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# Taming the Global Financial Cycle: Central Banks and the Sterilization of Capital Flows in the First Era of Globalization

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Abstract:
Are central banks able to isolate their domestic economy by offsetting the effects of foreign capital flows? We provide an answer for the First Age of Globalization based on an exceptionally detailed and standardized database of monthly balance sheets of all central banks in the world (i.e. 21) over 1891-1913. Investigating the impact of a global interest rate shock on the exchange-rate, the interest rate and the central bank balance sheet, we find that not a single country played by the "rules of the game." Core countries fully sterilized capital flows, while peripheral countries also relied on convertibility restrictions to avoid reserve losses. In line with the predictions of the trilemma, the exchange rate absorbed the shock fully in countries off the gold standard (floating exchange rate): the central bank's balance sheet and interest rate were not affected. In contrast, in the United States, a gold standard country without a central bank, the reaction of the money market rate was three times stronger than that of interest rates in countries with a central bank. Central banks' balance sheets stood as a buffer between domestic economy and global financial markets.

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# Taming the Global Financial Cycle: Central Banks and the Sterilization of Capital Flows in the First Era of Globalization*

Contents



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*Completely monetarized communities could not have stood the ruinous effects of abrupt changes in the price level necessitated by the maintenance of stable exchanges unless the shock was cushioned by the means of an independent central banking policy. [...] Absence of such a mechanism would have made it impossible for any advanced country to stay on gold without devastating effects as to its welfare, whether in terms of production, income, or employment.*

Karl Polanyi, *The Great Transformation* (1944: 218)

Countries wish to reap the benefits of financial integration while shielding themselves from the vagaries of international financial markets. But can they have it both ways? A large body of work acknowledges the constraints of a *trilemma*, in the spirit of Robert Mundell's international macroeconomic model, pointing out that a fixed-exchange rate regime and full capital account openness lead countries to give up their monetary autonomy (Obsteld and Taylor 2004, Aizenman et al. 2010, Farhi and Werning 2014, Bordo and James 2015, Klein and Shambaugh 2015, Jordà, Schularick and Taylor 2019). The first era of globalization, also referred to as the period of the classical gold standard (1880s-1914), is often taken as the paradigmatic example of such constraints, with central banks changing their discount rate in function of international pressures only (Eichengreen 1992, 2008, Obstfeld and Taylor 2004, Bordo and James 2015). Yet, beyond the focus on interest rates, there is a lack of quantitative information on what central banks actually did during this period, and especially how they adjusted their portfolio in response to international shocks. A historical detour can show us how strong the constraints of international finance used to be, and what solutions have been devised in the past to meet the challenges we face today.

In the spirit of the recent literature looking at the influence of US interest rates on the global financial cycle and foreign monetary policy (Rey 2013, 2016; Bruno and Shin 2015; Dedola et al. 2017, Miranda-Agrippino and Rey 2018, Jordà, Schularick, Taylor and Wald 2019), we revisit the history of the classical gold standard by examining the response of central banks to an increase in the interest rate of the Bank of England – then the leader of global financial markets (Lindert 1969, Eichengreen 1987). In a fixed-exchange rate regime with capital mobility, an increase in the leading international interest rate attracts capital flows to the centre country, and it forces foreign central banks to increase their rate in a

similar way. Our study is based on a new and exceptional dataset of detailed and standardized monthly balance sheets of all central banks in the world from 1891 to 1913, as well as interest rates and exchange rates. This is a first time that such a comprehensive and monthly dataset is assembled to study central banking during the pre-WWI gold standard.[1]

Thanks to the high frequency and large coverage of this dataset, we provide a new way to identify a central bank's sterilization policy, and we are able to highlight the importance of central banks' balance sheets instead of interest rates. Besides, our paper extends considerably the coverage of the previous comparative literature on monetary policy autonomy in the first era of globalization. Including peripheral countries (the emerging markets of the time), comparing countries on and off gold, and adding a country without a central bank (USA) to the analysis, we revisit the role of central banks and the constraints of the exchange rate regime.

Three results stand out. First, as already suggested by Bloomfield (1959), central banks in the gold standard did not follow the "rules of the game". That is, they did not raise their interest rates by the same order of magnitude as the Bank of England (the average pass-through was around 20%). Instead, they "sterilized" the effect of international shocks on the domestic money supply: they increased their loans to the domestic economy to offset capital outflows. Second, while central banks in core countries relied exclusively on sterilization to offset short-term international shocks, the central banks in the periphery of the gold standard also used restrictions on gold convertibility (i.e. capital controls) to minimize reserve losses. Such strategy allowed them to operate with wider exchange-rate bands, without suspending officially their adherence to the gold standard. Third, none of the mechanisms described above was observed by central banks in countries off gold: in floating countries, the exchange rate absorbed fully the international shock.

By comparison, we study the response of interbank interest rates and gold held by the Treasury in the United States, a major country without a central bank during the classical gold standard. We find that the response of the US money market interest rate to a change

1 A recent collection of statistics on historical central bank balance sheets (Ferguson et al. 2015) provides only annual data and broad categories for 12 central banks over the 20th century, with unsystematic distinction between foreign exchange and domestic assets.

in the English rate was three times as large as the response of rates in countries with a central bank. Consistent with a strong and rapid response of interest rates, the exchange rate between New York and London adjusted more quickly than in countries with a central bank. The United States enjoyed much less autonomy and – as suggested by Davis, Hanes and Rhode (2009) and Hanes and Rhode (2013) – lacked a central bank that could have sterilized the effects of shocks on the domestic money supply.

Taken together, our results show in a novel way why central banks matter. They also highlight the different ways – combining sterilization and convertibility restrictions – that were used by central banks during the first globalization to mitigate the potentially adverse effects of short-term international shocks. The immediate response of foreign exchange rates to an increase in the Bank of England interest rate confirms that the integration of global financial markets during this period was very high. Our findings also confirm the textbook *trilemma* (Obstfeld and Taylor 2004), as a floating exchange rate gave full autonomy to domestic monetary policy. Questions remain about whether the second era of financial globalization, since the 1990s, is different in this respect (Rey 2013, Obstfeld et al. 2019). Yet it is worth emphasizing that – despite the apparent benefit of floating exchange rates – most countries in the first era of financial globalization preferred to join the gold standard in order to attract long-term capital flows (Bordo and Rockoff 1995, Mitchener and Weidenmier 2015), while letting their central bank use various devices to offset undesired effects of short-term international capital flows. The most important conclusion of this study is that the era of the first globalization was not a period of total submission of countries to the fluctuations of international financial markets. The balance sheets of central banks stood as a buffer between the domestic economy and the global financial cycle.

The contribution of this article goes beyond the historical analysis of the international monetary system. Our identification strategy can be applied to other contexts in order to assess when central banks sterilized the effects of capital flows on domestic money and credit. The important role played by central banks' balance sheets to round (partly) the corner of the *trilemma* is unlikely to be unique to the gold standard. Similar sterilization policies can be used, even if central banks face a *dilemma* instead of a *trilemma*. Implications are straightforward for emerging market today that are willing to maintain a fixed-exchange rate – as peripheral countries during the gold standard – while relying on a combination of

capital controls and sterilization policy to absorb the effect of short-term international shocks (Fratzscher et al. 2019, Obstfeld et al. 2019).

Sections I defines sterilization in the context of the classical gold standard and first era of globalization. It also explains why previous empirical studies failed to identify sterilization and the method we propose to achieve a robust identification. Section II presents our method of estimation and identification, based on straightforward theory of international macroeconomics. Section III describes our original historical database on monthly central bank balance sheets, and presents the different groups of central banks that we are investigating. Section IV deals with the main results of the paper, including a comparison between countries with a central bank and the United States. Section V discusses alternative specifications, endogeneity issues and robustness checks.

## Sterilization, the "rules of the game" and the trilemma: the gold standard view

This paper is the first to study in detail short-term (monthly) adjustment and responses of central banks to international shocks during the gold standard. Yet our main argument is not entirely new. Since Arthur Bloomfield (1959)'s seminal study, economic historians have argued that gold standard's central banks could temporarily suspend convertibility and "sterilize" the effects of international capital flows on the domestic money supply, which allowed them to achieve significant levels of autonomy, breaking the "rules of the game" (Keynes) and avoiding partly the constraints of international finance.[2] However, the argument of Bloomfield (1959) and his followers is based on a limited set of countries (and without comparisons with countries off the gold standard) and annual data. Moreover, as we explain below, his definition of "sterilization" (negative correlation between international

[2] Scholars have confirmed Bloomfield's results about sterilization showing a negative correlation between the international and domestic assets of some individuals central banks: Drummond (1976) for Russia, McGouldrick (1984) for Germany, Dutton (1984) and Pippenger (1984) for England, Bazot et al. (2016) for France, Reis (2007) for Portugal before 1887, Jonung (1984) and Ogren (2012) for Sweden and Oksendal (2012) for Norway, Fratianni and Spinelli (1984) for Italy. Following Bloomfield (1963) and Lindert (1969), they have also provided a detailed description of foreign exchange intervention in some countries: Reis (2007) and Esteves et al. (2009) for Portugal, Jobst (2009) for Austria-Hungaria, Ugolini (2012) for Belgium and Oksendal (2012) for Norway. Ford (1962) provided landmark evidence for the use of imperfect gold convertibility in England and, most of all, Argentina. The paper by Bazot et al. (2016) on France was the first to suggest a different methodology than Bloomfield in order to assess the extent of sterilization though the observation of central bank balance sheets. The present paper follows and expands this idea to a much larger set of countries.

and domestic assets of the central bank) suffers from a severe identification problem, and is not able to examine the response of central banks to a shock on international financial markets.

*Definition of sterilization and "rules of the game"*

The current literature in international macroeconomics (Reinhart and Reinhart 2008, Aizenman and Glick 2009, Blanchard and Adler 2015, Fratzscher et al. 2019) defines sterilization in both a narrow sense (i.e sterilization of foreign exchange interventions) and in a broader sense (i.e sterilization of the effect of foreign capital flows on the domestic money supply). Following Nurkse (1944), Bloomfield (1959) and Triffin (1964), the literature on the gold standard uses the broad definition of sterilization (alternatively called "neutralization"). This meaning of sterilization should be understood in the context of the price-specie flow mechanism at the heart of the gold standard (Bordo and Schwartz 1984, Eichengreen 2008, chp. 2). A deficit country loses gold. The ensuing deflationary impulse would stabilize the balance of payments, as domestic goods become cheaper. In such a framework, the central bank is supposed to play by the "rules of the game", i.e., to accelerate the system's natural adjustment process by increasing its interest rate. On the contrary, the central bank could refuse to play by the "rules of the game", and "sterilize" capital outflows in the process, by expanding domestic credit while maintaining stable interest rates. The conclusion reached by Nurkse (and subsequently applied by Bloomfield to the classical gold standard) was that the absence of interest rate movement in response to capital flows, and the negative correlation between the domestic and international assets of a central bank, were evidence of a "sterilization" of such flows.

It is easy to reformulate the "rules of the game" vs. "sterilization" debate in the context of the *trilemma* (Obstfeld and Taylor 2004). In a context of free movement of capital and fixed exchange rates, the central bank's interest rate should be concerned with defending the peg. Therefore, when capital flows out of countries, the central bank must also increase its

interest rate. Breaking the "rules of the game" through sterilization is therefore equivalent to trying to escape the *trilemma*.[3]

Contrary to central banks' operations today, it is unlikely that "sterilization" was fully deliberate in the gold standard (Bloomfield 1959, p. 47). Central banks were reacting to the borrowing demand of banks at a fixed rate, rather than purchasing or selling bills on an open market or setting reserve requirements (Bazot, Bordo and Monnet 2016). An increase in the international rate pushes the domestic money market rate up, due to arbitrage on international financial markets. At the same time, agents demand foreign assets (gold or foreign exchange) from the central bank to obtain a higher return. The central bank's international assets are declining while the domestic money market rate approaches the level of the central bank discount rate. When it becomes cheaper to borrow from the central bank rather than from the market (at least for a fraction of the banking system), the demand for borrowing increases at the central bank. In response, the central bank's domestic assets increase. Hence, fully effective sterilization keeps the domestic interest rate and money supply stable through increased central bank lending to the domestic economy.

### *Identification of sterilization*

In order to assess whether central banks offset capital flows, Nurkse (1944), Bloomfield (1959) and subsequent authors look at the correlation between the domestic and the international portfolio. This method suffered from a key identification problem.[4] Measuring sterilization by looking at the simple correlation between international and domestic assets suffers from strong reverse causality and omitted variable bias (see, for example, Obstfeld 1982). Many factors can influence the path of domestic assets, and might be linked to the

[3] One may wonder why central banks wanted to enjoy policy autonomy under the gold standard, since macroeconomic policies, inflation targets or unemployment targets were not yet a concern of monetary authorities. Although they did not have macroeconomic objectives, central banks sought to keep interest rates as stable as possible. This objective was considered essential for the financial development of countries, and in line with the profit objective of those private institutions (Conant 1915, Bloomfield 1959, Reis 2007, Jobst 2009, Martin-Acena et al. 2012, Bazot et al. 2016). Thus, their goal was to maintain stable domestic interest rates and stable exchange rates.

[4] Bloomfield (1959, p. 51) in fact noticed this caveat, without implementing an alternative method.

balance of payments, such as domestic economic shocks or banking crises. [5] The literature on monetary policy autonomy under the gold standard has rarely addressed this endogeneity issue. The authors who acknowledged it have turned away from examining the assets of central banks. Instead, they focused on interest rates and the credibility of target zones (Giovannini 1986, Bordo and MacDonald 2005).

We propose a new identification strategy that allows us to turn the attention back to the central bank's balance sheet. In the context of the classical gold standard, a change in the discount rate of the Bank of England provides an exogenous shock that affects international capital flows in the same way in all countries in our sample. A change to the discount rate of the Bank of England – the conductor of the orchestra in Keynes' famous words, an assessment supported by subsequent research (Lindert 1969, Eichengreen 1987, Morys 2013, Bazot et al. 2016) – is the quintessential shock to the monetary system of another country. An increase in the Bank of England discount rate would attract capital to England and create capital outflows and exchange rate depreciation in foreign countries.

The advantage of such identification is twofold. First, movements in the Bank of England (BoE) discount rate can be deemed exogenous to the behaviour of other central banks during this period. Such assumption is also the basis for the work of Obstfeld and Taylor (2014), Jordà et al. (2019) on the *trilemma* during the gold standard period. Second, we can verify – for each country – whether this shock is indeed a shock that is likely to drive capital flows, by looking at the reaction of the exchange rate. If the exchange rate does not react to an increase in the BoE rate, it means that the country was not financially integrated enough to require its central bank to offset the effects of capital flows.

This identification is consistent with the recent literature looking at the influence of US interest rates on the global financial cycle and foreign monetary policy during the second era of financial globalization starting in the 1980s (Rey 2013, 2016; Bruno and Shin 2015;

[5] Consider, for example, a negative domestic shock on agricultural activity that, at the same time, increases borrowing from the discount window and increases imports (to compensate for crop failure) and capital outflows (as described in Hanes & Rhode 2013). It could also be the case of a banking crisis, for example, which causes at the same time an outflow of capital and an increase in the domestic portfolio of the central bank if the latter is playing the role of lender of last resort.

Miranda-Agrippino and Rey 2018, Jordà et al. 2019).[6] We will show in a robustness section (Section V) that our conclusions still hold if we use alternative measures of English monetary policy shocks during the gold standard that are free of endogenous reactions to the domestic and international economy.

## Theory, identification and methods of estimations

### *Theoretical predictions*

Consistent with this definition of sterilization, the works of Nurkse (1944), Bloomfield (1959), Mundell (1963) and recent reformulations of the *trilemma* in international macroeconomics (Obstfeld and Taylor 2004, Farhi and Werning 2014) imply the following four scenarios after an increase in the Bank of England discount rate. The first scenario ("rules of the game") is equivalent to the plain *trilemma* case with fixed exchange rate and full capital mobility. Scenario 2 is the same case where we consider the role of effective central bank sterilization rounding the corners of the *trilemma*, as explained in the previous section. Although discussed in theory (Mundell 1963, Obstfeld 1982), this scenario is usually not investigated in empirical studies of the *trilemma*, as it requires balance sheet data. Scenario 3 is the *trilemma* case with fixed exchange rates and capital controls. Scenario 4 is the case with floating exchange rates.

*Scenario 1: Playing by the rules of the game*

In a country playing by the "rules of the games", an increase in the BoE rate will be followed by a similar increase in the domestic central bank's discount rate, stabilising the exchange-rate in the process. If the central bank increases its rate by the same magnitude as the BoE, the reaction of the exchange rate may not be visible at all at monthly frequency, since the exchange rate adjusts quickly through uncovered interest rate parity. If the exchange rate does not come back to parity immediately and the shock of the BoE rate is large enough to reduce gold reserves, we should observe an equivalent decrease of domestic

[6] Jordà et al. (2019) instrument domestic monetary policy shock with the BoE rate during the gold standard (and US Fed rate thereafter).

assets. The positive correlation between domestic and international assets of a central bank is what Nurke (1944) and Bloomfield (1959) identified as the second element of the "rules of the game": a central bank was meant to exacerbate the external shock in order to accelerate the adjustment process.

*Scenario 2: Sterilization*

On the contrary, a decrease in international assets coupled with an increase in domestic assets is evidence of sterilization. The central bank compensates capital outflows with credit creation. Expanding credit means that the discount rate needs to be raised by less than under scenario 1; consequently, we observe a smaller reaction of the discount rate to an increase in the Bank of England rate.

As long as the central bank is committed to convertibility (unconditional and immediate conversion of bank notes into gold), the exchange rate will quickly move back to mint parity as a result of gold outflows or foreign exchange intervention. If uncovered interest rate parity holds, this is reinforced if investors themselves expect the exchange rate to come back to mint parity (Bordo and MacDonald 2005). Sterilization does not prevent the global functioning of the Gold Standard either, i.e, gold flows play a strong stabilizing role on the exchange rate.

*Scenario 3: Imperfect convertibility*

We expect the impact of an increase on the BoE rate on the exchange-rate to be larger in the case of imperfect convertibility (i.e. restrictions on convertibility between notes and gold at the central bank; see Bloomfield 1959 and Ford 1989 for a review). Restrictions on gold convertibility widen the gold points, allowing the exchange-rate to depreciate further than in scenarios 1 and 2. Such capital control policies aimed at protecting international reserves and reducing the interest rate adjustment; on both variables, we expect a smaller response than in scenarios 1 and 2. In the absence of a large reserve outflow, the central bank might nevertheless increase domestic credit. Imperfect convertibility mitigates the decrease of gold reserves by the central bank but does not necessarily stop it entirely. Nor does it stop gold exports. Thus, central bank credit must expand to avoid an increase in market rates and offset the effect of gold outflows on the aggregate money supply.

*Scenario 4: Countries off gold*

A fourth scenario is concerned with countries on a floating exchange-rate. Assuming an open capital account (i.e., the norm during this period), the exchange rate will fully absorb the shock. The central bank does not need to expand either the domestic credit nor increase its discount rate.

## *Method of estimation*

We study the reaction of central banks' balance sheets, exchange rates and interest rates to an exogenous increase in the Bank of England (BoE) rate. Our identification strategy allows us to study simultaneously the degree of monetary autonomy (the response of the domestic rate to the English rate) and the means employed by central banks to achieve such autonomy (sterilization, foreign exchange interventions, floating exchange rates or imperfect convertibility).

Following a now well-established empirical literature on the effects of monetary policy shocks (Jordà, 2005, Ramey 2016, Jordà et al. 2019), we use local projections to estimate the effect of a shock on the BoE interest rate. This method allows estimating impulse-responses (IR) directly from an exogenous shock without relying on a predefined model. By contrast with VAR methodology, the IR is not based on the assumption that the true model has been estimated. Local projections are particularly well suited for panel data since it is straightforward to include country-fixed effects in the estimations of the impulse response functions and to account for group heterogeneity through state-dependent estimations.

Let K be the dimension of the vector of macroeconomic aggregates of interest. M is the number of countries, $T$ is the time dimension, and $H$ the time horizon for which we want to measure the response to a shock. Let $y_{i,t+h}^{k}$ be the value of variable $k = 1, \dots, K$ observed for a country $i = 1, \dots, M$, for which we measure the response to a shock on the Bank of England rate in horizon $0 \leq h \leq H$. Lastly, let $Y_{i,t}$ denote the vector of $y_{i,t}^{k}$ variables.

If $r_t^{BoE}$ is the Bank of England discount rate, the impulse response to a shock ($\delta$) on $r_t^{BoE}$ is measured as:

$$IR\left(y_{i,t+h}^{k},\delta\right)=E_{it}\left(y_{i,t+h}^{k}|\delta=1;Y_{i,t},Y_{i,t-1},\ldots\right)-E_{it}\left(y_{i,t+h}^{k}|\delta=0;Y_{i,t},Y_{i,t-1},\ldots\right)$$

A shock $\delta=1$ means that $r_t^{BoE}$ increases by 100 basis points.

The local projections consists in measuring $IR\left(y_{i,t+h}^{k},\delta\right)$ based on a sequence of predictive fixed effects panel regressions of the variable of interest on an exogenous shock to horizon $h$:

$$y_{i,t+h}^{k}=\alpha_i+\Phi_h(L)Y_{t-1}+\beta_h\Delta r_t^{BoE}+trend+\varepsilon_{h,it}\text{ for }h=0,1,2,\ldots,H$$

where $\Phi_h(L)$ is the polynomial set of lag operator (which is set at 3 in our analysis), $\Delta r_t^{BoE}$the unanticipated change in the Bank of England discount rate, $\alpha_i$ the country fixed effects, and $\varepsilon_{h,it}$ the residual. The IR is the set of estimated $\widehat{\beta_h}$ from $h=0$ to $h=H$. There are as many sequences as there are variables of interest. Note that following the standard practice of Ramey (2016), we include a trend in the estimation to account for potential non stationarity (none of our results are sensitive to this assumption).

Starting with $h=0$ rather than $h=1$ is a timing restriction, implying that domestic macroeconomic variables can respond immediately to a change in the interest rate of the BoE.[7] This timing restriction is consistent with our assumption that this particular variable is exogenous to economic variables in other countries, and with the empirical observation in our data set that central banks moved their own discount rate typically a few days after the BoE changed its rate (for a similar observation cf. Lindert 1969).[8]

[7] See Barnichon and Brownlees (2019) on timing restrictions in local projections and a comparison with recursive structural identification in VARs. An alternative assumption (starting at h=1) will not modify our main conclusions about sterilization but it lowers the effect of the shock on the domestic central bank interest rate (since, in fact, central banks that moved their rate followed the BoE few days or weeks afterwards, usually within a month).

[8] Following Kilian and Kim (2011) and Jordà (2005), our impulse responses are constructed using a Cholesky structural form as in structural VAR methodology. This corresponds to recovering the coefficient of the Cholesky from a SVAR model and to adjust the IRF accordingly. Our statistical results are hardly affected if we use reduced form impulse responses and our qualitative conclusions remain the same.

Local projections offer numerous advantages. First, the non-parametric feature is particularly effective in panel data analysis since the set of endogenous variables that should be included in the predefined model explodes along with the number of countries. For that reason, the chance to rely on the true model before simulating the shock gets smaller. Second, because it estimates rather than simulates the effect of a shock, a local projection does not have to define a set of endogenous variables. Thus, each IR can be estimated independently using the right set of control variables. However, local projection may also come at some costs. First, observations from the end of sample are lost as h increases. Second, as shown in Ramey (2016), short run analysis should be given priority due to erratic and oscillating responses as the horizon gets large. Because our analysis is mostly focused on short-run (monthly) adjustment, we do not see this as a fundamental issue.

## Data and group of countries

### *Sources*

Our dataset is based on an exceptional source that has never been exploited before. The French central bank (Bank of France) began systematically collecting the weekly or monthly balance sheets of all the world's central banks in 1891. Central banks published these balance sheets at a high frequency, in addition to their annual reports to shareholders. The legal (or in some cases customary) obligation to publish these balance sheets was justified by the requirements (in terms of the relationship between the currency in circulation and the reserves, or the ceilings on circulation) to which central banks were subject. These ratios were carefully looked at by policymakers and investors; they were published in major financial newspapers, as well as data on exchange rates and discount rates (e.g. *L'Economiste Européen* in France, *The Banker* in the United Kingdom, *Le Moniteur* in Belgium, see Baubeau 2018). However, newspapers did not publish data on central bank assets, which were much more difficult to harmonize and compare, given the different financial and accounting practices of countries. [9]

[9] Some comparative books on central banking written by economists or journalists during this period reproduced annual balance sheets but not the monthly or weekly ones. See for example Sumner et al. (1896), Lévy (1911), Conant (1915).

The Bank of France took on this difficult and tedious task. Sufficient skills were needed to translate and understand the various reports. We use the original sources available in the archives of the Bank of France. We use monthly data to achieve the highest possible frequency available for all central banks.[10] We also consulted the annual balance sheets, likewise prepared by the Bank of France and based on the annual reports of the respective central bank, in order to establish whether some balance sheet items were missing from the weekly and monthly publications.[11] For instance, in a very limited number of cases and only when numbers were very small, foreign exchange reserves were only published in the annual report (see appendix).[12]

*Data*

The analysis of central banks' sterilization is based on the evolution of domestic and international portfolios. Fortunately, the harmonized balance sheet provided by the source helped us to build those series. We assembled five major series in this respect: (1) metallic reserves (gold plus silver); (2) foreign paper (bills of exchange drawn on foreign places); (3) funds held abroad; (4) discount portfolio of domestic papers; (5) short term advances on securities and other collateral. (1), (2), and (3) constitutes the international portfolio while (4) and (5) capture the domestic portfolio. Details about all five series are available in the data appendix.

Our dataset includes 21 central banks, encompassing all central banks in the world during the period 1891-1913 (the Swiss National Bank was created only in 1908 and the U.S. Federal Reserve in 1913). As Italy had three large banks of note issue (Bank of Italy, Bank of Naples and Bank of Sicily), we have a panel data set of 19 countries with a central

[10] Archives of the Banque de France (ABF), 1377200101/51-55.

[11] Archives of the Banque de France (ABF), 1377200101/46-58.

[12] In addition, the annual ledgers contain much more information on how Banque de France economists translated foreign terms into French, as well as institutional details on foreign central banks.

bank.[13] The data appendix discusses the few other cases of multiple banks of issue. In the next section, we will add one country without a central bank (U.S.), for the purpose of comparison. Series of discount rates of these central banks are also available in our original source (and compiled in Roulleau 1914). We gathered monthly series of exchange rates on London from various sources, mostly from Schneider et al. (1991, 1994, 1999) and Morys (2013).[14] We use exchange rates as deviation from the mint parity (that is the official exchange rate between gold and domestic currency). Mint parities were also available in our original source in the archives of the Bank of France. Countries off the gold standard also have a mint parity, but central banks in these countries had no commitment to redeem notes in gold at such a price. All data are end of the month values.

For all countries except Japan, the monthly balance sheet of the central bank is available starting in the early 1890s; usually as soon as January 1891. Data on Japan starts in 1899, one year after the country entered the gold standard. For a significant number of countries, we have data on their central bank both before and after they joined the gold standard (cf. below and Table 1).

### *Groups of countries*

Section 2 presented four theoretical scenarios, each one describing a different central bank reaction to an increase in the Bank of England discount rate. There is no reason to believe that the 21 central banks in our sample behave in the same way, particularly because they did not all have the same exchange rate regime and level of financial integration. For this reason, we look at different group of countries – defined in a way that is consistent with the historical context and the literature on the gold standard – and we will discuss how close they were from the theoretical predictions of section 2.

[13] Inclusion or exclusion of these two banks of note issue does not affect either our Italian or our overall results.

[14] Exceptions are Japan and Finland. Japanese exchange-rate data on London is published online by the Bank of Japan (original source: "Reference Book of Financial Matters" of the Financial Bureau of the Ministry of Finance) and Finish data on London is from Autio (1992).

We distinguish three groups of countries with a central bank: (1) core countries on the gold standard, (2) peripheral countries on the gold standard, (3) countries with a floating exchange-rate (fiat standard).

As for gold standard adherence, we follow the consensual classification that has emerged from an extensive literature on this matter (Flandreau and Zumer 2004, Obstfeld et al. 2005, Mitchener and Weidenmier 2015, Morys 2016).[15] The distinction between groups (1) and (2) hinges upon the definition of core versus periphery. Economic historians agree on considering Belgium, England, France, Germany and the Netherlands as core countries in the international financial system because they had mature money markets, a liquid foreign exchange market, and could issue sovereign debt in their own currency (Bordo and Flandreau 2003, p. 349, Flandreau and Jobst 2005, Morys 2013). Outside this group, Austria-Hungary is a borderline case. Money and exchange markets were liquid and well-developed (Reichsbank 1925, pp. 212-231, Jobst 2009), but Austria-Hungary had to insert gold clauses into their bonds to issue them abroad (Morys 2006). Since sovereign debt is less crucial to our study, we decided to classify Austria-Hungary as a core country. Such an approach is vindicated by a statistical analysis of Austria-Hungary on its own, when its results are in line with all other core countries. Please note the empirical conclusions presented in the next section are not modified qualitatively if Austria-Hungary is included in the periphery.

Table 1 summarizes our three groups of countries, with details about their date of entry into and exit from the gold standard where relevant.

[15] It is based on the following definitions: de jure adherence to gold (immediate and unlimited convertibility of bank notes into gold) or de facto adherence (maintaining the exchange rate within a +/- 2% band).

TABLE 1

COUNTRY GROUPS: CORE COUNTRIES ON GOLD, PERIPHERAL COUNTRIES ON GOLD, FIAT STANDARD COUNTRIES

| | ***Estimation period*** | |
|---|---|---|
| *Group 1: Core countries on the gold standard (5 countries)* | | |
| Austria-Hungary[1] | 01/1896 | 12/1913 |
| Belgium | 01/1891 | 12/1913 |
| France | 01/1891 | 12/1913 |
| Germany | 01/1891 | 12/1913 |
| Netherlands | 01/1891 | 12/1913 |
| *Group 2: Peripheral countries on the gold standard (11 countries, 13 central banks)* | | |
| Bulgaria | 01/1906 | 09/1912 |
| Denmark | 01/1891 | 12/1913 |
| Finland | 01/1891 | 12/1913 |
| Greece[1] | 01/1910 | 12/1913 |
| Italy[1] | 01/1903 | 09/1911 |
| Naples[1] | 01/1903 | 09/1911 |
| Sicily[1] | 01/1903 | 09/1911 |
| Japan | 01/1899 | 12/1913 |
| Norway | 01/1891 | 12/1913 |
| Romania[1] | 01/1891 | 11/1912 |
| Russia[1] | 01/1897 | 12/1913 |
| Serbia[1] | 07/1909 | 09/1912 |
| Sweden | 01/1891 | 12/1913 |
| *Group 3: Countries on a fiat standard (8 countries, 10 central banks)* | | |
| Austria-Hungary[2] | 01/1891 | 12/1895 |
| Greece[3] | 01/1896 | 12/1909 |
| Italy[3] | 01/1891 | 12/1902 |
| | 10/1911 | 12/1913 |
| Naples[3] | 01/1894 | 12/1902 |
| | 10/1911 | 12/1913 |
| Sicily[3] | 01/1894 | 12/1902 |
| | 10/1911 | 12/1913 |
| Portugal | 01/1895 | 12/1913 |
| Romania[3] | 12/1912 | 12/1913 |
| Russia[3] | 01/1891 | 12/1896 |
| Serbia[3] | 01/1899 | 06/1909 |
| Spain | 01/1892 | 12/1913 |

Sources: Gold standard adherence based on de-facto exchange-rate classification proposed by Obstfeld et al. (2005) and exchange-rate sources as described in the main text.

Notes: [1] Also in group 3 for other estimation periods. [2] Also in group 1 for other estimation periods. [3] Also in group 2 for other estimation periods.

## Estimations and results

### *Specification and variables*

Local projections are easy to estimate with state-dependent variables. We can thus include "Gold Standard" and a "core-periphery" dummy variables to interact with the set of other variables. This allows to estimate the effect of the shock for each group of countries defined in the previous section. As such, our model is the following:

$$
\begin{aligned}
y_{i,t+h}^{k} = \alpha_i \\
+core\ in\ GS_{t-1} \times \left[\Phi_h(L)Y_{t-1} + \beta_{a,h}\Delta r_t^{BoE}\right] \\
+periphery\ in\ GS_{t-1} \times \left[\Phi_h(L)Y_{t-1} + \beta_{b,h}\Delta r_t^{BoE}\right] \\
+floating_{t-1} \times \left[\Phi_h(L)Y_{t-1} + \beta_{c,h}\Delta r_t^{BoE}\right] \\
+trend + \varepsilon_{h,it}
\end{aligned}
$$

$core\ in\ GS$ is a dummy variable equals to 1 if the country belongs to the core and adheres to the Gold Standard at time $t$, $periphery\ in\ GS$ is a dummy variable equals to 1 if the country belongs to the periphery and adheres to the Gold Standard at time $t$, $floating$ is a dummy variable equals to 1 if the country's exchange rate is floating. $\beta_{a,h}$, $\beta_{b,h}$, and $\beta_{c,h}$, are picked up from $h = 0$ to $h = H$, to build IRFs for each group. Thus, $\beta_{a,h}$ corresponds to the response of group 1, $\beta_{b,h}$ corresponds to the response of group 2, and $\beta_{c,h}$ corresponds to the response of group 3.

The variables of interest included in our estimations are the following: The BoE discount rate (in percent), the natural logarithm of total international assets, the natural logarithm of total domestic assets, the country-specific central bank discount rate, and the exchange rate deviation from mint parity (with positive values denoting depreciation). The vector of control variables is composed of three lags for each variable of interest.[16] Panel data unit root tests have been performed based on Fisher-type tests and Im-Pesaran-Shin tests. Non-

[16] The variables have been set in the following order: BoE discount rate change, international portfolio, domestic portfolio, central bank discount rate, and exchange rate. Our results and conclusions are not affected by the Cholesky order.

stationarity is rejected in all cases at the 1% confidence interval. Each regression includes fixed effects. To correct for heteroskedasticity and serial correlation, we cluster standard errors when estimation is in panel, or use the Newey West procedure when the estimation is for a single country (the U.S., in the next section).

In the Figures below, we look at the responses of the following variables to an increase in the discount rate of the Bank of England (BoE) by one percent (100 basis points). Given the afore-mentioned data manipulations, responses read in all four cases as the percentage change compared to month t= -1 (with positive values in the lower right panel meaning depreciation).[17]

*Core countries: sterilization of gold outflows*

Figure 1 shows how core countries reacted to a shock on the BoE discount rate. They increased their interest rate only by a small magnitude: 24 basis points after a shock of 100 basis points. Put differently, the interest rate pass through is much lower than unity and amounts to approximately 24% (for a similar finding from a different estimation perspective cf. Shambaugh et al. 2005 and Morys 2013). This imperfect pass-through allows for arbitrage in international markets. The exchange-rate depreciation is rather small (+0.08%, with positive values denominating depreciations), and comes back to parity after two months. This results contrast with peripheral countries where depreciation was bigger and of longer duration (see Figure 2).

What were the balance sheet effects? As core countries offered (almost) unconditional and unlimited convertibility, the international portfolio declines quickly and substantially: 1.8% after one month.[18] Yet core countries dilute the impact of this reserve drain by expanding domestic credit. This is exactly what Nurkse and Bloomfield called "neutralization"

[17] A mint parity is proposed by the BdF source even if a country did not adhere to the Gold Standard. However, because the constraints of the Gold Standard were not binding for those countries, it might be more consistent to use the percentage variation in the exchange rate value in lieu of the deviation from mint parity. The results and conclusions remain the same with such alternative measure (not reproduced here).

[18] Convertibility was however not perfect, even in these countries. As the Bank of England, the Bank of France used gold devices until 1900 and Austria-Hungary always maintained restrictions on gold convertibility (see Bloomfield (1959) among others).

(sterilization). The reaction of the domestic portfolio is, in percentage terms, more than three times larger than the reaction of the international portfolio, namely 5.5% after one month (a factor consistent with the result of Bazot et al. 2016 on France). The international portfolio was on average twice as large as the domestic portfolio. It was thus necessary to increase the domestic portfolio by more than the decline of the international portfolio. It is consistent with the fact that foreign assets exiting the vaults of the central bank were not the integral part of capital outflows.

Adjustment operates quickly, with the exchange rate and central banks' balance sheet responses becoming statistically insignificant after three to four months. This short-term adjustment is consistent with the high level of financial integration that characterized the gold standard era. It also means that we would not be able to capture adequately the role of central banks as shock absorbers if we worked with quarterly or annual data.

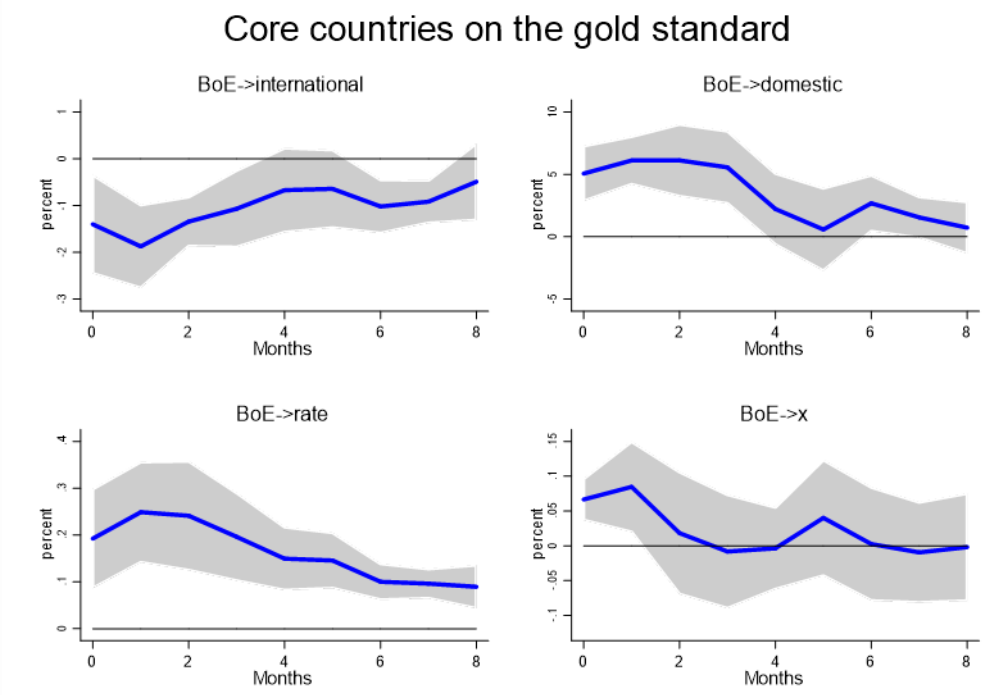


FIGURE 1. THE REACTION OF CENTRAL BANKS IN GOLD STANDARD CORE COUNTRIES TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" and "domestic" denote the international and domestic portfolios of central banks, "rate" is the discount rate of central banks and "x" the exchange rate on London.

*The gold standard periphery: imperfect convertibility*

Countries on the gold standard periphery react fundamentally different to core countries along all four dimensions (Figure 2), yet the most striking difference relates to the absence of immediate reaction in the international portfolio in the periphery. For the first four months, results are not statistically different from zero at the 5%-level. This quantitative finding confirms the qualitative statement of Martin-Acena et al. (2012) on the absence of gold convertibility on the periphery, which – to the best of our knowledge – has never been assessed econometrically.

This is accompanied by a sharper and longer reaction of the exchange rate. The exchange-rate on the periphery depreciates not only by 70% more than in core countries, but it does not bounce back after month 1. It remains instead at depreciated levels for several months. Imperfect convertibility allows peripheral countries to let the exchange-rate depreciate more strongly than under the scenario of perfect convertibility between gold and domestic currency. Core countries could not afford such depreciation, as gold points were narrow between Europe's financial centres and their commitment to convertibility beyond doubt.[19]

The response of the interest rate and the domestic portfolio reveals differences and similarities to core countries. As in the core countries, the discount rate reacts significantly to the English shock, but smaller (0.17% only after one month, compared to 0.24% for the core) and in a protracted fashion (as opposed to an immediate re-bounce for the core countries). Second, the central bank's domestic portfolio increased, although there was no loss of foreign reserves in the central bank. Therefore, after an increase in international interest rates, the national central bank had to extend credit to the domestic economy in response to the commercial banks' demand at its discount window. This finding means that

[19] In the case of Romania, a quintessential peripheral country, it was well understood at the time that the National Bank of Romania typically sought to delay convertibility and/or put upper ceilings to the amount the central bank converted (Sonndorfer 1905, p.292). While in theory committed to convertibility to boost the country's credentials, practice often fell short of it.

there was still a transmission of the English interest rate increase to the domestic money market in the periphery, so that it became cheaper to borrow from the central bank than from the private market. Restrictions on gold convertibility could protect the central bank's cover ratio (ratio of reserves to banknotes) and widen the exchange rate range, but they were not sufficient to completely isolate the country from international financial markets (as shown by the fact that the exchange rate fluctuates). Sterilization was still necessary to stabilize the money supply and domestic interest rate, but of a lower order of magnitude than in the core countries.

In sum, peripheral countries were able to shelter from the global cycle by potentially imposing some capital controls. This deviation from a central pillar of the gold standard made their adherence less credible (Mitchener and Weidenmier 2015) – or, vice versa, low credibility forced them to impose restrictions on gold convertibility –, but it did allow them to combine quasi fixed-exchange rates (albeit with larger bands) with a certain level of monetary policy autonomy.

Incidentally, a comparison of all four responses core vs. periphery helps explain why peripheral gold standard countries limited convertibility. Core countries raise their discount rate fast and sizeably (although much less than the BoE), bringing in foreign funds quickly given high levels of financial integration between Europe's main financial centers. Adjustment was further helped by private agents who deemed the core countries' adherence to gold credible and bought domestic currency when it was "cheap", i.e. depreciated within the gold points (Bordo and McDonald 2005). By contrast, lower levels of financial integration and reduced credibility meant that the discount rate was a less sharp weapon for peripheral countries. The transmission mechanism of monetary policy (i.e a change in the discount rate) was also less likely to be effective, because of the lower development and higher fragmentation of the domestic banking system. This, in turn, created a reliance on – partial or complete – inconvertibility to make the gold standard work in this set of countries. Practice differed between countries (see Bloomfield 1959 and Ford 1989, for a review of gold devices), but immediate and unlimited convertibility remained a characteristic of the peripheral countries until the end of the Classical Gold Standard period (Martin-Acena et al. (2012), Morys (2013, 2014, 2017)).

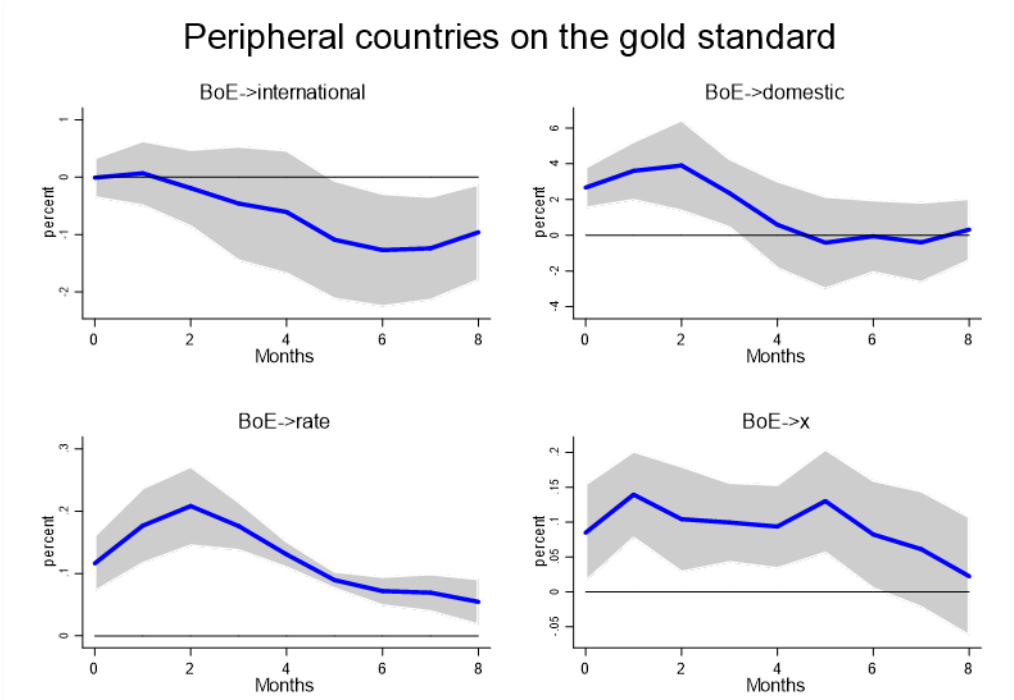


FIGURE 2. THE REACTION OF CENTRAL BANKS IN GOLD STANDARD PERIPHERAL COUNTRIES TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" and "domestic" denote the international and domestic portfolios of central banks, "rate" is the discount rate of central banks and "x" the exchange rate on London.

### *Floating exchange rates*

In line with the predictions of the *trilemma* (Obstfeld and Taylor 2004), countries that are not in the gold standard simply float their exchange rates in response to an international shock, as shown in Figure 3. Only the exchange-rate response is statistically significant, but this particular variable reacts more strongly by a wide margin than in gold standard countries. It falls 0.45% percent in month 1, that is approximately five times as much as in core countries and three as much as in peripheral countries on gold; and the exchange-rate remains at depreciated levels thereafter. In floating countries, the burden of adjustment is borne entirely by the exchange-rate, so that the central bank exhibits no statistically significant reaction either in its discount rate or on its balance sheet.

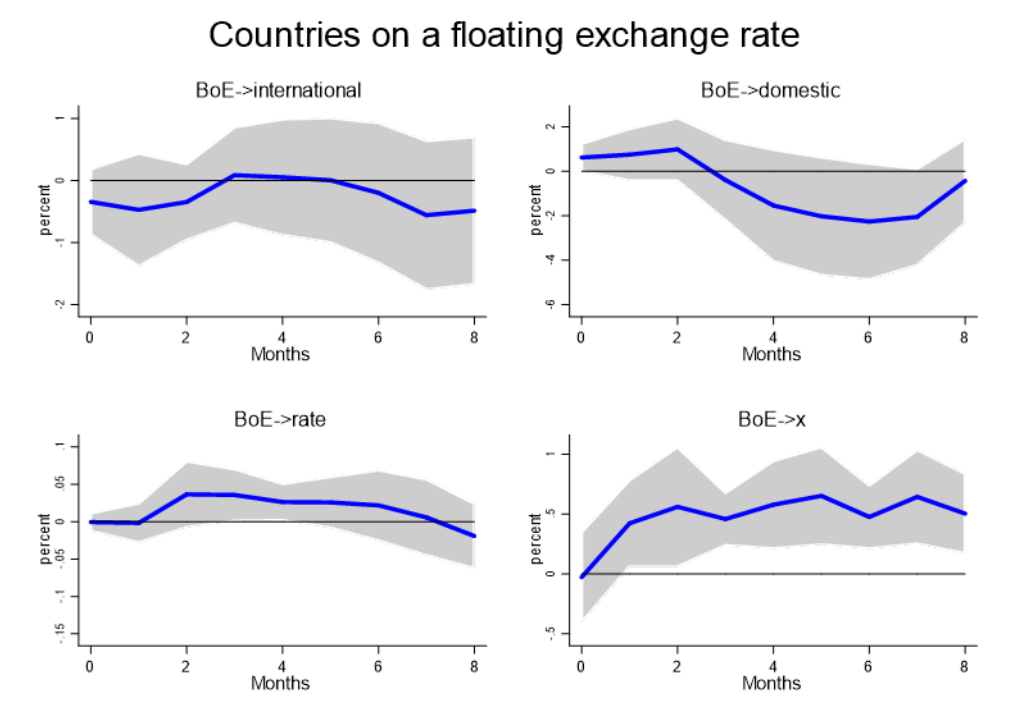


FIGURE 3. THE REACTION OF CENTRAL BANKS IN FIAT STANDARD COUNTRIES TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" and "domestic" denote the international and domestic portfolios of central banks, "rate" is the discount rate of central banks and "x" the exchange rate on London.

### *The United States of America*

The most important country without a central bank during this period was the United States. It was on the gold standard although this system was more contested than in many other countries and political support for bimetallism remained strong until the 1896 US presidential election. A large number of studies have examined what could have happened to the U.S. economy if a central bank had existed before 1913. There is consensus that a central bank would have smoothed seasonal fluctuations in credit and interest rates (Mankiw and Miron 1986, Canova 1991) and perhaps reduce the frequency of banking crises (Davis, Hanes and Rhode 2009, Hanes and Rhode 2013, Bordo and Wheelock 2011). However,

precise comparisons with central bank operations over the same period remained limited due to the lack of data.

A simple extension of our previous analysis is to compare the reaction of the US economy to that of countries with a central bank. The United States had no central bank, so the Treasury was responsible for backing banknotes in circulation with gold.[20] The Treasury accepted deposits from the state and transferred private deposits between New York and other cities, but it did not lend to domestic banks or non-financial companies. Thus, there is no equivalent to the domestic portfolio of central banks. A more difficult choice concerns the relevant US market interest rate that we should compare with counterparts in countries with a central bank. As already discussed by contemporaries (Roulleau 1914), the most relevant rate to compare with European discount rates would be the interest rate on 60-90 day commercial paper in New York. However, the only monthly series that is available for this commercial paper rate (published by Macaulay (1938) and then on the NBER website) is the average of the minimum and maximum values of the month. Using this monthly average value may smooth considerably the effect of an international financial shock. For this reason, we prefer to use the call money rate in New York. This money market rate was not an interbank rate, but the rate of overnight loans from banks to stock market brokers (see Hanes and Rhode 2013, among others, for more details on this market). Although lower that the commercial paper rate, its fluctuations also reflected changing financial conditions in New York. End of the month values of the call money rate in New York are available from weekly series published by *The Economist* and then reproduced in Neal and Weidenmier (2003).

Figure 4 presents the results of local projections with US data, from January 1891 to December 1913. As indicated above, there are only three panels, as there is no equivalent to the domestic portfolio in the absence of a central bank. The only variable reacting in a statistically significant way is the interest rate. Note that the interest-rate pass-through is

[20] The US Treasury also conducted some infrequent foreign exchange interventions in 1895 and 1906 (Bordo, Humpage and Schwartz 2015, p. 45). Gold held in the Treasury (monthly data) is from the NBER macroeconomic history database series m14137a. Note that the Bank of France also recorded the balance sheet of the US Treasury, together with the balance sheets of foreign central banks. The exchange rate in New York on London is from Neal and Weidenmier (2003); the average between bid and ask prices.

much higher than in gold standard countries with a central bank: more than twice as high as in core countries (0.55% after one month compared to 0.24%) and thrice as high as in peripheral countries (0.55% compared to 0.17%). Put differently, the U.S. is closest to scenario 1 outlined above (playing by the rules of the game), as the domestic portfolio – a key adjustment factor for gold standard countries with a central bank – cannot come to the rescue in the absence of a central bank. This is precisely the "sheltering" function assigned to the central bank by Polanyi in the quotation given at the beginning of this paper. Before the establishment of the Federal Reserve System in 1913, the US monetary system lacked such a "cushion" (Polanyi), and had in turn to rely more strongly on the interest rate.[21] Our finding also supports the claim of the economic historian Alec Ford (1989, p. 209) who, based on his knowledge of central bank operations rather than on quantitative evidence, claimed that "[i]n those economies with no central bank, commercial banks could react in a similar way by raising their lending and borrowing interest rates [when confronted with a decline in international reserves] […] Such institutions had less discretion than central banks, and indeed, were more wholehearted followers of the rules of the game."

The quick and sizeable response of the interest rate in the US case also explains why neither the international portfolio nor the exchange-rate react in a statistically significant way: adjustment is borne almost exclusively by the interest rate. This finding is consistent with Officer (1986) who found the exchange-rate adjustment between London and New York in the time period 1890-1908 to be efficient and extraordinarily quick.

[21] The U.S. had clearing houses that could provide liquidity to banks in bad times but, as argued by Moen and Tallman (2013), the central banking powers of these institutions were limited. Clearing house loan certificates were imperfect substitutes for cash and their issuance was limited by the pool of members.

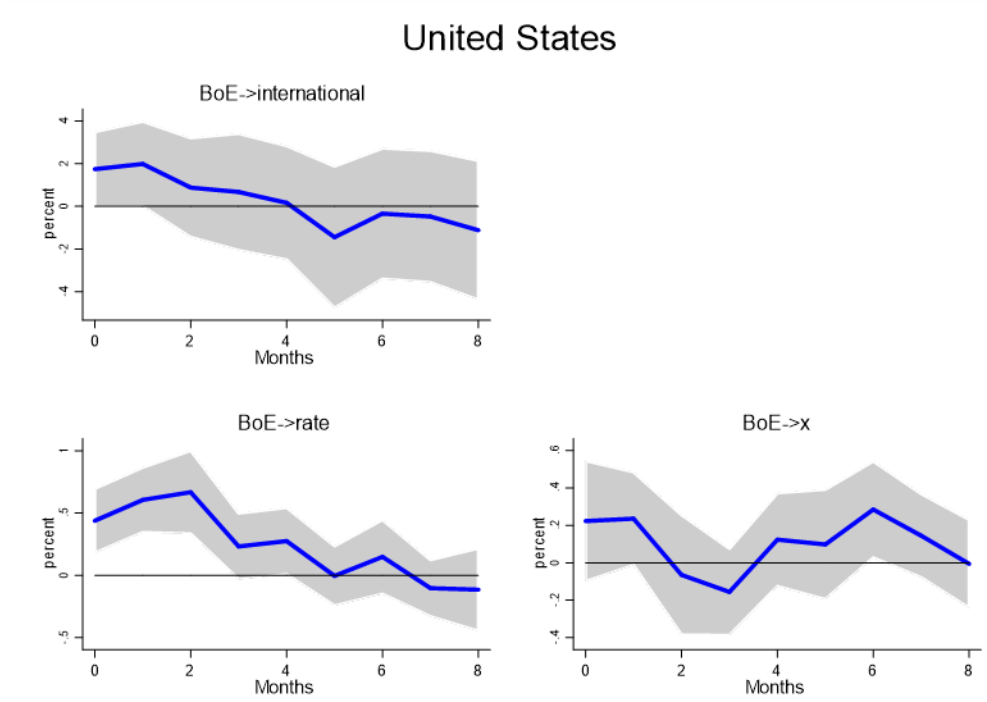


FIGURE 4. THE REACTION OF THE U.S. MONETARY SYSTEM TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" denotes the gold reserves of the U.S. Treasury, "rate" is the call money rate in New York and "x" the exchange rate in New York on London.

## Discussion of endogeneity and robustness checks

So far we have used the change in the BoE discount rate to estimate a central bank's reaction to an international shock. For our identification to be reliable, the increase in the English rate should be exogenous to the behaviour of other central banks. Several authors have shown that the BoE was first to move its rate among the other important central banks (Lindert 1969, Eichengreen 1987, Morys 2013, Bazot et al. 2016). A change in the interest rate of the Bank of England was not sufficient to lead to changes in the rates of other central banks. But it was a necessary condition. A recent literature relies on this assumption to identify monetary policy shocks in a number of countries (Jordà, Schularick and Taylor 2015, 2019). These authors call the *trilemma* instrument the identification that, in a fixed

exchange rate regime, the interest rate of the leading central bank (England in the case of the classical gold standard) determines exogenously the interest rates of other central banks.

Let us discuss, however, how our results would be affected if the changes in the English discount rate takes place in reaction to foreign variables or to changes in English variables (including the Bank of England gold reserves and the exchange rate) that would be correlated with international factors. There are three cases to discuss. First, if the BoE changes its discount rate in reaction to gold outflows, this should coincide with international reserves increase in other central bank balance sheet. This would underestimate the effect of the BoE interest rate shock on the international portfolio of foreign central banks. Second, the same reasoning applies if the BoE reacts to a depreciation of the pound sterling compared to other currencies. Then we would underestimate the depreciation of exchange rates of foreign countries in reaction to an English monetary policy shock. Third, if the BoE increases its discount rate in response to inflationary demand pressures (high output growth), and if there is a common international business cycle, then the positive response of the domestic portfolio of foreign central banks may in fact reflect the positive international business cycle that the BoE is responding to. In this case, we would overestimate the reaction of the domestic portfolio to an English monetary policy shock.

Empirical results presented in the previous sections suggest that those potential endogeneity issues do not significantly affect our results. As a matter of fact, each group of countries reacts differently to the same BoE shock. It means that there is no systematic bias driving the results towards a unique conclusion. Second, if one assumes that an international business cycle is at work, its frequency was surely not of two or three months only. In our estimations of impulse response functions, the response of the domestic portfolio is a very short-term reaction, taking place within a quarter. We do not see a common mid-term business cycle across countries.

*Shocks identified from a narrative approach*

In order to address those potential endogeneity issues with econometric robustness checks, we follow Lennard (2018) who build a series of exogenous English monetary shocks during the gold standard period, in the spirit of the narrative approach of Romer and Romer (2004). To build a monetary shock, Lennard first identified the dates of monetary policy decisions

and the information set of policymakers using archival sources. He then purged the series from the endogenous component of monetary policy changes by taking the residual of a regression explaining the BoE discount rate by real time data (BoE gold stock change, the wheat price inflation rate, and the exchange rate change with marks and French francs among other variables). Figures 5 to 8 displays local projections results with the Lennard monetary policy shock instead of BoE discount rate variation. We use the same structure as in the previous estimation: The BoE monetary shock affects the variables of foreign countries contemporaneously. The results appear very similar to those produced in figure 1 to 4, confirming the lack of endogenous biases affecting our estimations. As an additional robustness check (results not displayed here), we add English railways receipts into LP estimation, in order to control for the English (and potentially international) business cycle. Results remain unchanged.

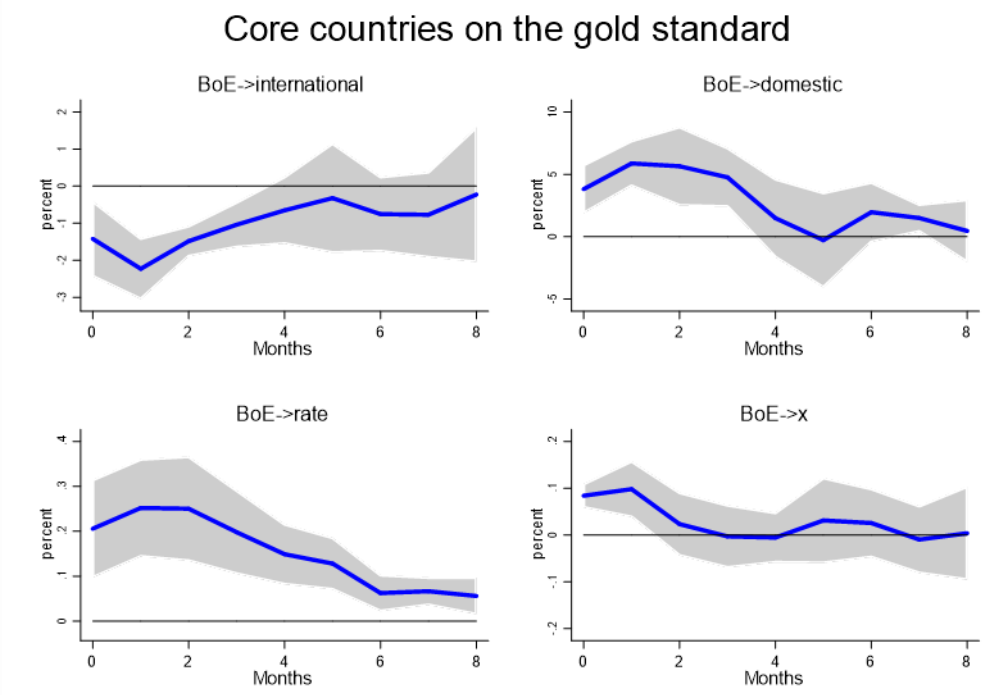


FIGURE 5. THE REACTION OF CENTRAL BANKS IN GOLD STANDARD CORE COUNTRIES TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS. ALTERNATIVE MEASURE BASED ON LENNARD (2018) AS DISCUSSED IN THIS SECTION.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" and "domestic" denote the international and domestic portfolios of central banks, "rate" is the discount rate of central banks and "x" the exchange rate on London.

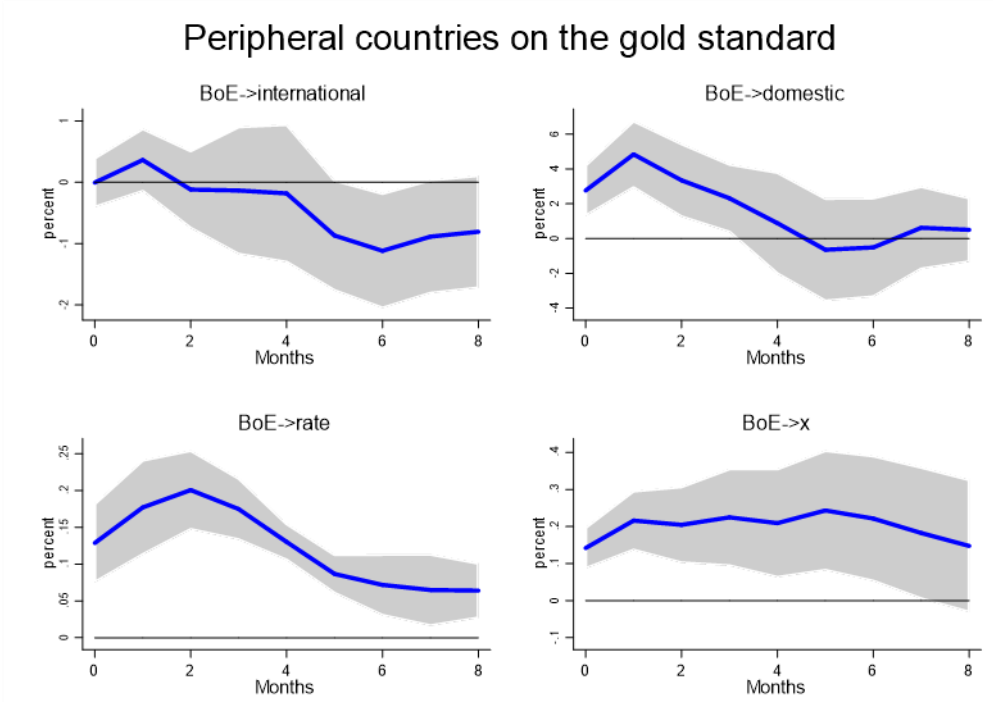


FIGURE 6. THE REACTION OF CENTRAL BANKS IN GOLD STANDARD PERIPHERAL COUNTRIES TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS. ALTERNATIVE MEASURE BASED ON LENNARD (2018) AS DISCUSSED IN THIS SECTION.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" and "domestic" denote the international and domestic portfolios of central banks, "rate" is the discount rate of central banks and "x" the exchange rate on London.

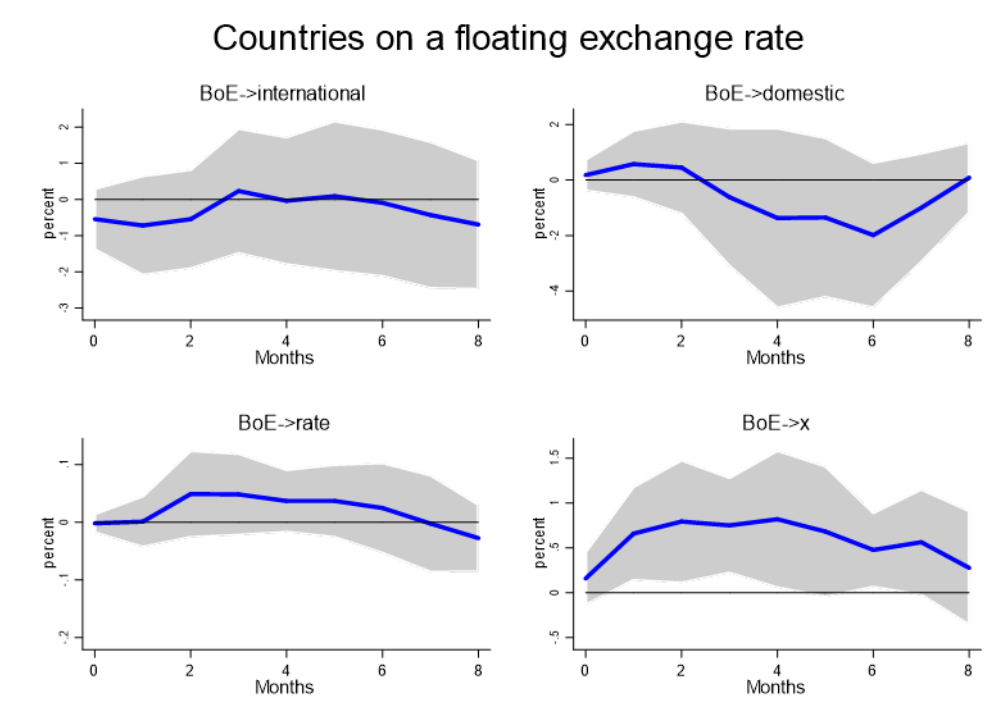


FIGURE 7. THE REACTION OF CENTRAL BANKS IN FIAT STANDARD COUNTRIES TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS. ALTERNATIVE MEASURE BASED ON LENNARD (2018) AS DISCUSSED IN THIS SECTION.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" and "domestic" denote the international and domestic portfolios of central banks, "rate" is the discount rate of central banks and "x" the exchange rate on London.

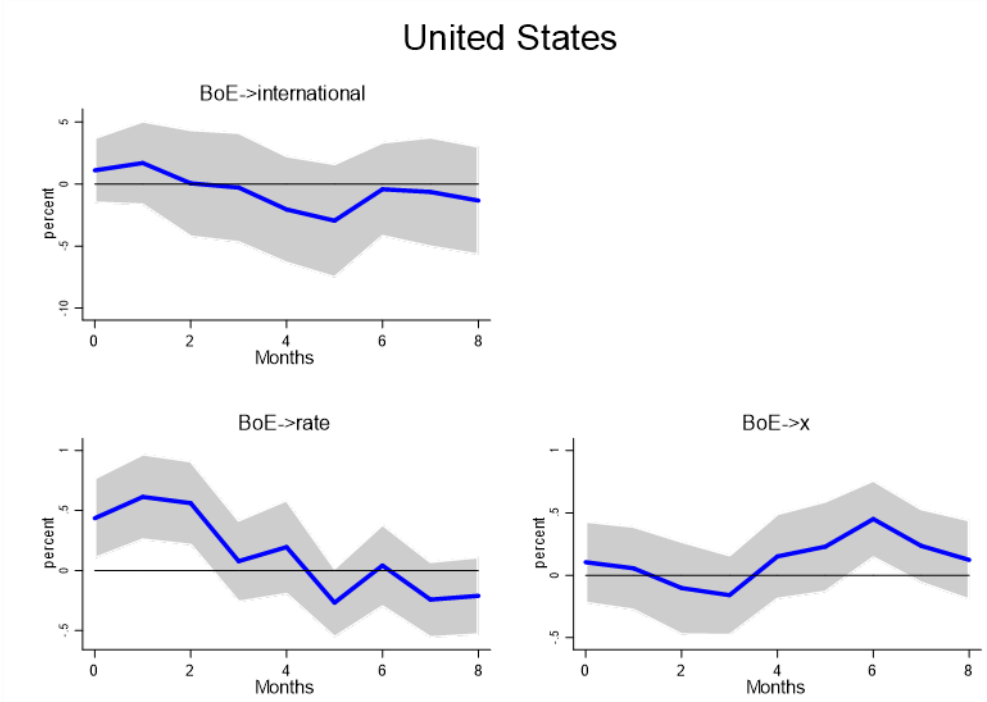


FIGURE 8. THE REACTION OF THE U.S. MONETARY SYSTEM TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS. ALTERNATIVE MEASURE BASED ON LENNARD (2018) AS DISCUSSED IN THIS SECTION.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" denotes the gold reserves of the U.S. Treasury, "rate" is the call money rate in New York and "x" the exchange rate in New York on London.

### *The special case of the United States*

The endogeneity issue is of particular concern in the case of the US because this country experienced an unusual number of banking panics between 1890 and 1913, which impacted the English economy and pushed the Bank of England to increase its interest rate (Jeanne 1995, Neal and Weidenmier, 2003, Hanes and Rhode 2013). For this reason, Green (2018) has built a specific measure of English monetary decisions which were unaffected by US events. Based on the archives of the board meetings of the BoE, she identifies all discount rate changes motivated by a change in US economic and financial conditions. Building on her work, we construct a series of BoE interest rate changes which are exogenous to the US economy. Similar to an average treatment effect, this corresponds to multiplying the BoE

discount rate change by a dummy variable that equals one when the change is classified as exogenous to the US by Green (2018). Figure 9 shows that our conclusions remain the same when such an exogenous measure is used.[22] The only difference in results is the stronger (and more significant) depreciation of the exchange rate (0.5 vs 0.2). This difference confirms that – as explained above – endogeneity problems lead to an underestimation of the depreciation of exchange rates of foreign countries in reaction to an English monetary policy shock. Yet, the reaction of the U.S. exchange rate is short-lived (no longer significant one month after the shock). It is consistent with the large, immediate and persistent response of the U.S. interest rate.

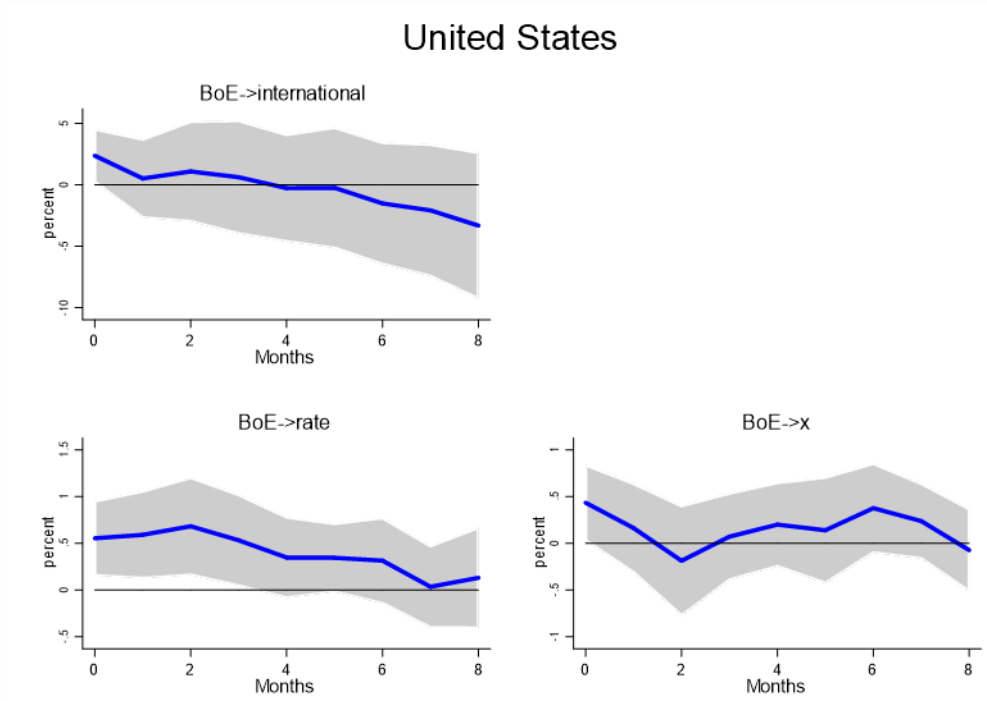


FIGURE 9. THE REACTION OF THE U.S. MONETARY SYSTEM TO AN ENGLISH DISCOUNT RATE SHOCK OF 100 BASIS POINTS IN THE FIRST EIGHT MONTHS. ALTERNATIVE MEASURE BASED ON GREEN (2018) AS DISCUSSED IN THIS SECTION.

Sources: Own calculations based on sources as described in the main text and the appendix.

Units: Percentage change compared to month t = -1 (positive exchange-rate response in lower right panel indicates depreciation).

Notes: "international" denotes the gold reserves of the U.S. Treasury, "rate" is the call money rate in New York and "x" the exchange rate in New York on London.

[22] Green (2018) estimated the effect of her exogenous English monetary shocks on the US economy and – contrary to us – found a small impact on money market rates. Her result is driven by the use of the commercial paper rate that – as we explained above – should not be used for this purpose because it is computed as an average of maximum and minimum values.

## Conclusions

This article challenged the widespread view that central banks did not enjoy autonomy during the classical gold standard (1870s-1913), the paradigmatic historical regime combining capital mobility and fixed exchange rates. Central banks were able to avoid raising interest rates as much as in the leading country of the system (England), as they could sterilize the effects of capital inflows on the domestic economy. In peripheral countries, where adherence to the gold standard was less credible, the extensive use of restrictions on gold convertibility also complemented sterilization. In doing so, central banks could avoid reaching the corner of the *trilemma*.[23] In the absence of a central bank, the US economy was more exposed to negative financial shocks from abroad. While a fairly recent literature (Bordo and MacDonald 2005) on a few core countries had highlighted a channel of autonomy through a target zone mechanism similar to Krugman (1991), this article proposes a different channel and proves that it was systematic. Our argument finds some precedent in the work of Polanyi (1944), Bloomfield (1959) and Ford (1962, 1989), but no study has ever provided a comprehensive analysis of sterilization and monetary policy autonomy during the first era of globalization. In the absence of such a quantitative investigation, there were many doubts as to whether sterilization was widespread and systematic. We were able to close the gap in the literature thanks to the exceptional archival discovery of the balance sheets of all central banks in the world at monthly frequency between 1891 and 1913 (including non-Gold, Core and Peripheral countries), as well as to a new identification method and a comparison with the United States.

[23] Quarterly, let alone monthly, macroeconomic data are almost non-existent for the Gold Standard period and are confined to Britain. Using such high frequency series over the period 1890-1912, Lennard (2018) found that a one-percentage-point increase in the Bank of England interest rate caused unemployment to rise by 0.9 percentage points, while inflation fell by 3.1 percentage points. If other countries over the same period could experience similar effects of interest rate changes, the central bank's ability to avoid following the English rate was indeed a key function in stabilizing macroeconomic outcomes. As in the usual trilemma framework (Obstfeld & Taylor 2004), our definition of monetary policy autonomy is very different from the ability to run persistent fiscal and balance of payments imbalances (Eichengreen 1992). The latter option was not possible for gold standard countries: they had to follow tight fiscal rules to remain credible (Bordo and Kydland 1995).

We anticipate at least two important areas of further research based on these findings. First, this paper focuses on the paradigmatic case of a capital mobility and fixed exchange rate regime in history, but the same empirical method can be applied to other periods, including today, as long as central bank balance sheets and exchange rate series are available at a high frequency. Given our results on the extent of sterilization and the role of central bank balance sheets during the gold standard, we expect that the recent debate on the *dilemma vs. trilemma* in international finance (Rey 2013, Obstfeld et al. 2019) will take into account and attempt to estimate this potential role. Second, showing that central banks made the constraint of international finance less binding in practice than in theory, our results should shed new light both on the historical evolution of central banks and on the choice of exchange rate regime (historical and current). Until 1913, the United States illustrated the cost of a fixed exchange rate without a central bank. On the other hand, we show that for peripheral countries with a central bank – relying on sterilization and imperfect gold convertibility – the cost of the fixed exchange rate was low compared to the full autonomy enjoyed in floating countries. It is probably not by chance that the rapid spread of central banks around the world during the second half of the 20th century has been associated with the somewhat surprising persistence of pegs, despite the theoretical appeal of floating exchange rates.

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# DATA APPENDIX

A unit was created in 1884 within the Banque de France whose sole objective was to produce harmonised balance sheets of foreign central banks (it was called the *Foreign Banking Statistics Service*), and economists were hired because of their skills in understanding foreign languages. It was not until 1891 that this unit began to systematically produce ledgers with weekly or monthly statistics for a significant number of foreign central banks. Later, in the mid-1890s, it became a real research department, broadening the scope of its studies. The interest in comparing central bank balance sheets can be tracked to a 1881 volume published by the Italian statistical institute. It was published in French. *Statistique International des banques d'émission: Autriche-Hongrie, Belgique, Pays-Bas, Suède, Norvège, Espagne,* Direzione Generale Della Statistica, Rome, Imprimerie Héritiers Botta. During this period, only the Bank of England, the Banque de France and the Reichsbank had a research department (Martin-Acena & Tortella 2013) but we found no evidence of similar work in the other two central banks.

**Description of the balance sheet data found in the Banque de France archives**

The harmonized balance sheet data provided by the source helped us to build comparable series across countries. We assembled five series for each bank of note issue: (1) metallic reserves (gold plus silver); (2) foreign papers; (3) foreign funds; (4) discount portfolio of domestic papers; (5) short term advances on securities and other collateral. (1), (2), and (3) constitute the international portfolio while (4) and (5) capture the domestic portfolio.

In describing the data below, we also provide the French terminology based on the monthly archival data and the quarterly and annual publications of the Bank of France we rely on. Some of the notions do not lend themselves to a straightforward translation into English. This reflects the fact that the Bank of England followed a unique classification due its separation of an issuance and a banking department (1844 Bank Act); and that the U.S. did not have a central bank at all until the establishment of the Federal Reserve System in 1913. By contrast, continental European terminology and classification is typically similar

to French practice, as evidenced by country-specific balance sheet data which we have consulted if and where possible. As the French classification is broadly identical to the approach pursued in an important Reichsbank (1925) publication covering seven key Classical Gold Standard central banks, we also provide German terminology.

Most banks in our sample enjoyed the exclusive right of note issuance. They constitute the natural candidate for analysing the monetary policy of a specific country, irrespective of how far they had already travelled on the way from a 19th century bank of note issue to a 20th century central bank. The situation is more complicated in the cases of Italy, Germany, Greece and Sweden given their system of multiple banks of note issue. In the first three cases, this reflected single banks of note issue on the political entities later forming (Italy and Germany) or joining (Greece) the country in question. In the Swedish case, the Riksbank was a state institution, but all other banks (so-called Enskilda banken) were private and had to deposit funds at the Riksbank to issue their own currency.

The Bank of France statisticians took the view that only the Italian case reflected a genuinely multipolar system; whereas the Reichsbank (Germany), the National Bank of Greece and the Riksbank (Sweden) dominated their respective monetary system to the point that they did not even include the data of the smaller banks into their data collection. Their judgment has been borne out by later research on the four countries (Sprenger 2002, Lazaretou 2014 for Greece, Bonelli 1991 for Italy, Ögren 2012 for Sweden) and we follow their lead as a result. Consequently, we include the Bank of Naples and the Bank of Sicily in addition to the Bank of Italy, but confine our analysis to one bank only for the cases of Germany, Greece and Sweden.

## *International portfolio*

### *1. metallic reserves / "en caisse" / "Barvorrat"*

Time series #1 consists for the most part of gold coin and gold bullion. It occasionally contains silver and other specie (e.g., copper and bronze in the case of Sweden). The proportion of silver is typically large only when silver coin retained its legal tender status after the country switched to gold at some point in the 1870s. This was often the case in

countries of the so-called limping gold standard (also referred to as limping bimetallism) which preserved silver as legal tender up to a certain amount. Contemporary sources refer to the entirety of specie as „metallic reserves“ (e.g., „Metallvorrat“ for the Reichsbank).

For some banks of note issue, “reserves” (Reichsbank: “Barvorrat”) are a marginally broader concept than “metallic reserves” (Reichsbank: “Metallvorrat”). In the cases of multiple banks of note issue (Germany, Greece, Italy and Sweden in our case), the category „en caisse“ / „Barvorrat“ also encompasses bank notes issued by other (domestic) banks of note issue. The Reichsbank, for instance, was allowed to include bank notes issued by other German banks of note issue on the grounds that such notes enjoyed metallic backing by their respective issuing bank. We follow this practice, not least because the Bank of France statisticians fully subscribed to it (despite coming intellectually from a single bank of note issue system).

In the cases of the Reichsbank and the three Italian banks of note issue (National Bank of the Kingdom of Italy, Bank of Naples, Bank of Sicily), we add – in line with domestic and French practice at the time – short-term treasury notes („Reichskassenscheine“ for the Reichsbank and „billets et bons de caisse de l‘Etat“ for the three Italian banks). These were highly liquid debt instruments and the four banks were allowed to include them into their note cover. It remains unclear why only these four banks of note issue include such notes into their note cover, and whether there is a connection to the system of multiple banks of note issue prevalent in Germany and Italy. The items described in this and the preceding paragraphs above were typically very small. E.g., in the case of the Reichsbank, they accounted for approximately 5% of total reserves.

*2. foreign paper / “portefeuille commercial – papier étranger” / “auswärtige Wechsel”*

Time series #2 consists of bills of exchange drawn on foreign places. Such a series is recorded for all 21 banks in our sample, even if values are very small (Russia, Serbia), a monthly series is reported but begins late (France in 1906) or the reported series only constitutes a lower-bound estimate (Romania). In the cases of Germany and Portugal, such data are only available on a yearly basis and are of very small value.

The very low numbers for France and Germany suggest that central banks in mature money markets bought such bills infrequently and left this business to specialised banks and

brokerage firms. By contrast, central banks in peripheral countries acquired an important share of the market for the lack of strong competitors; in some situations, they may have well have constituted the only domestic buyer of bills of exchange drawn on foreign places.

We acknowledge that the cases of Portugal, Russia and Serbia are difficult to square with this explanation. Yet the very low numbers in these cases might reflect country-specific idiosyncrasies. In the case of Russia, the treasury – and not the bank of note issue which we study – managed foreign bill (Drummond 1976). Portugal was not on gold in the time period under investigation. The case of Serbia might be similar to the Portuguese case. We have positive knowledge of no foreign bills until 1904 (when the country was on a fiat standard), but cannot be certain for the period thereafter (data for 1905-1013 only report "portefeuille commercial" without distinguishing between foreign and domestic); a period which roughly coincides with the country's de facto adherence to gold (1909-1912).

*3. foreign funds / „fonds à l'étranger" / „Auslandsguthaben"*

Time series #3 captures of funds held abroad. Such funds were usually held by so-called foreign correspondents, i.e., typically a foreign commercial bank with whom the bank of note issue was in regular contact. In many cases, funds held abroad reflect bills of exchange drawn on foreign places after reaching maturity. Such bills are classified as time series #2 before the settlement date and as time series #3 thereafter.

None of the five core countries of Britain, France, Germany, Belgium and the Netherlands report such a series, but all other countries do with the exception of Japan, Portugal and Romania. We hypothesize that core countries stabilised their exchange-rate in the currency market located in their own country, avoiding the need to hold foreign funds. Such purely domestic intervention was not possible for all other countries where currency trading took place abroad rather than at home.

Japan, Portugal and Romania are the only peripheral countries to not report such a series. In the case of Portugal, the absence might be explained by the country being off gold at the time (similar to the absence of time series #2, cf. above). The Romanian case might be similar to the Austro-Hungarian case where, if only relying on published documents at the time, we would have a lower bound estimate for time series #2 and no data at all for time

series #3 (Jobst and Scheiber 2014 for Austria-Hungary vs. Stoenescu et al. 2014 for Romania). The Japanese case awaits further investigation.

*Comment on the relative sizes of time series ##1, 2, 3*

Exceptions to #1 > > #2 + #3

Time series #1 is typically much larger than time series ##2 and 3 combined. The Classical Gold Standard (1870s-1914) was a specie standard at its heart and a larger role for foreign exchange was left to the interwar period. The gold exchange standard of the 1920s finds some precedents among late-stabilizing countries on the European periphery, namely Bulgaria and Greece(stabilising in 1906 and 1910, respectively). In the case of Greece, foreign funds account for the largest share of the international portfolio; foreign funds exceed metallic reserves by factor 7 at the time of currency stabilisation in 1910 and by factor 10 in 1913.

The other exception to the rule #1 > > #2 + #3 were the Nordic countries of Finland, Norway and Sweden (though not Denmark). The combined of ##2 and 3 are often larger than #1, and foreign funds in particular played an important role. This reflects the fact that these three countries were allowed, as members of the Scandinavian Monetary Union, to include foreign funds held at the banks of note issue of the other members countries as part of their note cover (and hence as international portfolio in our terminology). See Sumner et al. (1896), Lévy (1911), Conant (1915).

Exceptions to #2 > #3

There are typically more bills of exchange drawn on foreign places than foreign funds. Banks of note issue are typically last buyers (and in peripheral countries often first buyers) of such bills in the domestic market. We note that the only cases in which foreign exchange is typically larger than bills of foreign exchange are the four Nordic countries, Bulgaria and Greece. In the Nordic countries, this eflects the privileged situation which foreign funds enjoyed due to the rules of the Scandinavian Monetary Union referred to in the paragraph above. In the other two cases, it might reflect the mechanics of late stabilisation (in the case of Greece, we cannot even identify a separate time series #2, even though the data

description of time series #3 in Lazaretou (2014) leaves open the possibility that some of the foreign funds were actually foreign bills of exchange).

*Domestic portfolio*

*4. domestic paper / "portefeuille commercial – papier indigène" / „Diskontdarlehen" or „Wechsel"*

Time series #4 consists of bills of exchange drawn on domestic places and typically accounts for the majority of the domestic portfolio. (Re-)discounting bills of exchange was at the heart of central bank lending at the time (Bloomfield 1959 is particularly clear on this issue).

In a limited number of cases, time series #4 potentially includes a certain amount of foreign bills of exchange (Germany, Portugal). Yet we do know from the Bank of France Annual Data that these amounts were very small compared to domestic bills of exchange. End-of-year comparisons for Portugal and Germany suggest that foreign bills accounted for less than 1% and 10%, respectively.

*5. advances on collateral / „avances" / „Lombarddarlehen"*

Time series #5 consists of advances. Such advances were typically made available against safe and liquid assets such as government bonds. Yet practice varied with local conditions and we witness a considerable variety of what exactly classifies as an advance. For most countries, a careful comparison of the monthly, quarterly and annual data of the Bank of France delivered the same result. Advances were only made available against safe and liquid assets and their size was small compared to discounted bills of exchange (typically a quarter).

Only the cases of Bulgaria, Denmark, Greece, Norway, Russia, Serbia and Sweden posed specific problems. Incidentally, these seven countries were also the cases where time series #5 was large relative to time series #4, and in some cases even exceeded it. Given the economically backward nature of these countries (with the possible exception of Denmark and Sweden), we view these data problems as pointing to a more fundamental problem on

the European periphery: how to enable short-term lending in the absence of sufficient bills of exchange (discount lending) and a shortage of good collateral (conventional advances)?

In these seven cases, unsecured lending, lending against commodities (e.g., iron in the case of Sweden) and lending against real-estate played an important role. We have included all three categories as long as there was sufficient evidence that the lending was short-term.

*Comment on the relative sizes of time series ##4, 5*

Exceptions to #4 >> #5

Typically, there were many more bills of exchange than advances; a predominance captured in some languages to this day when a central bank's main lending rate is referred to as „discount rate" (e.g., "Diskontsatz" in German). In the cases of Denmark, Norway, and Sweden, #4 remains larger than #5 even if we include marginal balance sheet items such as lending against iron (cf. our description of time series #5 above). The only exceptions are found in Bulgaria, Greece, Russia and Serbia. This dichotomy between the Balkans (and possibly Russia) on the one hand, and all other peripherals countries on the other hand, is consistent with recent interpretations that South-East Europe (and Russia) were particularly backward, with implications for the development of its monetary system (Morys 2017).