Central banks and the absorption of international shocks (1890-2020)

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May 3, 2024

Abstract

Central banks help to absorb liquidity shocks by providing an "elastic currency". But how does this contribute to the autonomy of monetary policy in a financially globalized world? Relying on newly collected monthly data from 23 central banks since 1890, we examine how central bank balance sheets react to exogenous international interest shocks, drawing comparisons between different exchange rate regimes, degree of capital account openness and stages of financial globalization. Four results stand out. First, contrary to conventional wisdom, central banks do not only rely on foreign exchange intervention to tame international shocks but, in addition, also buy more domestic assets to stabilize the money market rate. Second, the use of the central bank balance sheet to relax the constraints of fixed exchange rates in an open economy has been the norm throughout history (with the exception of the European Monetary System). Third, until the 1980s, the textbook macroeconomic trilemma prevailed, so that central bank balance sheets did not need to respond to international shocks in the context of floating exchange rates or closed capital accounts. Fourth, the second financial globalization since the 1990s has created an unprecedented situation where central bank balance sheets are now called upon to absorb international shocks even in a floating exchange rate regime. The deepening of international financial markets has thus increased the reliance on the absorbing role of central bank balance sheets.

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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The[1] purpose of this article is to reintroduce central bank balance sheets into the literature on the autonomy of monetary policy in a financially globalized world. To do so, we examine short-term fluctuations in central bank assets and liabilities in response to exogenous international interest rate shocks from the late 19th century to the present day, drawing comparisons between different exchange rate regimes, degree of capital account openness and stages of financial globalization.

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."[2]

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.[3] Little is known about how central bank *elastic currency* can smooth short-term international financial shocks to which open-economy are frequently subject to. Standard models in international economics textbooks, or empirical studies of the global transmission of monetary policy shocks, leave little room for central bank balance sheets. And when they do, they deal with interventions in the foreign exchange

[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 Laura Bonino, Gautier Davy, Alessandro Ferrante, Théodore Humann, Oriane Pichon, Emma Sarhdaoui, Güzide Sofi. We owe special gratitude to Victor Degorce for sharing 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, Emmanuel Carré, Victor Degorce, David Guerreiro, Dirk Niepelt, Silvia Miranda-Agrippino, Hélène Rey, Moritz Schularick, Maria Sole Pagliari, Antoine Terracol, Cédric Tille, Miklos Vari, as well as seminar participants at the Bank of Spain, the Universities of Neuchâtel, Bordeaux, York, Paris 1, Paris 2, Aix-Marseille, Paris Saclay.

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

[3]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 policy include Monnet (2014); Jaremski and Mathy (2018); Reis (2019). Ferguson, Kornejew, Schmelzing, and Schularick (2023) provide a comprehensive overview of balance sheet expansions of central banks over five centuries - based on annual data - and studies the long-term consequences of lender of last resort policies on risk-taking.

market, not with how the domestic money market rate is stabilized by the provision of liquidity to meet banks' needs. In a fixed exchange rate regime with an open capital account, the domestic interest rate should follow the international rate. In an open economy with a floating exchange rate, the exchange rate absorbs all international shocks and the central bank plays no role.

Some recent studies, however, suggest that it is worth reopening the debate and that we should take a more holistic view of how central banks can react to international financial shocks. Global financial markets have operated differently from conventional models due to many imperfections. Even in economies where official capital controls are lifted, risk premia lead to large deviations in interest rate parity. This has important consequences for the transmission of international financial shocks(Bruno and Shin (2015); Gabaix and Maggiori (2015); Rey (2015); Miranda-Agrippino and Rey (2020); Kalemli-Özcan (2019)): foreign exchange market interventions are more effective than is usually thought, or a floating exchange rate is no longer sufficient to absorb international shocks. Yet financial frictions may also prompt the central bank to provide liquidity to stabilize the money market rate, if it wishes to offset the effect of international rate variations on the domestic economy. This question calls for new attention.

We investigate the issue of central bank balance sheet and international financial shocks in a comprehensive and long-run perspective thanks to a newly created dataset of monthly macroeconomic, financial variables and detailed central bank balance sheets for 23 countries since 1890. It covers most central banks that were created before the mid-20th century and still exist today (in our sample, twelve existed in 1890, four were created before 1920 and seven in the interwar period), so that we can build continuous series and compare responses across periods for a reasonably similar number of countries. This sample includes mostly today's "advanced economies".

Following the literature on the international transmission of monetary policy shocks and the trilemma (e.g. Obstfeld, Shambaugh, and Taylor (2010); Miranda-Agrippino and Rey (2020); Elliott, Meisenzahl, and Peydró (2024)), we consider a interest rate change in the leading country to be an exogenous financial shock for other open economies. Through different exchange rate regimes, degree of capital account openness and stages of financial globalization, we examine how central bank assets and liabilities, interbank rates, exchange rates and equity prices have reacted to international financial shocks. This methodology enables us to characterize how the central bank balance sheet could help countries cope with the constraints of international finance.

Our investigation yields four main findings. First, contrary to conventional wisdom, central banks do not only rely on foreign exchange intervention to tame international shocks but can also increase domestic assets to stabilize the money market rate in response to a rise in the international interest rate. Second, the use of the central bank balance sheet to relax the constraints of fixed exchange rates has been the norm throughout history (with the exception of the European Monetary System). Third, until the 1980s, the textbook macroeconomic trilemma prevailed, so that central bank balance sheets did not need to respond to international shocks in the context of floating exchange rates or closed capital accounts. Fourth, the second financial globalization since the 1990s has created an unprecedented situation where central bank balance sheets (and especially domestic assets) are now called upon to absorb international shocks even in a floating exchange rate regime. The deepening of international financial markets has thus increased the reliance on the absorbing role of central bank balance sheets.

Why did we need a new dataset of monthly central bank balance sheet? Historical monthly central bank data are difficult to obtain but turn to be crucial for our exercise. Contrary to wars or major financial crises, the elastic currency is supposed to absorb international interest rate shocks within months, and is thus unlikely visible in yearly data. The recent literature on the global transmission of US monetary policy shocks find that the effect on financial variables and exchange rates usually vanishes within 6 months (Miranda-Agrippino and Ricco (2021); Degasperi, Hong, and Ricco (2020)). Our previous investigations on the pre-1914 gold standard led to similar results (Bazot, Bordo, and Monnet (2016); Bazot, Monnet, and Morys (2022)). Not only central bank data need to be high frequency but also highly detailed. We not only distinguish between international reserves and domestic domestic assets but must also isolate the operations that were specifically used for liquidity provision to banks rather than structural investment or loans to the Treasury. In most cases, having detailed asset categories required to use original historical sources rather than retrospective balance sheets reconstructed and published ex post by central banks or historians (which are usually confined to historical annual series).

What justifies a long-term historical perspective on this question? Collecting long run historical data not only provides a resource that can be used for other investigations. As quantitative historians, we want to know whether the role of central banks have changed in the long-run, if it depends on the exchange rate regimes and global finance, and with what effects. In the spirit of recent work on banking crises or public debt (Schularick and Taylor (2012); Meyer, Reinhart, and Trebesch (2022), we use long run data to investigate whether

the recent financial globalization - of unprecedented scale in the last 30 years - have changed the role of central banks within the international monetary system. In the spirit of studies on the *trilemma* in historical perspective Obstfeld and Taylor (2004), we want to know what are the margins of manoeuvre of countries in the international system, and how central banks play on these margins. Being able to compare responses over different historical periods is also a way of giving more meaning to the results over the recent period. It is thanks to the comparison between different historical periods (in light of the theory of the *trilemma* of international finance) that we can propose an explanation for the results obtained over the current period.

How to obtain exogenous monetary policy shocks since the 19th century? Exogenous changes in interest rates in the leading country (i.e. one that influences international financial markets, such as the USA today) are crucial to our identification strategy. The current consensus in the literature (high-frequency identification) is to construct these shocks using market investors' expectations, extracted from intraday futures interest rates (e.g. Gürkaynak, Sack, and Swanson (2005); Nakamura and Steinsson (2018); Miranda-Agrippino and Ricco (2021); Bauer and Swanson (2023a,b)). The most recent and longest series for US monetary policy covers almost 25 years (Bauer and Swanson (2023a,b), but intraday futures rates are not available until the late 1980s. For earlier periods, we can rely on Lennard (2018), which constructed a series of exogenous monthly interest rate changes for the Bank of England prior to 1913, using a "narrative approach" in the spirit of Romer and Romer (2004). For other periods - and to provide an updated and more precisely estimated series prior to 1913 - we construct our own exogenous shocks.

Our approach combines Romer and Romer's methodology and "high-frequency identification", while taking into account the constraint of data availability in history. It is close to that of Cloyne, Hürtgen, and Taylor (2022) in their recent paper on the Bundesbank from 1974 to 1998.[4] The idea is to purge changes in the discount rate that were due to the state of the economy, based on knowledge of the main monthly macroeconomic indicators (in particular output, unemployment and prices). In addition, we take into account the market's

[4]The series of exogenous shocks constructed by Cloyne, Hürtgen, and Taylor (2022) is more reliable than ours and should be used in priority by other researchers. The authors were able to collect *real-time* data that was accessible to Bundesbank board members at every meeting. They therefore have better control over the information available to policy-makers. As their series and the underlying data are not yet available, we have opted for a default option and applied the same methodology to the Bundesbank in the 1980s as for the previous periods. As we show in the Appendix, our results are qualitatively similar to those of Cloyne, Hürtgen, and Taylor (2022), and point estimates are close, when estimating the impact of the exogenous monetary policy shock on German macroeconomic variables. Standard-errors bands are however larger in our case.

short-term expectations of the central bank's actions by purging the central bank's interest rate of changes in the market rate and the exchange rate on the day preceding the central bank's decision. We therefore use daily data on these rates from the end of the 19th century to the 1990s. The underlying intuition is simple: if the central bank raises its interest rate to follow the market (be it the domestic market or the exchange rate), we consider this decision to have been anticipated, so that it cannot be considered exogenous. Our monetary policy shock is deemed exogenous in the following sense: i) it is not expected by market participants in the day before the announcement; ii) it is not predicted by macroeconomic and financial variables that the central bank follows to set its policy. Thanks to new daily and monthly data collected for this purpose, we are able to follow this methodology and construct monetary policy shocks for the main central banks: the Bank of England under the classical and interwar gold standards (1891-1913, then 1925-1931), the US Fed under Bretton Woods (1946-1971) and the Bundesbank during the European Monetary System (1980-1991). We check the impact of these shocks on the domestic variables of these three countries to verify that our series lead to conventional results in terms of the impact of domestic monetary policy shocks.

Our paper contributes to several strands of literature. Our findings and methodology speak 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)). As noted earlier, we confirm the main predictions of this framework. Yet, while previous studies had noted that the pass-through of interest rates was far from perfect in exchange rate regimes without capital controls, they had not investigated the role of central bank balance sheet in this respect. Ferguson, Kornejew, Schmelzing, and Schularick (2023) built historical annual balance sheet data for 17 countries and study the impact of central bank expansions on the economy, but without drawing the link with global financial cycles.

Second, our work also relates to the papers that have investigated the evolution of the international monetary system in the long run. Like Bordo (2003); Ilzetzki, Reinhart, and Rogoff (2019), our results point out to large differences between the official exchange rate regime and the actual practices. Our contribution in this respect is to show how central bank balance sheet - including foreign exchange interventions, but not only - have partly mitigated the constraints of the exchange rate regime since the late 19th century.

Last, 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.[5] We show that the expansion of the domestic portfolio of central banks explain why central bank policy rates have not followed the global interest rate since the 1990s whereas asset prices respond strongly to a US monetary policy shock (the difference between the response of interest rates and asset prices was already highlighted in Miranda-Agrippino and Rey (2020), but without providing an explanation).

Since the main value of this paper is the long-term approach, rather than heterogeneity between countries at a given point in time, we focus on a quasi-homogeneous sample of central banks over time, and our sample is mainly composed of advanced economies. Our conclusions for today's emerging economies are therefore limited. Yet our results are also consistent with Kalemli-Özcan (2019), which shows that - all else equal - the spread between the money market rate and central bank policy rate increases more in emerging economies than in advanced economies after a rise in the US interest rate today. Our contribution to this debate is to show that this result is achieved in advanced economies through an expansion of the central bank's domestic portfolio. There could be several reasons why this is not the case in emerging countries, 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). These are key questions that we leave to future research.

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. In section 3, we display the results over the whole sample - regardless of period - and then focus on the two major periods of full capital mobility: first globalization (pre-1913), and second globalization (early 1990s to present). The reactions of the central bank's liabilities allow us to distinguish the different explanations for the positive reaction of the central bank's domestic assets. Section 4 explores central bank reactions across other historical periods of the international monetary system and exchange rate regimes. This requires constructing new monetary policy shocks before presenting the original results. We discuss how these new results bring coherence and robustness to our

[5]There is a dilemma in the sense that floating exchange rates are not 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)).

previous interpretations. Last, section 5 provide additional robustness checks, based on alternative estimation samples, and further discussion of potential biases arising from central banks' international asset accounting rules.

1 Theoretical Framework: the trilemma and 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 balance sheets in response to a rise of the international rate.

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. We simply state that the central bank has a target interest rate i^T and its objective is to ensure that the money market rate is in line with the target rate:

$$i_t = i^T$$

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 disconnected from domestic conditions. Thus, we also assume that the central bank is aiming at "monetary autonomy", that is it wants to keep i^T (and thus i) stable when i^* moves, so that domestic monetary policy remains targeted to domestic macroeconomic objectives (such as inflation and the output gap).

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 holding 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.

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 ($L \uparrow$) through domestic liquidity provision ($D \uparrow$) stabilizes the money market rate. So the domestic portfolio and short-term liability of the central bank react as follows:

$$D \uparrow, L \uparrow$$

if

$$i_t > i^T$$

In other words, 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 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. 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 (Boeckx, Dossche, and Peersman (2017); Arce, Nuno, Thaler, and Thomas (2020); Vari (2020); Copeland, Duffie, and Yang (2021)).[6].

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 (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 whose monetary policy influences directly i^*). In line with the recent literature on international finance and global dollar shocks (e.g. Miranda-Agrippino and Rey (2020);

[6]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).

Kalemli-Özcan (2019)), 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 in recent times.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 Rey (2020), 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 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. 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, 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 of the domestic currency), nor about a rise in i_t.

On the contrary, after an initial rise in i_t^*, a UIP wedge with $\sigma_t > 0$ generates an immediate increase in i_t that is not offset by an expected appreciation of the exchange rate. The central

bank thus faces $i_t > i^T$ and responds by expanding its domestic portfolio ($D \uparrow$), as explained previously. Thus, the expansion of central bank domestic assets ($D \uparrow$) at time t has an effect on i_t that offsets σ_t. We name δ_t the effect of an expansion of D on i_t at time t, with $\delta_t > 0$ when $D \uparrow$. We thus have:

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

If the intervention of the central bank on the money market is fully effective, we have $\sigma_t = \delta_t$. This leads to the paradoxical result that UIP in fact holds because of the immediate liquidity expansion of the central bank. This is because the central bank's *elastic currency* aims at reducing the effect of financial frictions on the money market rate.

In practice however, the central bank liquidity expansion may not be fully effective or may respond with a lag. 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)).

The literature thus suggests that central banks are more able to bring the money market rate in line with their target rate in advanced economies featuring a well-developed and liquid interbank markets in domestic currency. Eventually, we consider the effectiveness of central bank balance sheet expansion an empirical question. We will study the joint reaction of central bank domestic assets and the money market rate.

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 (1992) - 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, 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 in an exchange rate regime.

Following the target zone literature (Svensson (1992); Bordo and MacDonald (2005)), 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.[7]

By 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).

The central bank can act on χ_t through foreign exchange interventions (see below) to increase the credibility of its peg. But, even if this is successful, σ_t may still exist for reasons discussed above, such as a change in global risk perception. If so, the central bank in a fixed-exchange regime finds itself in a situation similar to the floating exchange rate case discussed above. It has to increase its domestic portfolio ($D \uparrow$) to offset the effect of σ_t on the domestic interest rate. Thus, if χ_t and σ_t both exist, the central bank will combine FX interventions with an additional increase in its domestic portfolio.

1.5 Foreign exchange interventions and the central bank domestic portfolio.

If the central parity of the fixed-exchange rate is not credible and there is a risk that the exchange rate goes out of the bands, a 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 $I \downarrow$.

If they are "unsterilized", these operations lead to a fall in bank reserves ($L \downarrow$) akin to a restrictive monetary policy, so that $i_t > i^T$. Those operations are known to be effective

[7] 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.

but force the central bank to increase its target rate i^T following the reduction of its balance sheet.

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 foreign exchange intervention. 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 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).[8]

Our paper is not about the effectiveness of FX interventions. We are interested in the fact that "sterilized" FX interventions ($I \downarrow$) can be combined with an expansion of the domestic assets ($D \uparrow$). This is because the UIP wedge $\sigma_t > 0$ may remain even after exchange rate expectations are stabilized. For example, studies on both historical periods Mitchener and Weidenmier (2015); Bazot, Monnet, and Morys (2022) and present times Kalemli-Özcan (2019); De Leo, Gopinath, and Kalemli-Özcan (2022) observe an increase of the interest rate differential ($i - i^*$) after an increase in i^* in various countries, including in those using FX interventions.

Thus, the central bank may have to expand D to reach $i_t = i^T$ *in combination with* sterilized FX interventions. Even in the case of "sterilized" FX interventions, we can observe an increase in D that does more that just offsetting the decrease in I. It is associated with an increase in L. The effect of a change in D on L is an important empirical prediction that will allow us to distinguish between an increase in D that only sterilizes FX interventions I, and an increase in D that also aims at stabilizing the money market rate ($i_t = i^T$).

1.6 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

[8]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 enough, or if domestic assets expansions are also required.

case, σ_t is the result of capital controls. It is negative 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. In practice, countries with incomplete capital account convertibility may 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); Jeanne (2022); Cezar and Monnet (2023)).

2 Data

2.1 Data collection 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 (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 obliged to do so by law, and the annual report always contains an annual balance sheet, as well as the profit and loss account, often translated into other languages so that they can be read by the international financial community. These data are therefore 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 not been translated into other 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. In general, 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 historical survey, we often found cases where total assets and liabilities are not published for weekly or monthly data. Fortunately, all the key series of central bank interventions in the foreign exchange and domestic money markets are still present. 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 value published yearly. 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.

Because of these difficulties, only a tiny number of central banks – the US Federal Reserve and the Bank of England (until 2006) to the best of our knowledge – have made historical weekly or monthly balance sheet data publicly available on their website.[9] 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.

2.1.2 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 (1897), Switzerland (1908) and the United States (1913), the number grew to 16 countries by 1914.[10] The Bank of France continued to record monthly data for these banks until the

[9] Original French data were compiled and published by Baubeau (2018). They display all categories present in historical sources. Baubeau provides an aggregation of some series which is to wide for our purpose.

[10] 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 (Morys, 2023). The Banks of Italy, Naples and Sicily began to dominate the

1950s and in some cases until the 1960s. This unique source forms the backbone for the first seven decades of our work.

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 1935).[11] We cover them based on archival sources located in the respective central bank, bringing the number of countries to 23.

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. [12]

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 countries before 1936. International reserves are actually managed by central bank staff, but kept in a separate account. 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) actually held international reserves on their asset side.

Because of the difficulties in obtaining complete data and consolidating the accounts of the

market and we amalgamate their balance sheets into one unified "Italian" balance sheet for our econometric purposes.

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

[12] 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 et al. 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.

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	1897
Switzerland	1908
United States	1914
Interwar additions (seven)	**Year**
South Africa	1922
Chile	1926
Mexico	1926
Colombia	1929
Argentina	1935
Canada	1935
India	1935

Stabilization Fund and the central bank, we turn 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 sending this data, at least annually, and with a 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 5, 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.

2.2 Central bank balance sheets and elastic currency

2.2.1 Focus on monetary policy operations

Building long-run series of central bank balance sheets creates 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, even when excluding international assets.

As explained in our theoretical framework (Section 1), we are interested in the elastic currency 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". This focus implies to exclude three types of assets (the second and the third being sometimes particularly 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 (a financial or non-financial company) or the government. This category especially includes direct loan to a public bank or a nationalized company at a subsidized interest rate, the purchase of equity

of a public 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 them is that none of these investments or loans affect the money market rate, since they were not intermediated by banks that participate to the interbank market.

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 often paid more attention to the multitude of tasks performed under their roof. The large *conti d'ordine* of the Bank of Italy are a case in point.

We have thus focused on the main operations, which we reframe in a typical modern central bank balance sheet (Table 2). 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.

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, 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, 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).[13]

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 market, the two were always 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 Classical Gold Standard), deposits dominate today. Bank notes in circulation is typically the time series easiest to reconstruct given the unambiguous labelling 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

[13]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.

off zero or issuing entirely new currencies made accounting difficult.

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[14]	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	

Given the complexity and variety of central bank operations, classifying original series in each of the categories of Table 2 required substantial institutional knowledge that we gathered in 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 (we will provide the list of these sources in a separate document for each country). 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. 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 USA and France where categories are not continuous in the published balance sheets.

In the quantitative analysis in sections 3, 5, 4, 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 (*elastic currency*).

3 Central bank balance sheets with full capital mobility

Our theoretical discussion 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 (possibly combined with sterilized foreign exchange interventions).

(i) is specific to a fixed exchange rate regime, while (ii) also applies to floating exchange rates. In both cases, the central bank elastic currency is at play because capital can move freely between countries but global financial markets are characterized by certain frictions that prevent perfect financial arbitrage.

3.1 The benchmark case

We begin by testing these simple predictions on our very long sample of 23 countries since the end of the 19th century. To do this, we need to distinguish between different regimes of exchange rate and capital account openness. We use the most common classifications of exchange rate regimes in the academic literature for different periods.[15]. We also need to define which country sets the international interest rate for each period. Consistent with the standard history of the international monetary system, we consider that England was the leading country until 1939, and the United States after the Second World War. In each case, we take care to define that a country had a fixed exchange rate when it pegged to that leading country only.

3.1.1 Econometric model

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

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

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 $y^k_{i\in g,t+h}$ 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

[15]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 other scholars. 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, the sterling or the Deutsche Mark (or euro).

shock on the endogenous variables. Our equation also includes a vector of control variables X_t, monthly dummies, and a trend.

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

For the time being, we define our global interest rate shock as a mere increase in the central bank rate of the leading country. In the rest of the paper, we will use various measures of exogenous monetary policy shocks in leading countries (constructed by other researchers or by ourselves). Here, we simply control for a measure of economic and financial cycles in the leading country, to account for the fact that monetary policy decisions may have been taken in response to economic conditions common to several other countries.

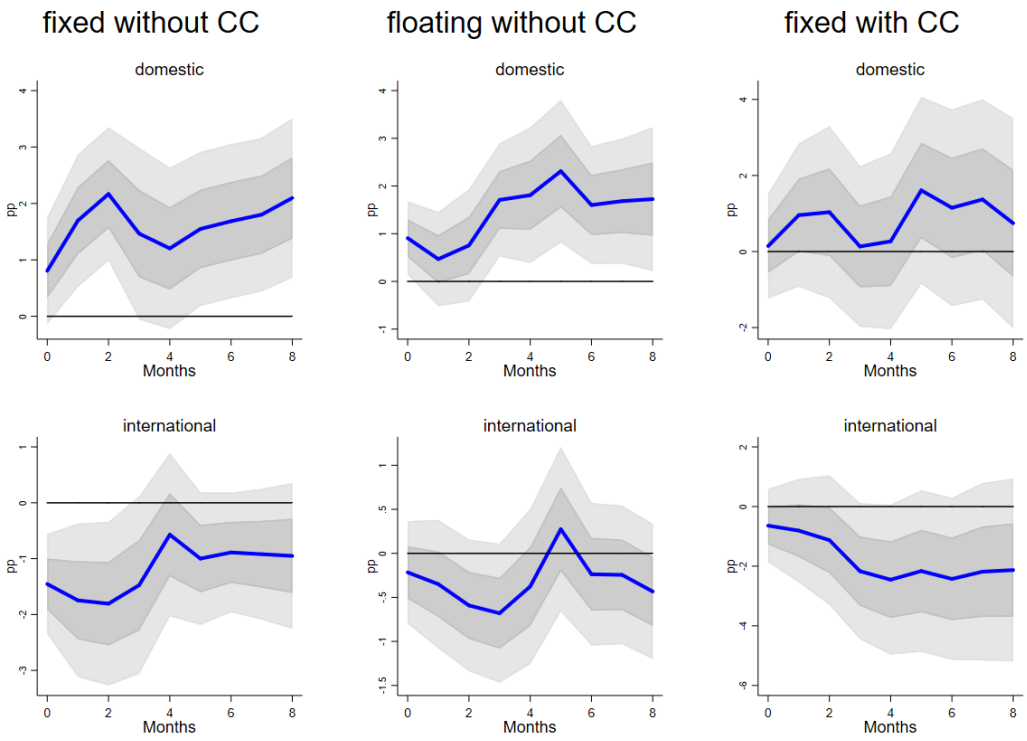
Starting with this simple specification with a policy shock that is not totally exogenous is justified by the fact that there is no reliable, continuous measure of exogenous monetary policy over the long term. Modern identification of monetary policy shocks relies on context-specific information and data (central bank forecasts, market expectations, etc.), so shocks are identified by different techniques depending on the period and the central bank. While it is possible to construct such shocks for historical sub-periods (as we will do in the next section), it is not possible to scale them up and merge them into a single series.

Note, however, that unlike the literature on the impact of domestic monetary policy, the literature on the international transmission of the monetary policy shock generally finds results that are qualitatively close if the leading central bank's interest rate is used alone or if the estimation incorporates a well-identified monetary policy shocks (see, for example, the comparisons displayed in Bruno and Shin (2015); Elliott, Meisenzahl, and Peydró (2024) for the post-1990 period using the US Fed interest rate, and Bazot, Monnet, and Morys (2022) for the effect of the Bank of England rate before 1914).[16] It suggests that endogeneity issues are less problematic than with changes in national monetary policy.

For both these reasons, we regard this first step as a useful - although imperfect - benchmark. In a second stage, we will carry out additional estimations over separate periods and using well-identified monetary policy shocks.

[16]In line with the recent literature (e.g. ,Elliott, Meisenzahl, and Peydró (2024), we use the Fed Fund rate as a measure of US monetary policy until the 2008-2009 crisis. After, we use the shadow rate built by Wu and Xia (2016) to account for the zero lower-bound.

Figure 1: Balance sheet responses to an international shock. Full sample



Note: Panel local projections including 6 lags. Response to a change in the policy rate of the main central bank (BoE until 1939, Fed discount rate from 1945 to 1973, Fed fund rate from 1973 to 2007, Fed shadow rate from 2007 to 2019). Capital control classification is based on Chin and Ito financial openness index. The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also include the domestic policy rate, the exchange rate, monthly dummies, a time trend, and country fixed effects.

3.1.2 Results

The impulse response functions shown in figure 1 demonstrate that central bank balance sheets cannot be neglected when addressing the international transmission of monetary policy shocks. Only in cases of imperfect capital mobility (right-hand panels) do we find insignificant responses from central banks' international and domestic assets.

In fixed exchange rate regimes (left-hand panels), we observe a significant response from both portfolios. They react in opposite directions and therefore offset each other, implying that sterilized foreign exchange interventions are taking place. But the point estimates also suggest that the domestic portfolio reacts more than simply sterilizing foreign exchange interventions.

Even more strikingly, we observe a strong and significant reaction of the domestic portfolio in open economies with floating exchange rates (central panels). The reaction of the international portfolio is negative, but more moderate and barely significant. This result is consistent with the theoretical framework of section 1 according to which central banks must expand their national portfolio to stabilize the money market rate, even when they allow their exchange rate to float.

3.2 Focus on historical periods with full financial openness

Previous results have confirmed that - in line with economic theory - the central bank's balance sheet only reacts to international shocks in the absence of capital controls. This starting point suggests further investigations, deepening the analysis in three ways: (i) by extending the analysis to additional variables - in particular money market rates and exchange rates - which are key to understanding the mechanisms underlying central bank balance sheet expansions and their consequences; (ii) by relying on properly identified monetary policy shocks; (iii) by examining different time periods to check whether a change in financial globalization over time has turned the trilemma into a dilemma, and what this means for central bank balance sheets.

3.2.1 First vs. Second Financial Globalization

These three principles lead us to focus on countries without capital controls during the periods that economic historians call First Globalization and Second Globalization (e.g. Obstfeld and Taylor (2004); Schularick and Steger (2010); Bordo and James (2015); Meissner (2024). 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 (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. With financial globalization, the world also rediscovered the international financial crises that had been a marked feature of the pre-1914 world. But the scale of the second globalization rapidly exceeded that of the first. International assets and liabilities, or FDI, as a proportion of GDP reached unprecedented levels (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, 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 (Ivashina, Scharfstein, and Stein (2015); Aldasoro, Ehlers, McGuire, and von Peter (2020)). Another important difference between the first and second globalizations is the exchange rate regime. Whereas the most financially developed economies had a fixed exchange rate regime (gold standard) prior to 1914, the opposite situation has recently arisen.

The singular characteristics of the Second Financial Globalization from a historical perspective (in particular the predominance of the floating exchange rate and the unprecedented level of financial openness and role of global banks) has led researchers to investigate how current times differ from the standard textbook model of international macroeconomics (*trilemma*), which was forged with reference to the First Globalization and periods of limited capital mobility (see in particular Rey (2015); Miranda-Agrippino and Rey (2020)).

So, in the spirit of what previous researchers have done for the banking crises (Schularick and Taylor (2012)) or public debt (Meyer, Reinhart, and Trebesch (2022)), our long historical perspective is uniquely capable of characterizing the extent to which current times differ from earlier periods of financial globalization.

3.2.2 Exogenous Monetary Policy Shocks and Sample Choices

Another advantage of comparing the First and the Second Globalization is that previous scholars have already built exogenous shocks to the central bank policy rate of the two main central banks during each period.

For the Gold Standard period we use the series computed by Lennard (2018) for the BoE policy rate shocks. He follows the seminal study of Romer and Romer (2004) by identifying the information set of the board members of the BoE based on a reading of transcripts of meetings. He then purged the BoE discount rate from the relevant information on expected economic changes that was available to policymakers at the time of decision making. The residuals identified at a decision-by-decision frequency are transformed into a monthly series by matching the shock with the month in which it occurred and summing shocks in months with multiple decisions.[17] The advantage of such a shock compared to the plain discount rate change is that: (i) it captures covariates affecting both the BoE decision and the world economy, (ii) it accounts for expectations, which can be accounted for by other central banks at the time of the BoE discount rate change.

For the most recent period of we use the shock produced in Bauer and Swanson (2023a,b). They follow the recent literature on high frequency identification based on federal funds futures markets change around FOMC announcements.[18] This allows to account for the set of unexpected decisions of central bankers. Those decisions can be the mere change in the targeted policy rate or explicit forward guidance. However, Bauer and Swanson noticed that the standard high-frequency identification strategy does not account for simultaneity issues, as the central bank decision is also the result of events affecting their decision while market participants are about to adjust for the set the relevant news. For that reason the Bauer and Swanson's shock is calculated from the federal funds futures markets change after being purged for those news. Therefore, the advantage in using this shock is to account for expectation, omitted variables, simultaneity issues, and forward guidance, which gain an important role over the past 30 years. In addition, this series has the advantage of being recently produced and covers a long sample from 1989 to the covid pandemic. So, for the post-1980s period, we have the same sample as when we use the uninstrumented US Fed policy rate in figure 1.

[17] Among the 13 variables in the information set, some are domestic (stock prices, wheat prices), while others are international (gold reserves and exports, French and German discount rates and exchange rates, U.S. exchange rate).

[18] For standard references on the high-frequency identification of monetary policy shocks, see Gürkaynak, Sack, and Swanson (2005); Nakamura and Steinsson (2018); Miranda-Agrippino and Ricco (2021); Bauer and Swanson (2023a,b) among others.

3.2.3 The First Globalization

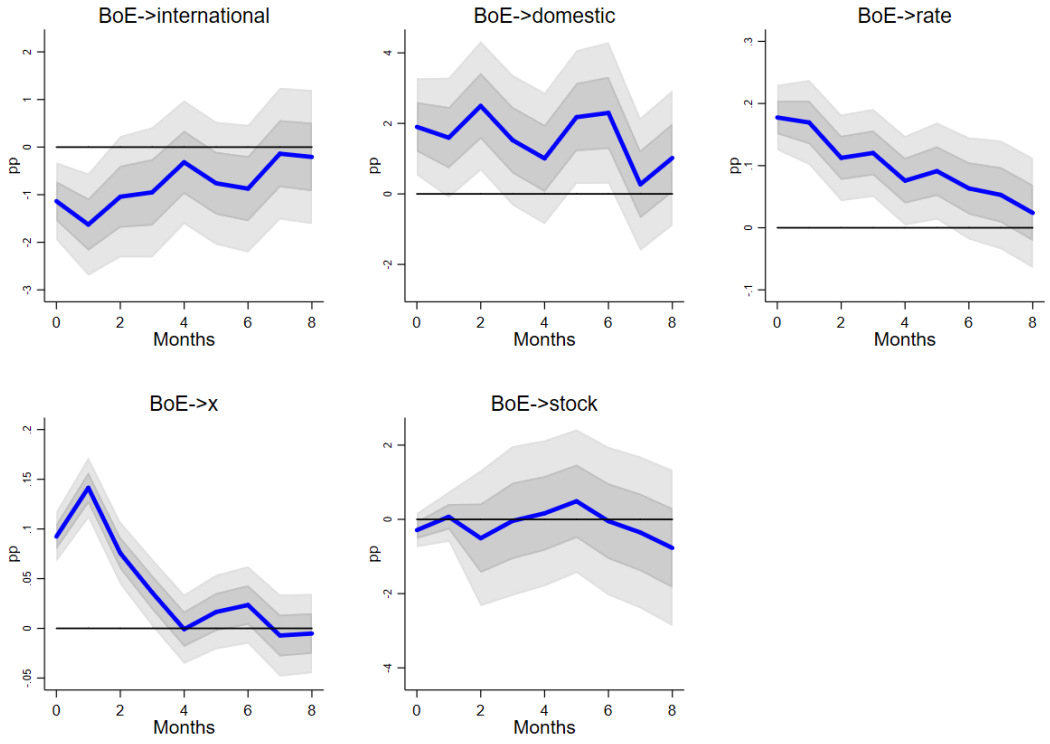
Most countries with central banks were on the gold standard before the First World War, but this did not mean that exchange rates never moved. Market exchange rates could fluctuate within bands around the central gold parity. The upper and lower limits of these bands were called gold points. Gold points existed because shipping gold from one country to another involved significant transaction costs. Gold points were therefore determined by the difference between the price at which gold could be bought from the central bank and the cost of exporting it.

If the peg was credible, and if the variation in the international interest rate was not too great, the exchange rate band could offer a country substantial flexibility (Bordo and MacDonald (2005)). However, as Figure 2 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.

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 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 Bloomfield (1959), had already suggested with descriptive statistics.

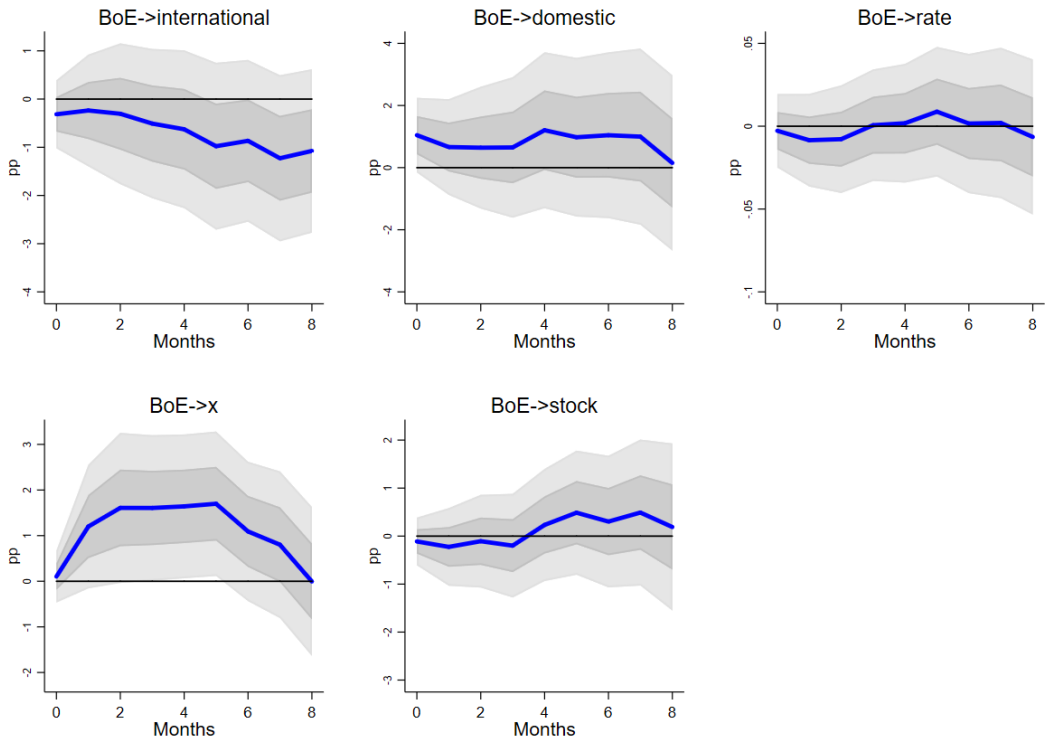
It is also interesting to note that equity prices did not ultimately react significantly to the shock to the international rate despite the well-known strong integration of stock markets during this period. We interpret this as a sign that the moderate increase in the domestic interest rate following the international shock was not sufficient to have an impact on the stock market and the economy. 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 2: Classical gold standard, pegging countries (1891-1913)



Note: Panel local projections including 3 lags. Response to BoE policy rate shock based on 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.

Figure 3: Classical gold standard, floating countries (1891-1913)



Note: Panel local projections including 3 lags. Response to BoE policy rate shock based on 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.

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. The exchange rate reaction is significant with the 2-standard error bands, and it is much stronger than for the gold-standard countries. After two months, a 100 basis point rise in the British rate is entirely absorbed by the depreciation in the exchange rate. No other variable reacts so significantly and strongly. 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.

3.2.4 The Second Globalization

One of the main differences between the first and second globalizations is the predominance of floating exchange rates in the second. 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 adopted floating exchange rates during the second globalization. The few emerging markets in our sample have rarely had an open capital account over the last thirty years, so will be treated separately in a later stage.

Figure 4 shows the response of key variables to an exogenous US monetary policy shock (using the Bauer and Swanson (2023a) shock). We start the sample in 1994 to ensure that all economies in our sample are fully financially open.[19].

It is interesting to comment on this figure, bearing in mind the results of the first globalization. As in the case of floating countries prior to 1914, the exchange rate reacts strongly, in line with standard economic theory (the results in figure 4 are highly significant). However, the specificity of the second globalization lies in the fact that several other key variables also react. Our main variable of interest - the central bank's domestic portfolio - also reacts significantly. 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, on the other hand, do not react. The lack of response from international reserves is consistent with the exchange rate response. 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 reaction of the money market rate, which is immediate after the shock, but weak (less than 10 basis points), and quickly disappears. Expansion of the central bank's domestic portfolio therefore keeps the money market rate in line with official interest rate, which do not react significantly.

In contrast to the first wave of globalization, the exchange rate is not sufficient to absorb the international shock, and the central bank must increase domestic liquidity. The second-globalization central bank in a floating country thus paradoxically resembles a central bank under the gold standard, except that no intervention in the foreign exchange market is necessary.

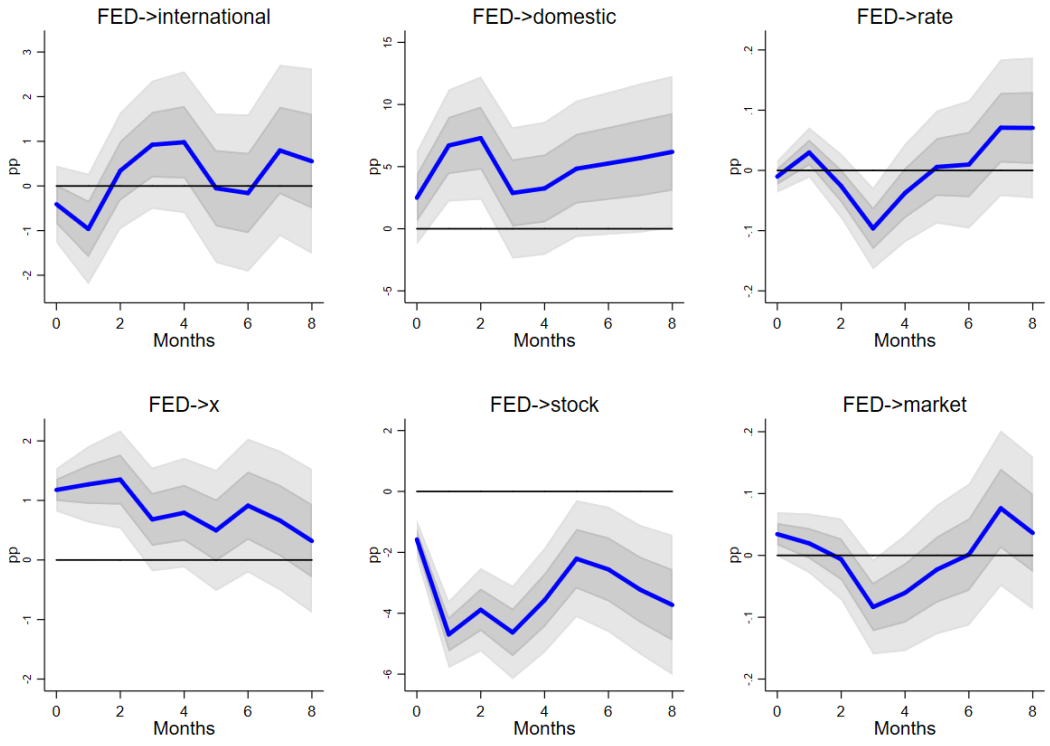
Figure 5 shows the responses of the central bank's short-term liabilities over different

[19]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)).

periods. This confirms that the expansion of the domestic portfolio in gold-standard countries during the first globalization was primarily intended to sterilize the decline in foreign exchange reserves: there is no increase in central bank liabilities after the shock. In contrast, central bank liabilities in floating countries during the second globalization increase after the shock, in line with the response of central bank assets shown in figure 4. It should be noted, however, that we also encountered some cases in the gold standard period where the domestic portfolio was used in addition to the sterilization of foreign exchange interventions. When we expand our sample for the pre-1914, including countries for which we struggled to obtain stock-market data (Netherlands, Austria and some Scandinavian countries in particular), we also find an increase in the central bank liability (see north-est panel from figure 5). Hence, the role of the domestic assets to tame the effects of international shocks is not new to the Second Globalization. But only in the later case it has been used in floating exchange rate and without being combined to FX sterilization.

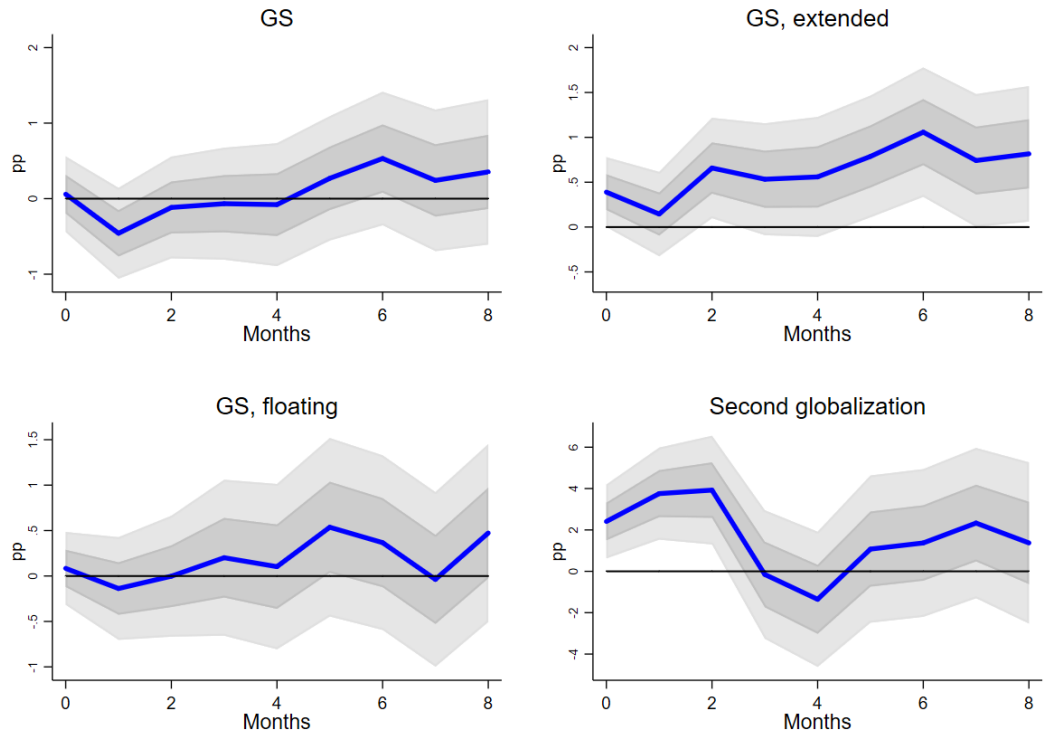
Figure 4 presents another important result. Before the First World War, exchange rate movements or interventions on the foreign exchange market were sufficient to control the effect of an international interest rate shock on the domestic stock market. This has no longer been the case since the 1990s. This result is entirely consistent with those of Miranda-Agrippino and Rey (2020); 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.

Figure 4: Second globalization, floating countries without capital control (1994-2019)



Note: Panel local projections including 6 lags. Response to Fed policy rate shock based on Bauer and Swanson (2023). The responses of both domestic and international portfolios are in 12-month variation. International portfolio valuation is set in special drawing right. The set of local projections also includes the international business cycle, the price index, the industrial production index, monthly dummies, a time trend, and country fixed effects.

Figure 5: Responses of Central Bank Monetary Liability



Note: Panel local projections based on the same sub-samples and shock used for Figures 2 and 3. The response of total liability is in 12-month variation. The set of local projections also includes the same set of variables used in figure 2 and 3 (except for domestic and international portfolios).

4 From trilemma to dilemma: central banks in other historical cases

The comparison between the first and second globalizations has highlighted the changing role of central banks in the international monetary system. In the past, short-term fluctuations in the central bank's balance sheet merely rounded off the corner of the trilemma. They now play an additional 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. But our previous analysis underlines that the expansion 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.

We now turn to a more comprehensive use of our historical data, going beyond the comparison between the two most intense periods of financial globalization and including some emerging markets in the sample. In addition to presenting a comprehensive history of central banks in the international monetary system, this section plays two additional roles. Firstly, we highlight the behavior of central banks in other corners of the trilemma: fixed exchange rates with capital controls (Bretton Woods period) and stricter pegs than the gold standard (illustrated by the European monetary system of the 1980s). This approach makes it possible to test the trilemma further in history, and to characterize the way in which central banks have or have not rounded the corners of the trilemma. Secondly, covering other historical periods allows us to verify the robustness of our previous results concerning the first and second globalizations. Indeed, it is important to show that central bank asset reactions make sense in other periods too, given what we know about the exchange rate regime. In particular, we verify that the most distinctive result of the second globalization (i.e. the reaction of the central bank portfolio solely for the purpose of stabilizing the money market) is not observed in other periods.

4.1 Identification of exogenous international monetary policy shocks

One major issue of the analysis for other periods is the lack of available measure of exogenous monetary policy shock in the literature. We thus make an attempt to construct such 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 futures rates are not available before the late 1980s, we collect daily interest rate 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 the money market and foreign exchange market. Our approach (high-frequency identification with historical daily data) is in the same spirit as the recent article of Cloyne, Hürtgen, and Taylor (2022) on 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 market variation in a very short window around policy meeting. The literature uses data on intraday futures contracts. Absent such financial instrument and intraday data for the historical periods we are interested in, we use daily data on the exchange rate and the money market rate. Our identification relies on the idea that changes in the policy rate which are not driven by exchange rate and interest rate movements in the day before the decision of the central bank are truly 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 (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 the narrative approach of 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. Although we lack data on the forecasts produced by the central bank, we can have access to historical data (production and price indices) 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:

$$\Delta r_d^{\text{ref}} = \beta_0 + \beta_1 r_{d-1}^{\text{ref}} + \beta_2 \Delta r_{d-1}^{\text{ref}} + \sum_j \gamma_{j,p} y_{d-2}^j + \sum_j \phi_j \Delta_{d-1 \to d-T} y^j + \epsilon_d \tag{2}$$

$$\Delta r_m^{\text{ref}} = \sum_k \sum_{p=1}^{4} \theta_{k,p} x_{m-p}^k + \sum_k \sum_{p=1}^{4} \mu_{k,p} \Delta x_{m-p}^k + \epsilon_m \tag{3}$$

With r_d^{ref} as the policy rate of the reference country (the UK, the US, and Germany 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; $\Delta_{t \to t-T} y^j$ 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.

Two critics can be addressed to our shock: (i) it does not account for forecast to capture the information channel; (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. 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 90s. Besides, our measure directly deals with the simultaneity issue thanks to high-frequency identification on daily market rate and exchange rate.

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 figure A1-A6 in the appendix, our shock produces coherent responses, especially about prices. Results are particularly good for the Bretton Woods and the Gold Standard era and is in line with the literature for the post-1973 period. The only case for which the responses appear unconventional is the interwar gold standard. BoE had

to cope with during this troubled period.

4.2 Classical vs. 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 goal seemed to have been achieved. Other countries followed suit, private financial flows resumed debt financing worldwide, and stock markets exploded everywhere (Eichengreen (1992); Kuvshinov and Zimmermann (2022). This 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 withdraw as the economic crisis spread around the world, but many countries 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 to the pre-1914 gold standard, as far as central bank operations were concerned.

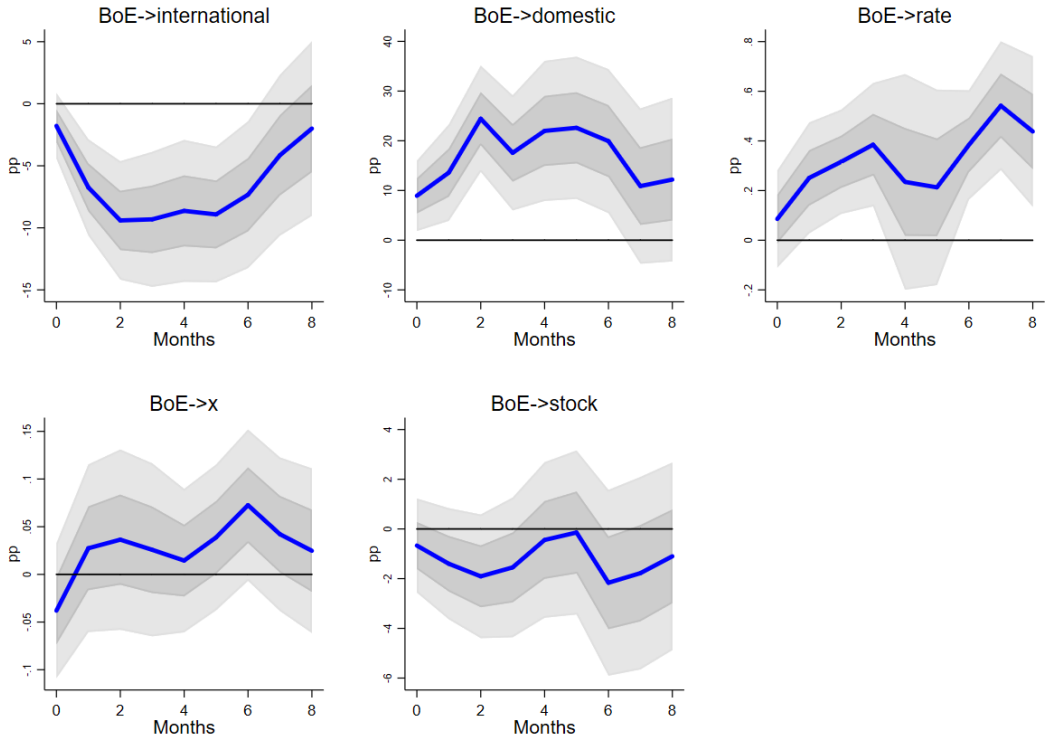
Figure 6 shows that domestic and international central bank portfolios reacted with the same pattern as before 1914. The exchange rate constraint appears to have slightly stricter than before, with higher interest rate reaction and lower exchange rate response. But the response of the interest rate still far from the 100 basis point increase in the Bank of England rate. The reactions of the central bank's assets are stronger than in the case of the gold standard, suggesting that more action was needed to make the peg credible.

A notable difference with the pre-1914 gold standard is the negative reaction of stock market prices to the increase in the Bank of England interest rate, although this reaction is only significant according to the 1 standard error band. We see this as consistent with the view of contemporaries and economic historians who have noticed an impact of the Bank of England on the US stock market in the year prior to the Great Depression (see Cadorel (2021) for a recent discussion). The late 1920s stock market boom was stronger than ever and so was potentially the international comovement between stock markets.

4.3 Bretton Woods

Unsurprisingly, we do not observe a large and significant reaction in financial variables and central bank balance sheets during the Bretton Woods period (see figure 7). This period is well known for the prevalence of capital controls that prevented international arbitrage Obstfeld and Taylor (2004); Bordo and James (2015). Not only did capital controls block the transmission of international shocks, they were also associated with strong domestic banking

Figure 6: Responses to a rise in the Bank of England interest rate. Interwar gold standard, 1925m1-1931m8



Note: Panel local projections including 3 lags. Response to BoE policy rate shock (see the main text 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 industrial production index, the price index, monthly dummies, a time trend, and country fixed effects.

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 played little role, internally and externally. For our purpose, the main conclusion to draw from figure 7 is that central bank balance sheets were barely required to tame international shocks since, as predicted by the trilemma, capital controls already did the job.[20]

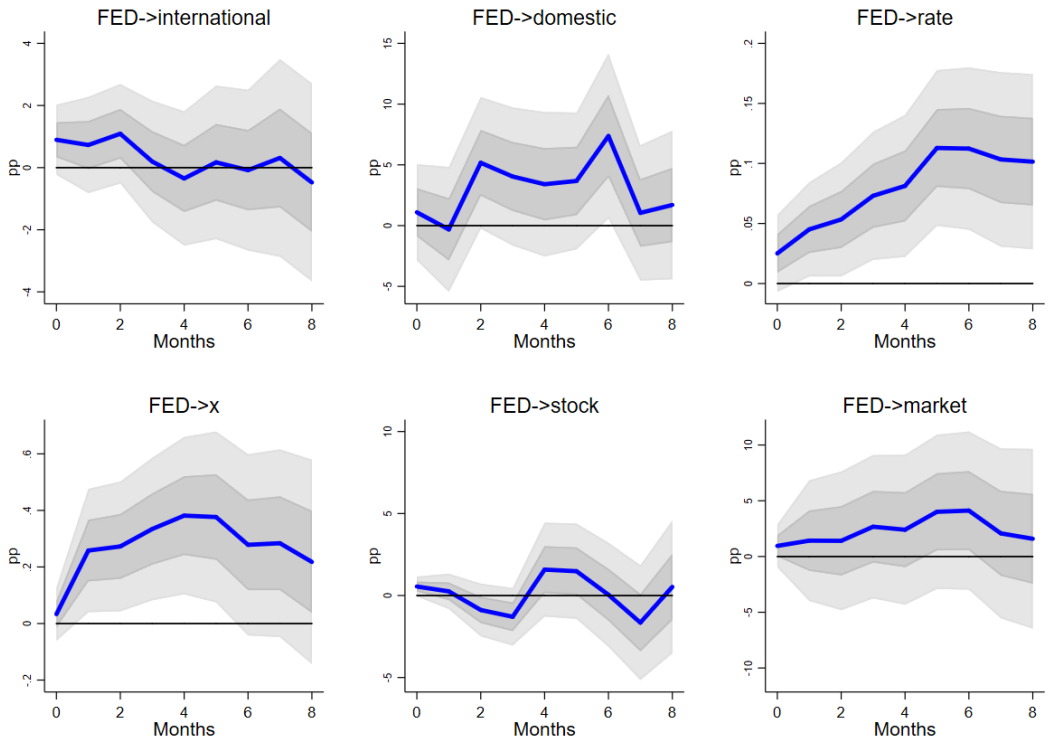
The results displayed in figure 7) nevertheless show a barely significant depreciation of the exchange rate and an increase in the central bank interest rate in the months following the US shock. This suggests that capital controls may not have been fully binding in all countries. However, these reactions were extremely weak. The central bank's interest rate rises by less than 10 basis points following a 100 basis point increase in the US rate. The exchange rate depreciates by 0.3%.

4.4 The European Monetary System

After the end of the Bretton Woods system, Western European countries decided to restore a system of fixed-exchange rate between themselves (while floating towards the dollar). Germany became progressively the core of the system since its inflation rate was lower than in other countries in the 1970s. Various exchange rate pegs were tested throughout the 1970s but it is only at the end of 1979 that the European Monetary System (EMS) was fully in force. During this period, some European countries maintained some capital controls, but limitations were less constraining for intra-european financial flows, except during the 1992-1993 exchange rate crisis (Bakker (2012)). We thus take the period 1980-1991 as the benchmark period of full operation of the EMS with capital mobility. The Bundesbank was the undisputed leader of the EMS (Höpner and Spielau (2018); Cloyne, Hürtgen, and Taylor (2022)). Exchange rate bands were narrow, and each participating central bank was required to intervene to keep the market rate for its own currency against each other participating currency within 2.25% of its cross-parity. From the beginning, the purpose was to create a currency union close to a monetary union. Hence, a common currency was created (the ECU) as a basket of currencies of EMS members. A European Monetary Cooperation Fund was also created to narrow the fluctuation margins between currencies. Although constraining on a daily basis, it gave rise to many parity adjustments - devaluation towards the Deutsche

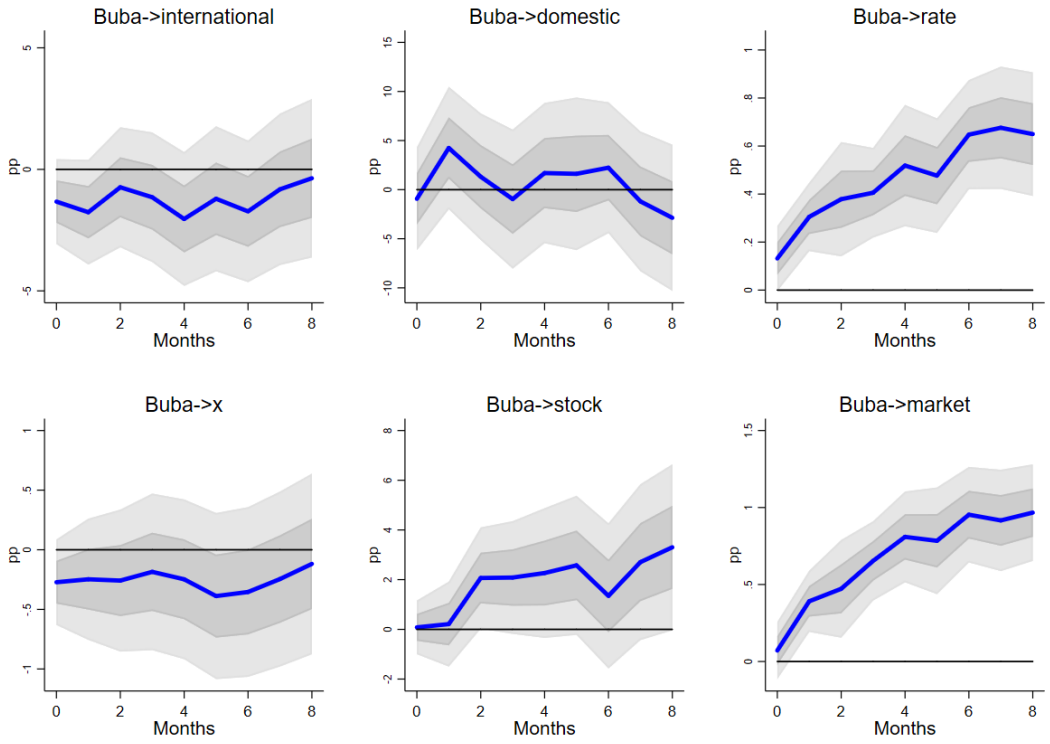
[20] Of course, this result does not imply that central banks did not resort to foreign exchange intervention during the Bretton Woods era. But they did do so when faced with current account imbalances - due to budget deficits or trade shocks - rather than in response to an international financial shock. 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 7: Responses to a rise in the US Fed interest rate. Bretton Woods, 1946-1971



Note: Panel local projections including 3 lags. Response to an exogenous Fed policy rate shock (see the main text for details). The responses of both domestic and international portfolios are in 12-month variation. International portfolio valuation is set in special drawing rights. The set of local projections also includes the US industrial production index, the US price index, the US stock market index, the industrial production index, the price index, monthly dummies, a time trend, and country fixed effects.

Figure 8: Responses to a rise in the Bundesbank interest rate. European Monetary System, 1980-1991



Note: Panel local projections including 6 lags. Response to an exogenous Bundesbank rate shock (see the main text for details). The responses of both domestic and international portfolios are in 12-month variation. International portfolio valuation is set in special drawing rights. The set of local projections also includes global business cycle index, the industrial production index, the price index, monthly dummies, a time trend, and country fixed effects.

Mark - over the years (Höpner and Spielau (2018)).

As under Bretton Woods, devaluations could provide short-term flexibility to resolve large current account imbalances. But figure 8 clearly shows that the interest rates of EMS members really followed the German interest rate. No other exchange rate regime in our sample - not even the gold standard - showed such a strong correlation between the main international interest rate and the domestic rate. The money market reacts on a one-for-one basis after 6 months, and the pass-through to the central bank rate is over 80%. This choice was consistent with a narrow-band exchange rate zone and a clear objective towards economic and political integration. As a result, positioned in the extreme corner of the trilemma, the central bank's balance sheet shows no significant and important reaction. Reactions may suggest minimal intervention in the foreign exchange market, but they are not significant.

The absence of sizeable response of the domestic portfolio is also consistent with a reaction of the money market rate higher than the central bank policy rate. European countries fully played the game of financial and monetary integration, and central bank balance sheets were of little use. Contrary to the gold standard, the EMS appears as the textbook trilemma case of a fixed-exchange rate regime with capital mobility. And this is also clearly visible in the absence of central bank's reliance on its *elastic currency*.

5 Further discussion and additional robustness checks

5.1 Accounting rules and the revaluation of assets

5.1.1 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 exceptions. The main ones concern a few countries (e.g. Belgium in 1926, France 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. Another important case in our sample concerns the eurozone countries in 1998. It was agreed that all new members of the Eurosystem would revalue their national assets at market value. In all these cases, we fix a missing value for the month in which this accounting change took place. In this way, we avoid calculating a monthly growth rate induced by this accounting change. 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.

5.1.2 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 also applied to gold reserves until 1971.

The difficulties are much greater when the 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 get rid of these potential biases completely, but we can reduce them considerably by using alternative measures (see below) and we can easily assess

the direction of the bias.

Biases go in the following directions. 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. 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 denominated in domestic currency rises. 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).

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 (Monnet, Humann, and Mitchener (2024)). Since the late 1990s, it has become standard practice to revalue them on a quarterly basis.[21]

When securities are revalued, the new valuation takes into account the exchange rate and the market price. It is very important to note that valuation gains and losses are clearly 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. 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. [22]. 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.

[21] 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/).

[22] 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

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. [23] The literature on central bank losses - which are generally mainly due to exchange rate revaluations as a result of currency appreciation - also confirms this fact (Archer and Moser-Boehm (2013); Monnet, Humann, and Mitchener (2024)).

5.1.3 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:

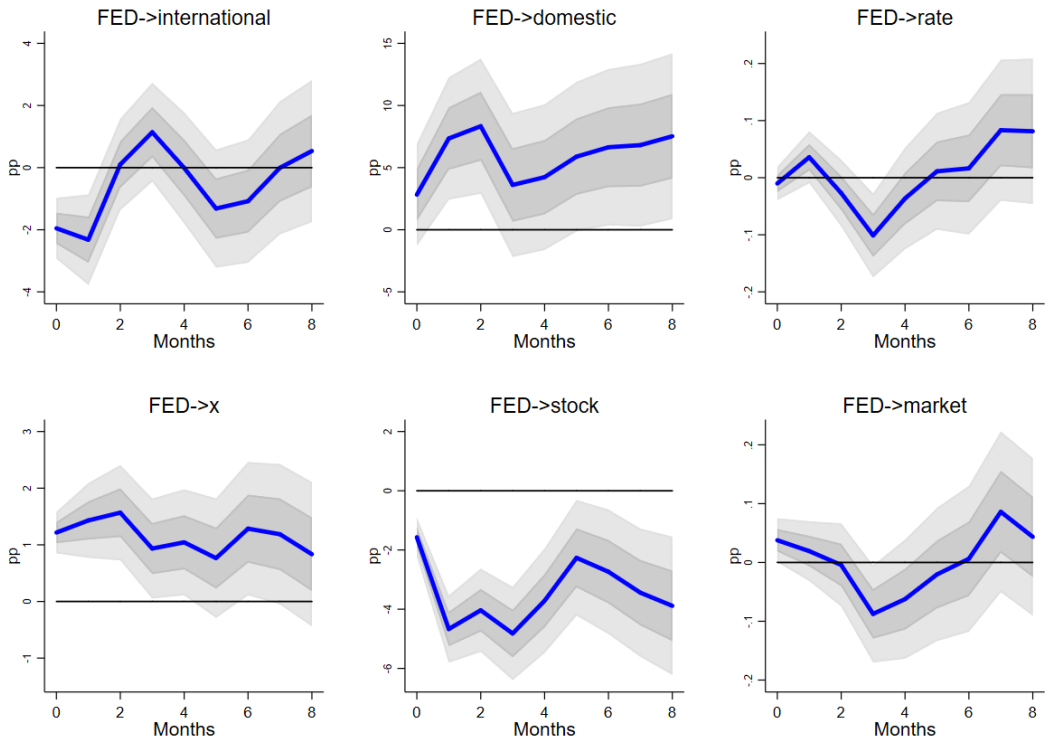
1. In all cases, we can isolate the revaluation account on the liability side. Thus, our assessment of the expansion of the domestic portfolio beyond the sterilization of foreign exchange intervention (see figure 5) is not affected by the revaluation of international assets.

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. 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 Scandinavian countries that hold a substantial proportion of their reserves in euros, this bias may be non-negligible. For this reason, we have so far preferred to use SDR reserves, since the SDR is a basket of all major international currencies.

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

Figure 9: Second globalization, USD valuation



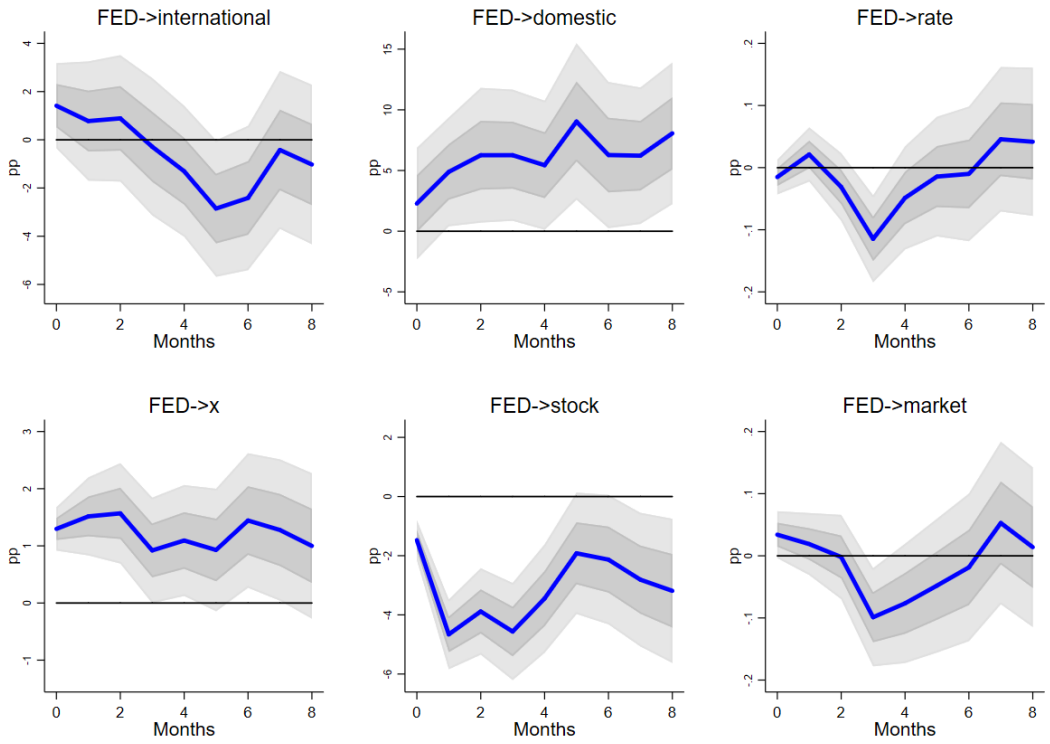
Note: panel local projection similar to figure 4 but with foreign exchange reserve valuation in USD

The results presented in figure 10 show that our results are similar over the period 1994-2019 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). However, as displayed on figure 9, foreign exchange reserves expressed in USD react negatively to the shock. As explained above, this is probably due to the fact that reserves held in other currencies depreciate against the dollar after an increase of the US interest rate.

5.2 Alternative samples

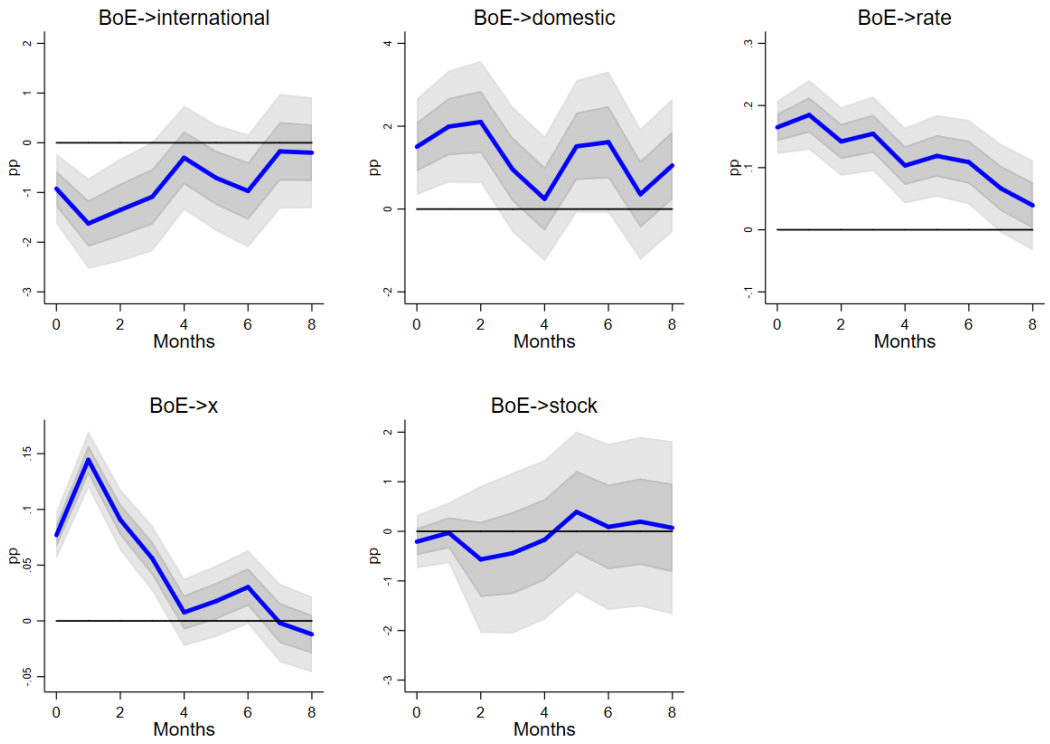
In this section we discuss several robustness to our results. First, we build our own series for Bank of England monetary policy shocks during the gold standard. Instead of using the series of Lennard (2018), we use the same strategy as we did for other periods (following Cloyne, Hürtgen, and Taylor (2022)) and apply it to England from 1891 to 1913. This allows to test both the quality of the results displayed in figures 2 and 3 but also the pertinence of

Figure 10: Second globalization, LCU valuation



Note: panel local projection similar to figure 4 but with foreign exchange reserve valuation in USD

Figure 11: Classical gold standard, pegging countries: our alternative shock



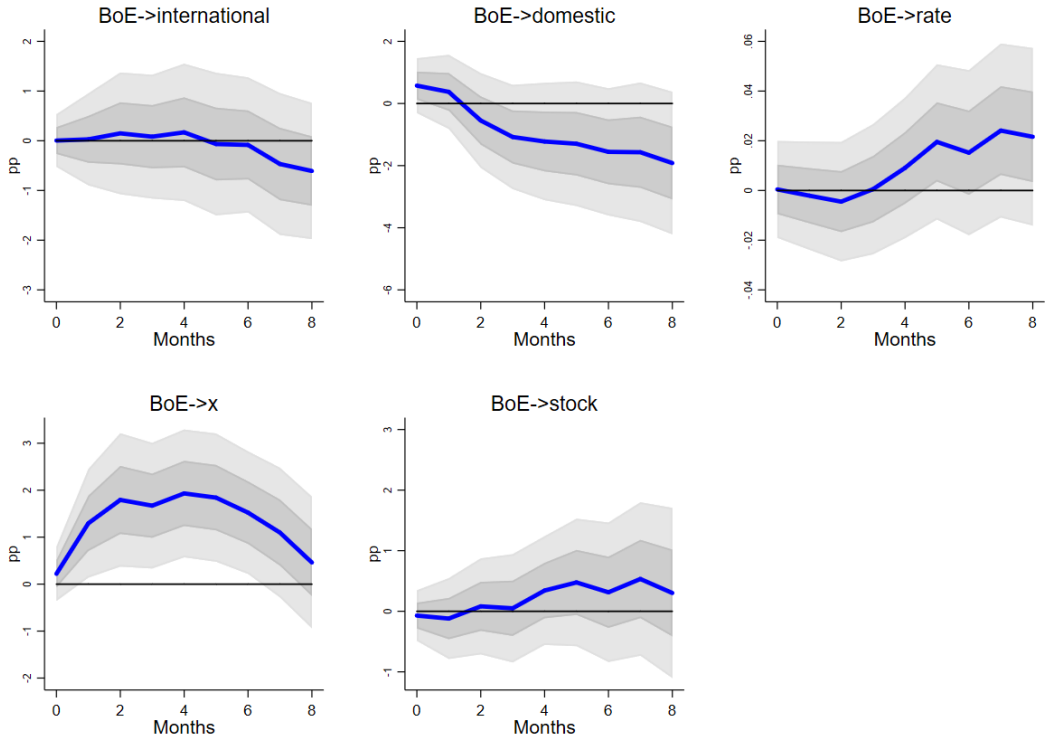
Note: Panel local projections including 3 lags. Response to BoE policy rate shock based on shock methodology disclosed in section 5.1. The responses of both domestic and international portfolios are in 12-month variation. The set of local projections also includes the UK business cycle, the UK stock market index, monthly dummies, a time trend, and country fixed effects.

the methodology used to produce our shock.

In fact, Lennard (2018) applied only the second step of the identification procedure we followed in section 4, 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.

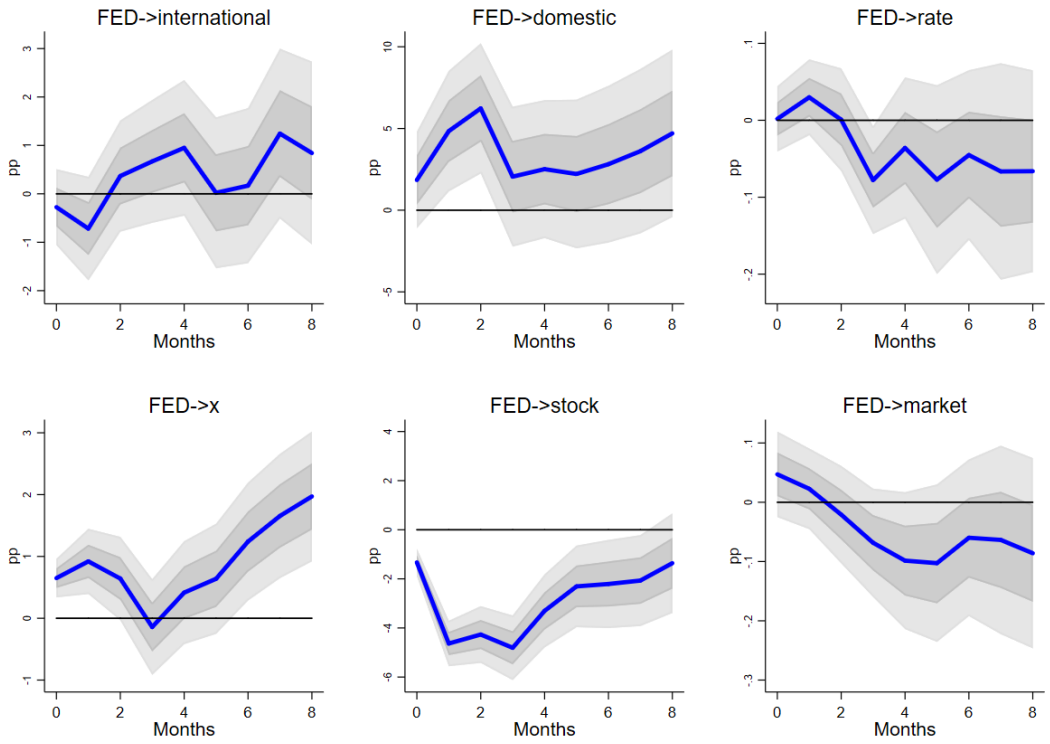
Figures 11 and 12 show that the results are fully in line with our previous calculation based on Lennard's shock. We still observe a decline in the international portfolio and a rise in the domestic portfolio for pegging countries. This also coincides with the limited rise in the discount rate and a 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.

Figure 12: Classical gold standard, floating countries: our alternative shock



Note: Panel local projections including 3 lags. Response to BoE policy rate shock based on shock methodology disclosed in section 5.1. 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.

Figure 13: Second globalization, extended sample (1988-2019)



Note: panel local projection similar to figure 4 using extended sample.

In a second robustness check, we extend the estimation sample for the second globalization period. So far, our analysis focused on the post EMS period, although the shock produced by Bauer and Swanson allows to extend the analysis back to 1988. Figure 13 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.

6 Conclusion

This paper explores the role of central bank balance sheets in taming the effect of the global financial cycle 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 dataset of monthly exchange rates, (money market and policy) interest rates, and central bank balance sheets. It is supplemented – wherever possible – 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 1891-2020.

We were able to confirm for the 1891-2020 period some results already encountered in the literature: we have moved from a trilemma world to a dilemma world. It means that floating exchange rates are no longer enough to insulate money market rates and assets prices from international financial shocks. We document a clear contrast between the First Financial Globalization (pre-1914) and the Second one starting in the 1980s.

Our main novel contribution relates to the institutional underpinnings. We add a dimension not previously considered in the literature, that is the role of central bank balance sheets, and especially the domestic assets. First, central bank balance sheets (both the international and domestic portfolio) were key to round the corner of the trilemma in fixed exchange rate regimes with financial openness before World War II, namely the classical gold standard before 1914 and the interwar gold exchange standard. We show that, in the past as today, the reaction of central banks' domestic assets to international financial shocks goes far beyond the simple sterilization of foreign exchange interventions.

Second, there were periods in which central bank balance sheets were little active. It can either be due to strong capital controls, as under Bretton Woods, or - on the contrary - to a very strict exchange rate regime. In the European Monetary System (1979-1992/93), Interest rate pass-through was higher than in any other period under investigation and monetary autonomy hollowed out. Yet this period did not last long in a centennial perspective, succumbing to its own contradictions.

Third, the reactivation of the shock absorbing role of central bank balance sheets in the 1990s has been effective to isolate monetary policy – and thus the money market – from international shocks but not necessarily the stock market. This shows that central bank balance sheets are still needed in a regime of floating exchange rates, in contrast to what the macroeconomic trilemma holds. Yet we also document that isolating monetary policy and the money market rate from exogenous shocks – the paramount objective of an "elastic currency" – no longer translates simultaneously into isolating other financial markets as well. This disconnect between asset prices, on the one hand, and other credit conditions, on the other, was already highlighted in Miranda-Agrippino and Rey (2020); Monnet and Puy

(2021), but this paper is the first to explain how it relates to the actions of central banks.

These results pave the way for further research into why 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.

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