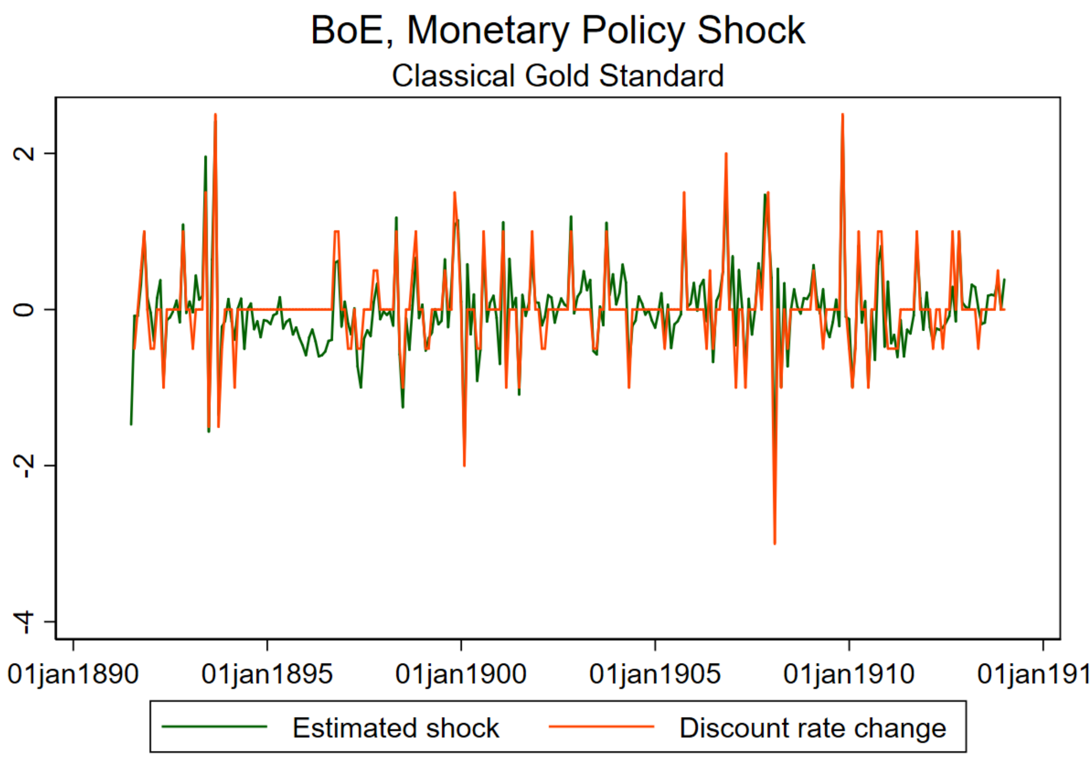
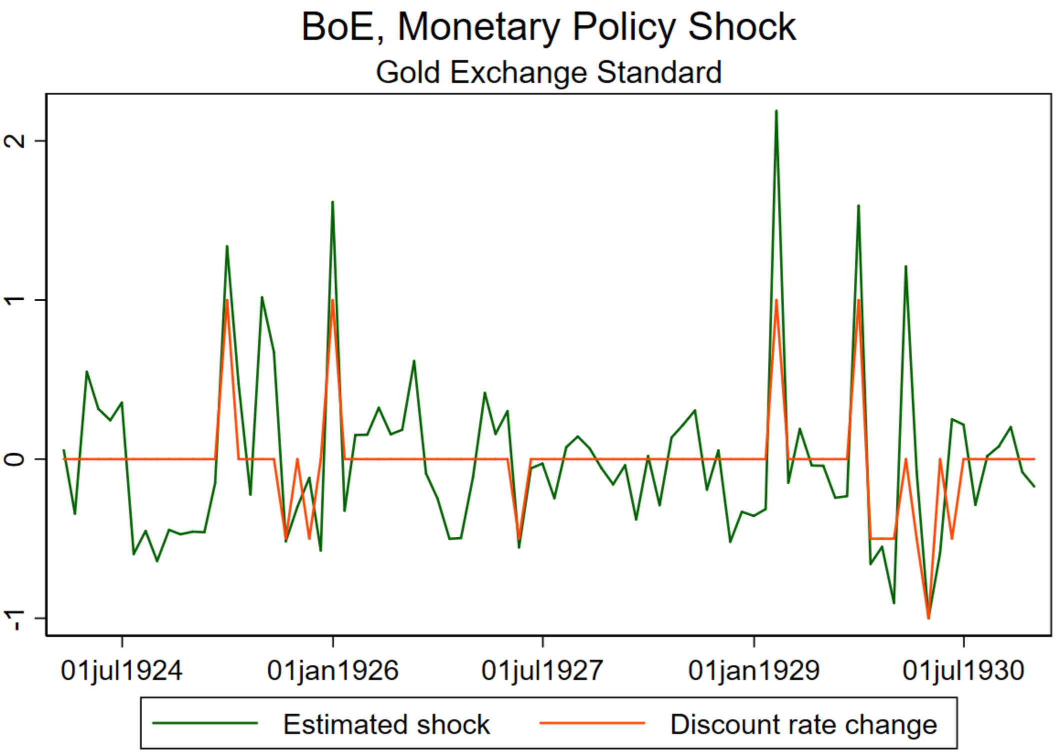


Figure B.2: Monetary policy shock, gold exchange standard



in London The frequency between two meetings is seven days ($\tau = 7$).

At monthly frequency: the dependent variable is the residual of the daily frequency regression, summed for each month. The explaining variables are: the production index, the annual inflation rate, the unemployment rate, and the international reserves of the BoE (gold and foreign exchange). We used 4 lags in the monthly calculation ($P = 2$).

B.3.3 Bretton Woods

For the Bretton Woods, we use the discount rate as the targeted rate of the US Federal Reserve (Fed). The Fed also started to look at the Fed Funds rate - a money market rate - from the late 1950s onward and to use it officially as a target rate in 1982, but the neglect of the discount rate as a policy rate did not materialize before the second half of the 1970s and the intended Fed Fund rates were not used before 1969. The discount rate was clearly the key interest rate that foreign central banks looked at in their meeting and official publications. Although we consistently use the discount rate as the targeted rate until 1971, we include the daily Fed Funds rate in the first step starting 1954 when it is recognized that it reflects well the conditions of the money market. For that reason, the estimation is divided into two sub-periods with 1954 as the changing year.

At daily frequency: the dependent variable is the daily rate change of the Fed discount rate agreed upon during discount committee meeting. Explaining variables are: the exchange rate vis-à-vis London, Paris, Berlin (after 1954), and Tokyo (after 1954), the Fed Fund rate (after 1954), Treasury bill yields (after 1954) and the Dow-jones index. The time between two meetings is 14 days ($\tau = 14$).

At monthly frequency: the dependent variable is the residual of the daily frequency regression, summed for each month. The explaining variables are: the production index, the annual inflation rate, the unemployment rate, the Fed international reserves, the market index, the bonds yield, and, before 1955, the set of variables unavailable at daily frequency. It is finally worth noting that we used vintage data for inflation and production in the estimation. This allows to account for the information available to the central bank in the moment of its choice. We used 4 lags in the monthly calculation ($P = 2$).

B.3.4 Post Bretton Woods (1973-2019)

At daily frequency: the dependent variable is the targeted Fed Fund rate agreed upon during FOMC meeting. Explaining variables are: the lagged value of the initial intended Fed fund rate, the lagged exchange rate vis-à-vis London, Paris, Berlin, and Tokyo in level and variation, Treasury bills yield and the Dow-jones index in level and variation. FOMC meeting day does not follow a fixed frequency so that the time between two meetings can change.

At monthly frequency: the dependent variable is the residual of the daily frequency regression, summed for each month. The explaining variables are: the production index the annual inflation rate, the unemployment rate, the FED international reserves, the market index, the bonds yield, and the broad money indicator (M3). We used vintage inflation and production in the estimation to account for the information available to the central bank in the moment of its choice. We used 2 lags in the monthly calculation ($P = 2$).

B.4 Responses of domestic variables to each monetary policy shock

The aim of the exercise is to calculate the response of key macroeconomic variables in order to verify that our monetary policy shocks (MPS) produce effects that are close to the conventional results in the literature on the effects of monetary policy shocks. For that reason, we

Figure B.3: Monetary policy shock, Bretton Woods

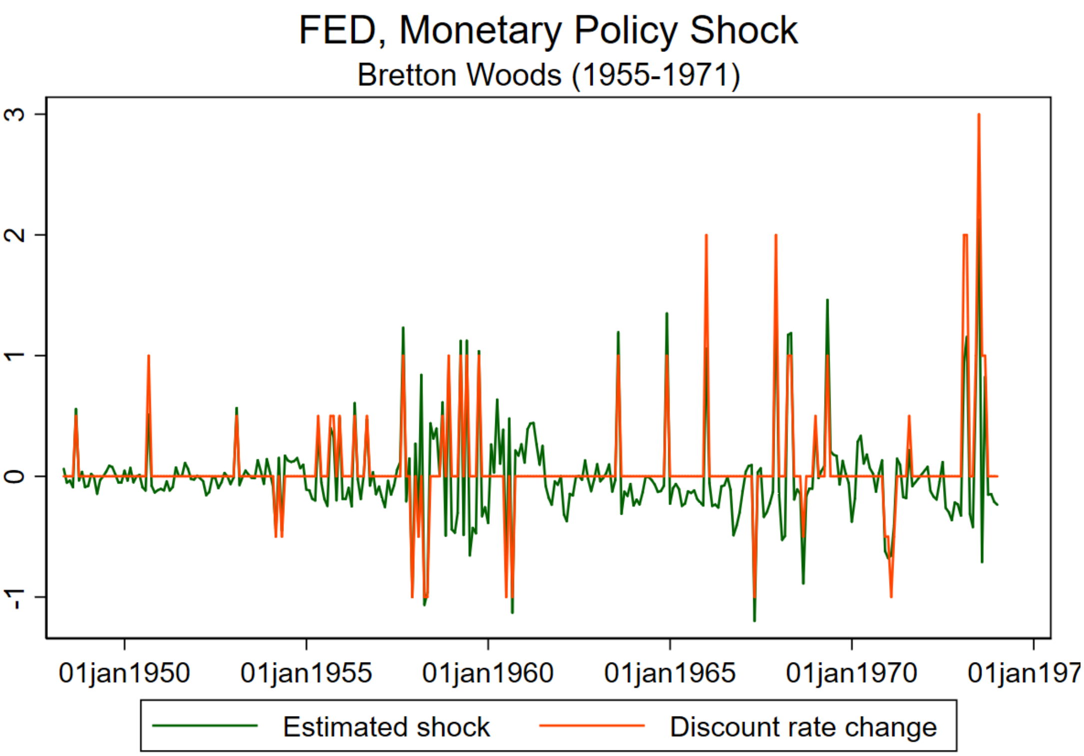


Figure B.4: Monetary policy shock, (1974-1994)

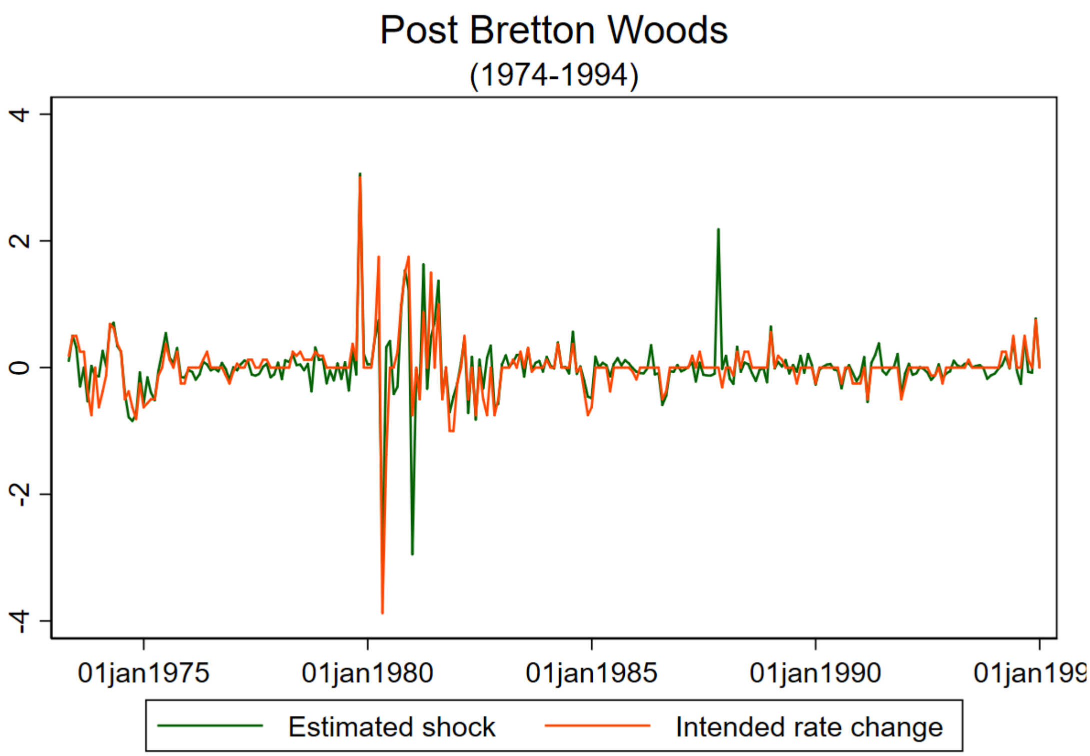
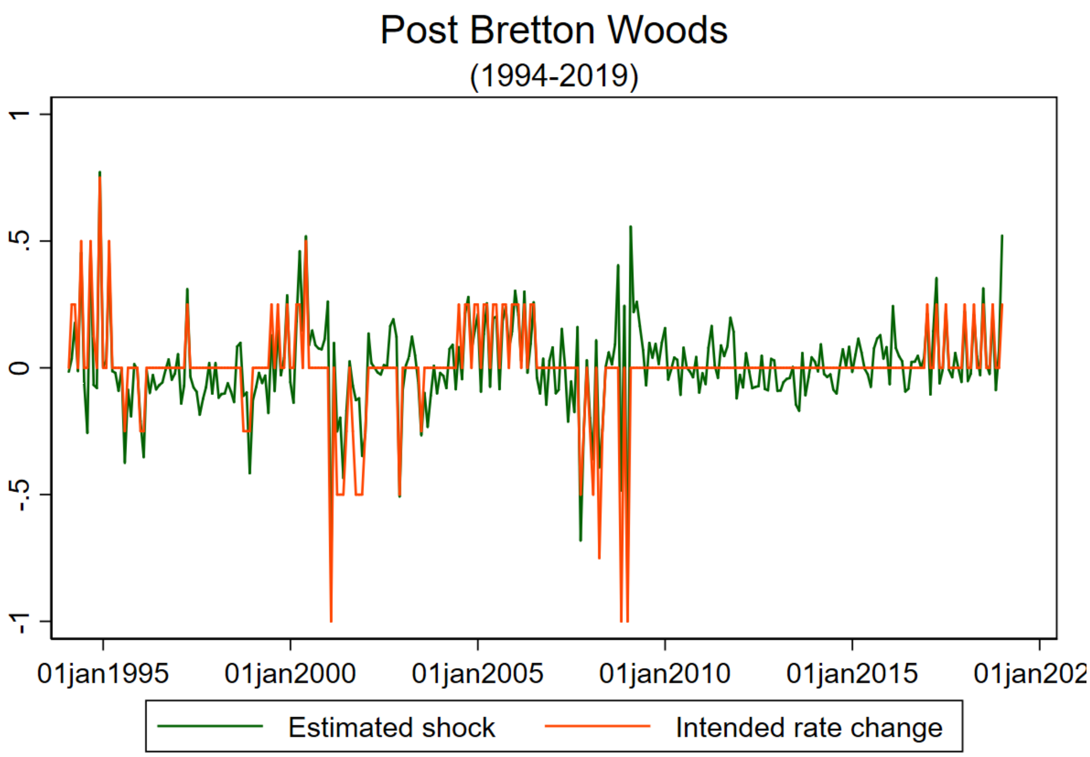


Figure B.5: Monetary policy shock, (1994-2019)



examine the unemployment rate, the annual inflation rate and the growth rate of industrial production.

To estimate the effect of the MPS we use local projection:

$$y_{t+h}^{k} = \alpha + \Phi_h(L)Y_{t-1} + \beta_h \Delta r_t^* + month + trend + \epsilon_{h,t} \tag{6}$$

For $h = 0, 1, 2, ..., H$, with H the time horizon for which we want to measure the response to a shock. y_{t+h}^{k} is the value of variable $k = 1, ..., K$ at horizon h. α_i is a constant $\Phi_h(L)$ is the polynomial set of lag operator for endogenous variables, Δr_t^* is the monetary policy shock, and β_h is the estimated parameter which we focus on to see the effect of the shock on the endogenous variables. Our equation also includes monthly dummies and a trend. The number of lags depends on information criteria and can differ in all subperiods. Newey and West standard errors are used in each estimation.

B.4.1 Gold Standard

Local projection with 4 endogenous variables: The MPS, the UK unemployment rate, the UK inflation rate, and the UK production growth rate. The estimation includes 3 lags.

The analysis shows (figure B.6) that the variables responses are conformed to what is expected in the literature. In particular, we see an increase in unemployment rate after 10 months, a reduction in inflation after eight months, and a decline in production after 2 months. By comparison, a shock on the plain discount rate change (figure B.7) shows no effect on prices and a limited effect on unemployment. This suggests that our exercise allows to control for endogenous biases due to common factors affecting both domestic variables and the BoE discount rate policy.

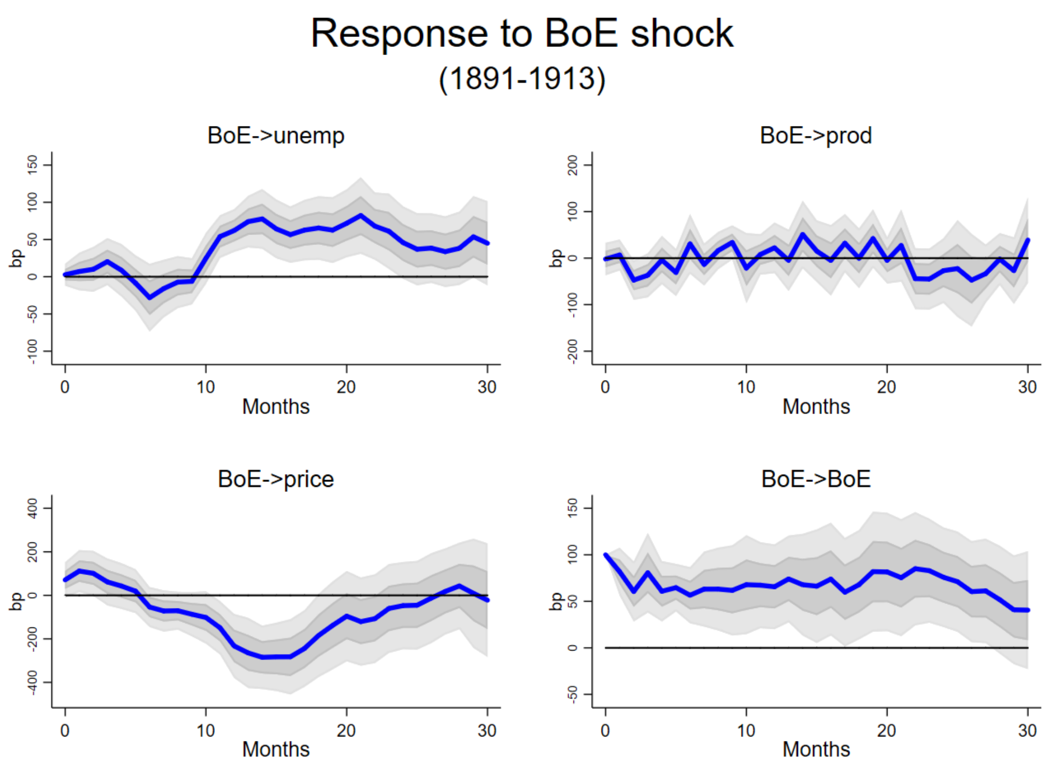
It is worth noting that our results produce more persistent effect than in Lennard (2018). This might come from the use of daily variables and the inclusion of an output index into the set of endogenous variables.

B.4.2 Interwar (Gold Exchange Standard)

Local projection with 4 endogenous variables: The MPS, the unemployment rate, the inflation rate, and the production growth rate. The estimation includes 2 lags.

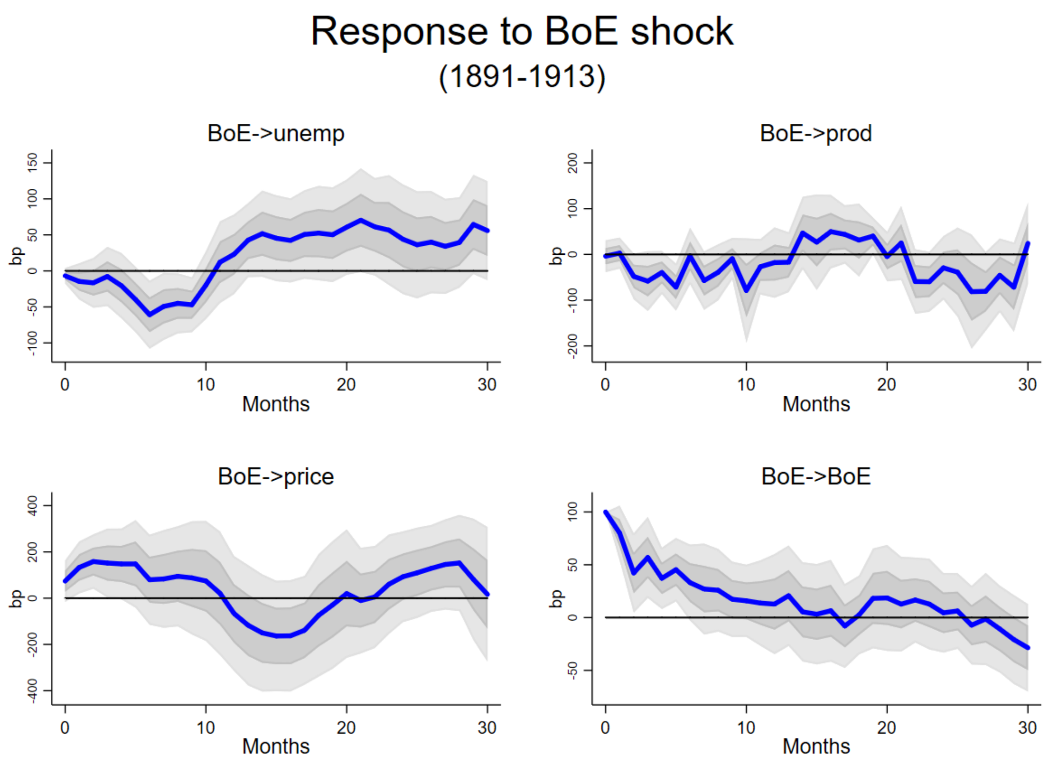
The analysis shows that the variables responses are rather conformed to what is expected in the literature (figure B.8). We see an increase in unemployment rate after 10 months and a reduction in inflation from one to four months. The production index does not react quickly

Figure B.6: Response to an exogenous monetary policy shock. England, classical gold standard.



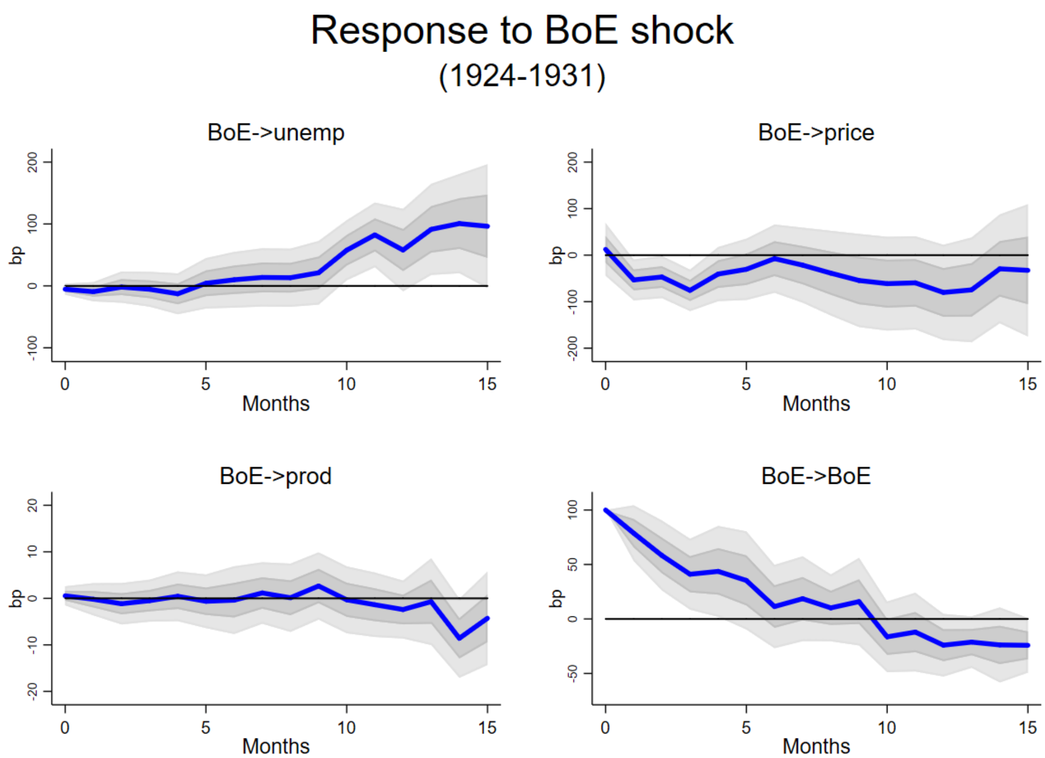
Note: Responses (in basis points) of the unemployment rate, the annual inflation rate and the growth rate of production (railway revenues).Error bands correspond to the 68% and 90% confidence intervals.

Figure B.7: Response to a policy rate change. England, classical gold standard.



Note: Responses (in basis points) of the unemployment rate, the annual inflation rate and the growth rate of production (railway revenues). Error bands correspond to the 68% and 90% confidence intervals.

Figure B.8: Response to an exogenous monetary policy shock. England, gold exchange standard.

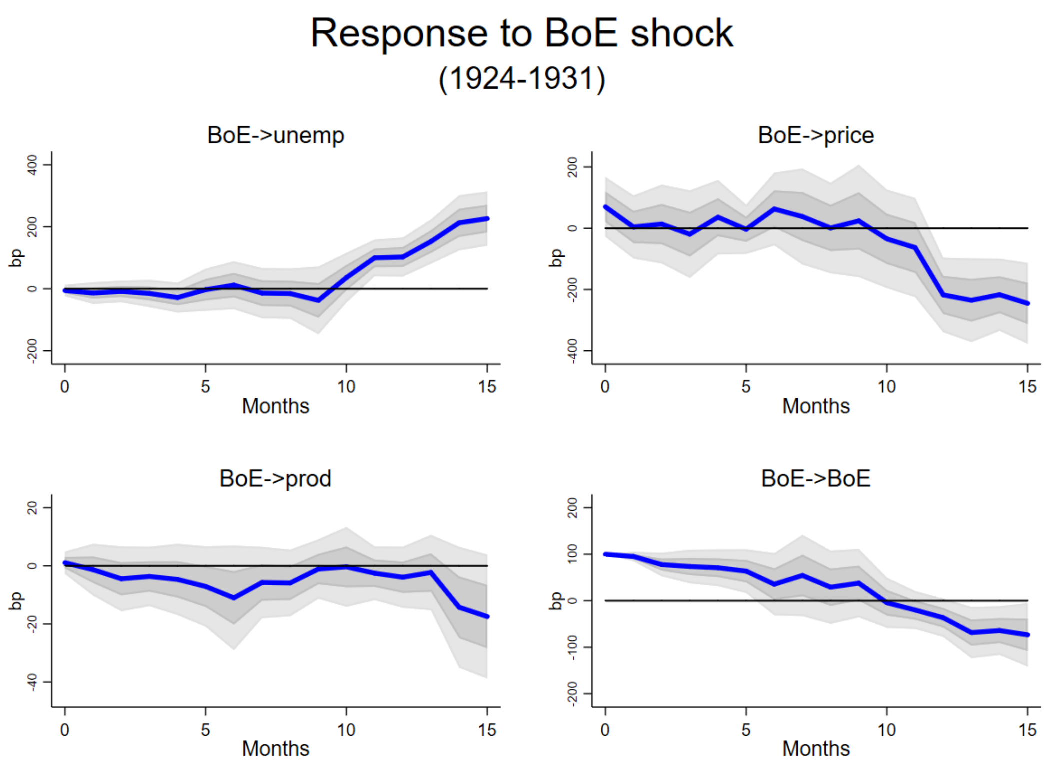


Note: Responses of the unemployment rate, the annual inflation rate and the growth rate of industrial production (basis points). Error bands correspond to the 68% and 90% confidence intervals.

but significantly declines after 14 months. This may be due to the fact to the quality of the output data which is highly volatile. Besides, the gold exchange standard only holds for a short period of time, the number of observation is rather small here, so, results tend to be less significant.

Since our paper is the first to propose such a monetary policy shock for the Bretton-Woods, we propose to compare our results to a shock on the plain BoE discount rate (figure B.9). In this case, the price index does not react before one year. By contrast, the reaction of inflation to our shock occurs within one month. Thus, because it accounts for macroeconomic conditions and captures financial information available at the moment of the BoE decision, our shock manages to account for endogenous biases affecting the response of inflation.

Figure B.9: Response to a policy rate change. England, gold exchange standard.



Note: Responses of the unemployment rate, the annual inflation rate and the growth rate of industrial production (basis points). Error bands correspond to the 68% and 90% confidence intervals.

B.4.3 Bretton Woods

Local projection with 4 endogenous variables: The MPS, the unemployment rate, the inflation rate, and the production growth rate. The estimation includes 3 lags.

The analysis shows an increase in unemployment rate after 12 months, a reduction in inflation after 15 months, and a drop in production growth from 12 to 16 months (figure B.10. It is worth noting that the adjustment to monetary policy shock are longer compared to the interwar but there are still in the right direction. One explanation could be that monetary policy effect takes more time due to a change in the regulation of the economy and the extent of state intervention, which were both restricted during the gold standard and the gold exchange standard.

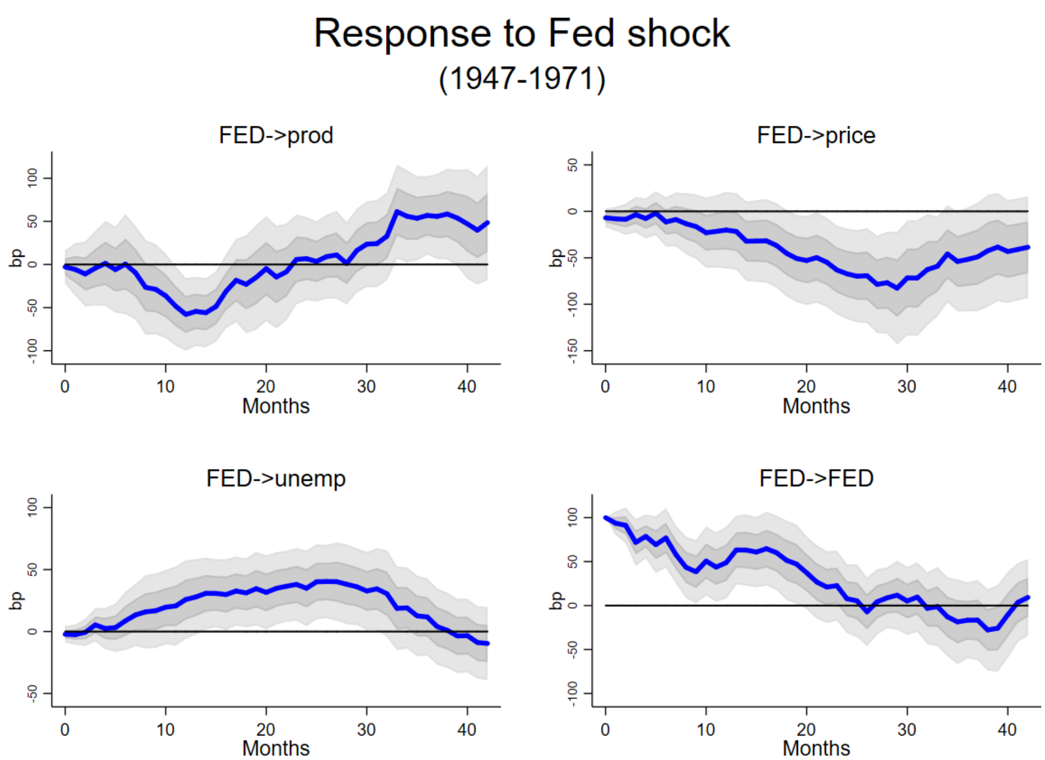
Since our paper is the first to propose such a monetary policy shock for the Bretton-Woods, we propose to compare our results to shock on the plain discount rate (figure B.11). In this case, none of the variables react as expected by the literature—i.e. inflation and production increases while unemployment decreases. This contrasts strongly with the results we obtain with our shock, thereby suggesting that the plain interest rate is endogenous to financial and macroeconomic conditions. As such, this means that our shock manages to deal with these issues pretty well.

B.4.4 Post Bretton Woods (1973-2019)

Local projection with 4 endogenous variables: The MPS, the unemployment rate, the inflation rate, and the production growth rate. The estimation includes 3 lags.

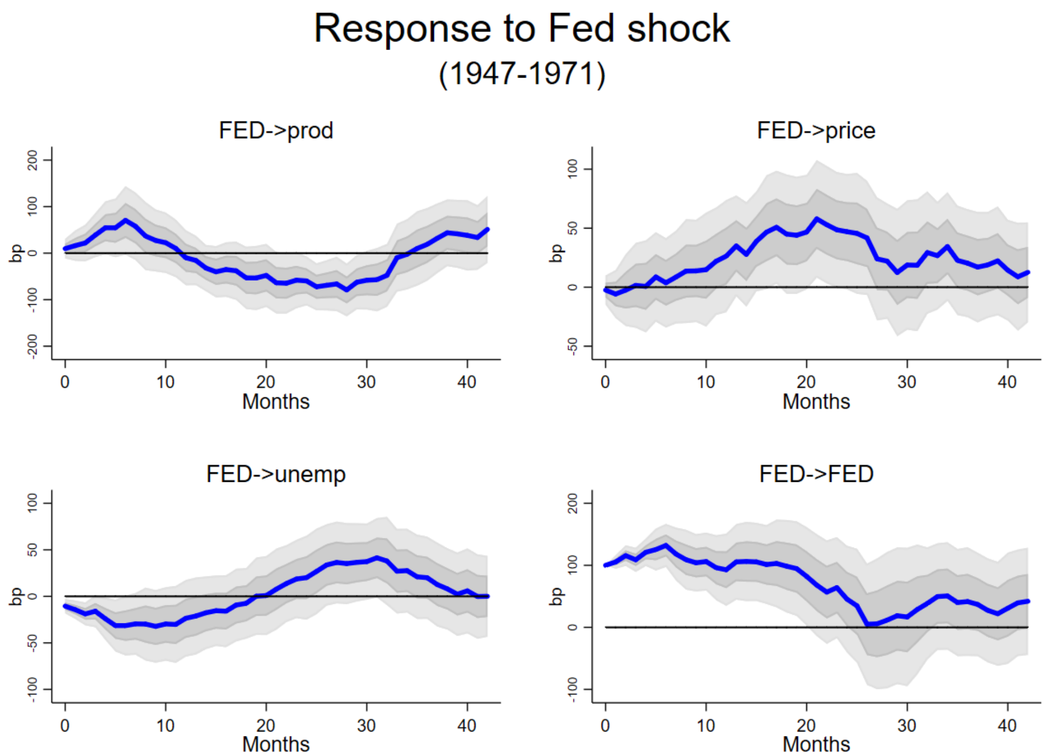
Figure B.12 shows that the variables responses are conformed to what is expected in the literature. We see a significant (10% interval) increases in the unemployment rate after 24 months, a reduction in inflation after 24 months, and a drop in production growth from 14 to 18 months. It is worth noting that those results coincide well with Romer and Romer (2004) estimation based on narrative approach. However, reaction in recent monetary policy surprise paper displays an immediate response of the price index. This is why we prefer to use the Bauer and Swanson (2023b) shock in our estimation for the most recent period, that is, when forward guidance and market development raises the prevents a narrative approach to capture all the endogenous biases.

Figure B.10: Response to an exogenous monetary policy shock. USA, Bretton Woods.



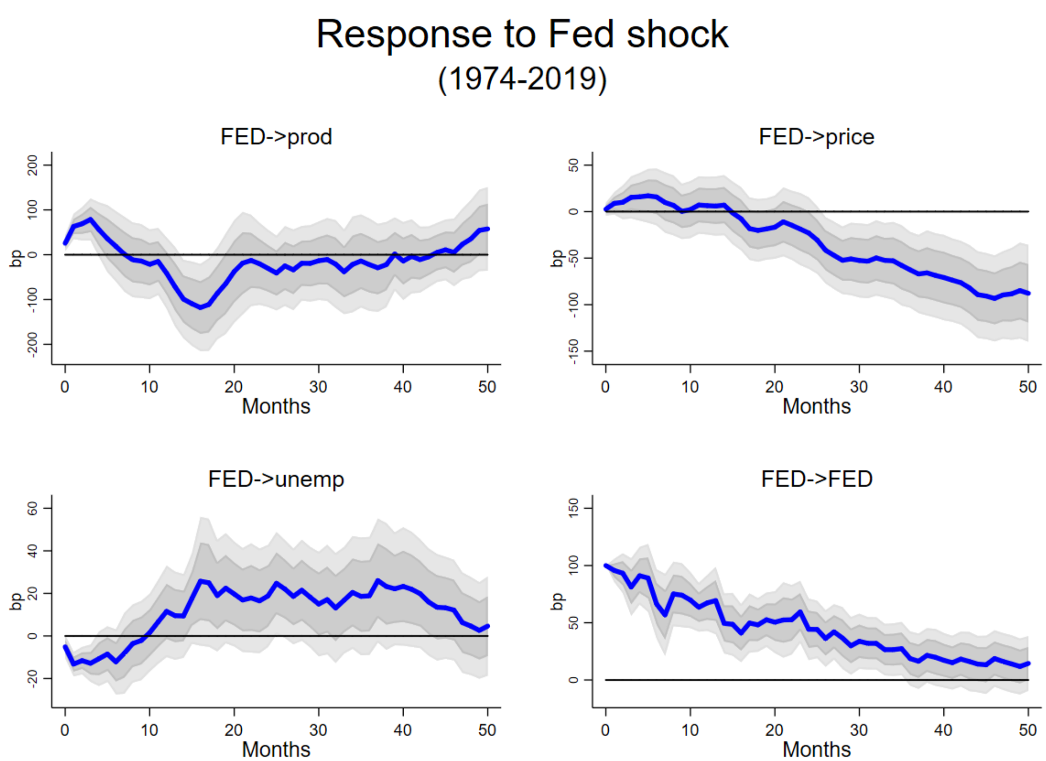
Note: Responses of the unemployment rate, the annual inflation rate and the growth rate of industrial production (basis points). Error bands correspond to the 68% and 90% confidence intervals.

Figure B.11: Response to a policy rate change. USA, Bretton Woods.



Note: Responses of the unemployment rate, the annual inflation rate and the growth rate of industrial production (basis points). Error bands correspond to the 68% and 90% confidence intervals.

Figure B.12: Response to an exogenous monetary policy shock. USA, post Bretton Woods (1973-2019)



Note: Responses of the unemployment rate, the annual inflation rate and the growth rate of industrial production (basis points). Error bands correspond to the 68% and 90% confidence intervals.

Appendix C List of Sources (Central Bank Balance Sheets)

Our main source before the Second World War (”Bank of France historical archive”) is presented at length in the section 2 , as is our methodology for classifying balance sheet items.

Argentina

1938-1940 Bank of France historical archive

1940-1997 Banco Central de la Republica Argentina, Boletín estadístico, table “Balance del Banco Central de la Republica Argentina Link to digitized source

1998-2019 “Balances semanales” Link to online data (imported in xlsx)

Austria (Austria-Hungary until 1918)

1891-1914 Bank of France historical archive

1919-1937 Bank of France historical archive

1946-1968 Bank of France historical archive

1969-1998 “Wochenausweise der Österreichischen Nationalbank”, kindly communicated by Clemens Jobst (University of Vienna)

1999-2019 “ECB and NCB contributions to the Eurosystem statistical balance sheet” Link to online data (imported in xlsx)

Belgium

1891-1914 Bank of France historical archive

1919-1969 Bank of France historical archive

1970-1998 Banque Nationale de Belgique, Bulletin de la Banque Nationale de Belgique”, table ”Bilans de la Banque Nationale de Belgique - Actif – Passif – Chiffres mensuels”

1999-2019 “ECB and NCB contributions to the Eurosystem statistical balance sheet” Link to online data (imported in xlsx)

Canada

1935-2019 "Bank of Canada monthly assets and liabilities". Link to online data (imported in xlsx) The main source was supplemented by the "Bank of Canada Statistical Summary" (a monthly publication from 1935 to 1982) in order to distinguish between gold and foreign currency, as well as to distinguish the investment in the Industrial Development Bank (IDB) from other assets. Scans of this publication were kindly communicated by Jane Boyko (Bank of Canada)

Chile

1926-1978 Banco Central de Chile, "Memoria annual", table "Saldos semanales de los rubros mas importantes del activo y pasivo", Circulante emitido por el banco central, Emision: Banco Central Link to digitized source

1979-1997 Banco Central de Chile, "Boletín mensual del Banco central de Chile" Table, Bacon central de Chile: Activos y Pasivos

1998-2019 "Activos y pasivos del BCCh, saldos" Link to online data (imported in xlsx)

Colombia

1927-1996 Banco de la República, "Revista del Banco de la República" tables'Estados financieros del Banco de la Rep´ublica'/ 'Series estad´ısticas de la econom´ıa colombiana'/'cuentas monetarias'/ 'Banco de la Rep´ublica y fondos financieros Link to digitized source

1997-2019 "Principales fuentes de la base monetaria and sectorización del Banco de la República" Link to online data (imported in xlsx)

Denmark

1891-1957 Bank of France historical archive

1958-1987 Danmarks Nationalbank, "Report and accounts"", table "Annual and monthly balance sheets of the Nationalbank" (occasionally also referred to as "Annual accounts and monthly balance sheets of Danmarks Nationalbank")

1987-2019 "DNSNB1: Specification on Danmarks Nationalbank's balance sheet by specification and item – Stock Link to online data (imported in xlsx)

Finland

1893-1957 Bank of France historical archive

1957-1963 Bank of Finland, "Yearbook", table "Balance sheet" Link to digitized source

1964-1997 Bank of Finland, "Monthly bulletin", able "Bank of Finland Balance sheetsLink to digitized source

1999-2019 "Balance sheet of the Bank of Finland" Link to online data (imported in xlsx)

France

1891-1998 Baubeau, Patrice. "The Bank of France's balance sheets database, 1840–1998: an introduction to 158 years of central banking." "Financial History Review 25.2(2018): 203-230" Link to digitized source

1999-2019 "ECB and NCB contributions to the Eurosystem statistical balance sheet" Link to online data (imported in xlsx)

Germany

1891-1945 Bank of France historical archive

1948-1969 Deutsche Bundesbank, "Monthly report", tables "Assets and liabilities of the Deutsche Bundesbank" Link to digitized source

1999-2019 "ECB and NCB contributions to the Eurosystem statistical balance sheet" Link to online data (imported in xlsx)

India

1935-1945 "Banking and Monetary Statistics of India", Table "Reserve Bank of India. Liabilities and Assets"

1946-2019 Reserve Bank of India, "Reserve Bank of India Bulletin", , tables "Reserve Bank of India. Issue Department. Banking Department." and "RBI-Liabilities and Assets" Link to digitized source

Italy

1894-1935 Bank of France historical archive, The Bank of Naples and the Bank of Sicily are included until 1926 (we aggregated the three balance sheets). The Bank of Italy became the sole bank of note issue in 1927.

1936-1990 "Serie storica bilanci Banca d'Italia. Stato Patrimoniale" Link to online data (imported in xlsx)

1999-2019 "ECB and NCB contributions to the Eurosystem statistical balance sheet" Link to online data (imported in xlsx)

Japan

1899-1960 Bank of France historical archive

1961-1998 Bank of Japan, "Economic Statistics Monthly", table "Principal accounts of the Bank of Japan"

1999-2019 "Balance Sheets of the Bank of Japan" Link to online data (imported in xlsx)

Mexico

1925-1985 Banco de México, "Informe anual" Link to digitized source

1985-2019 Banco de México, "recursos y obligaciones" Link to online data (imported in xlsx)

The Netherlands

1891-1969 Bank of France historical archive

1970-1982 De Nederlandsche Bank, "Quarterly Statistics", table "Balance sheet of the De Nederlandsche Bank"

1982-2019 "DNB's balance sheet" Link to online data (imported in xlsx)

Norway

1891-1940 Bank of France historical archive

1946-1957 Bank of France historical archive

1958-2019 "Norges Bank's balance sheets from 1817 to the present" Monthly balance sheets are available from this website starting onlin in 1950; we therefore rely on the other source until its discontinuation. Link to online data (imported in xlsx)

Portugal

1892-1956 Bank of France historical archive

1957-1979 Banco de Portugal, Relatório do conselho de administração. Tables: "Sinopse das situa¸c´oes semanais".

1980-2019 "Balanço das instituições financeiras monetárias/ Banco central" Link to online data (imported in xlsx)

South Africa

1921-1964 South African Reserve Bank, "Quarterly Bulletin", ", table "South African Reserve Bank. Assets and Liabilities" Link to digitized source

1964-2019 South African Reserve Bank, "Assets and Liabilities (monthly)" . Expanded and supplemented by using Quarterly Bulletin to include and build distinct series of discounts and advances between 1966 to 1985 (missing from xlsx file) Link to online data (imported in xlsx)

Spain

1891-1956 Bank of France historical archive

1957-1979 Boletín Estadístico de Banco de España. Tables:"Balance Banco de Espa˜na / Situac´ıon Banco de Espa˜na"

1980-2019 Banco de España, Activo-Pasivo Link to online data (imported in csv)

Sweden

1891-1969 Bank of France historical archive

1970-1986 Sveriges Riksbank, “Sveriges Riksbank Arsbok” (“Annual Report of the Riksbank”), table “Position as at the end of each month” Link to digitized source

1986-1989 Sveriges Riksbank, “Riksbank Tillgångar Skulder 1986-1989” Archival sources kindly provided by Anna Grodecka-Messi (Riksbank)

1990-1998 Sveriges Riksbank, “Finansmarknadsstatistik Riksbankens tillgangar/skulder Veckorapporter” Archival sources kindly provided by Anna Grodecka-Messi (Riksbank)

1999-2003 Sveriges Riksbank, “Economic Review of the Riksbank”, table “Riksbank’s assets and liabilities Link to digitized source

2004- Sveriges Riksbank, “Weekly report of the Riksbank” Link to online data (imported in xlsx)

Switzerland

1907-1969 Bank of France historical archive

1970-2000 Banque Nationale Suisse, Monatsbericht - Bulletin mensuel, table ”Situations de la Banque nationale Suisse” Link to digitized sources

2001-2019 “Balance sheet items of the SNB” Link to online data (imported in xlsx)

United Kingdom

1891-2006 “The weekly balance sheet of the Bank of England 1844-2006: Version 2” Link to online data (imported in xlsx)

2006-2014 “Central bank’s balance sheet (Bank of England ‘Bank return’)(until 24 September 2014) Link to online data (imported in xlsx)

2014- 2019 “Bank of England Weekly Report” Link to online data (imported in xlsx)

United States of America

1914-2017 Bao, C., Chen, J., Fries, N., Gibson, A., Paine, E., and Schuler, K.(2018). The federal reserve system's weekly balance sheet since 1914 (No. 115). The Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise. Link to online data (retrieved from FRED, Federal Reserve Bank of St. Louis)

2018-2019 The Federal Reserve's balance sheet Link to online data (imported in xlsx)