

How Powerful is Unannounced, Sterilized Foreign Exchange Intervention?

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ABSTRACT

Though most central banks actively intervene on the foreign exchange market, the literature offers mixed evidence on their effectiveness: particularly for unannounced interventions. We use new, declassified data from the archives of the Bank of England and the institutional features of the Bretton Woods era to estimate the effects of intervention on the exchange rate. We find that a purchase of pounds equivalent to 1% of the money supply causes a statistically significant, 4-5 basis point appreciation in the pound.

Keywords: Monetary Policy, Foreign Exchange Markets, Bretton Woods System.

JEL classification: F3, N2

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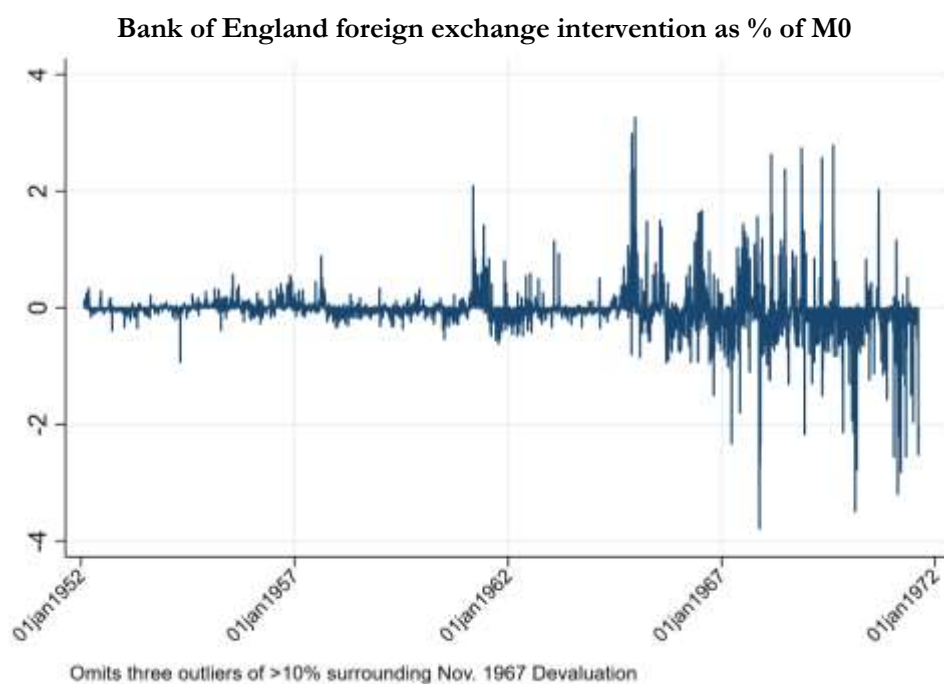
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NON-TECHNICAL SUMMARY

Most developing and many advanced economies intervene in foreign exchange markets to manage volatility and unwanted movements in the exchange rate. These operations involve sales and purchases of reserves to try to influence the exchange rate. Many central banks both sterilize their interventions (meaning they have no effect on the monetary policy stance) and conduct interventions secretly (meaning they are unannounced beforehand and unacknowledged after the fact). From a recent survey of 22 Emerging Market Economy central banks, 17 reported “Never” or “Rarely” pre-announcing their intervention.

Using a novel dataset on the Bank of England's daily operations during the Bretton Woods era, we conduct a new analysis of such unannounced, never-acknowledged sterilized intervention. We find modest, statistically significant effects on the level of the exchange rate. Our results suggest that a sterilized, unannounced sale of dollars equivalent to 1% of UK M0 causes a 4-5 basis point appreciation of the pound. This finding that sterilized intervention has significant effects even absent a significant signalling channel at least partially rationalizes the decision of many central banks to conduct intervention in secret.



Source: Authors' calculations based on data from the archives of the Bank of England.

Our analysis informs an ongoing debate on the impact of sterilized intervention on exchange rates. Policymakers believe that unsterilized intervention could work through impacting relative interest rates, and that public, sterilized intervention may work through a signaling channel. With sterilized, secret intervention these channels are muted, and policymakers exhibit less agreement on intervention effectiveness. While many central banks today announce their interventions, some still intervene secretly.

The academic literature on intervention focuses disproportionately on the few central banks that intervene publicly and publish their intervention data. Even when circumstances have allowed for the study of other central banks, it is not always clear whether the operations were really secret or promptly sterilized. This renders disentangling the channels at play challenging. Even with access to quality data, all studies of the effects of intervention must grapple with the issue of endogeneity, as intervention is far from randomly assigned.

In this paper we deal with the data availability issue by relying on historical daily data from the Bank of England archives (figure above). These now-declassified data record the Bank of England's secret, sterilized foreign exchange operations.

To deal with the endogeneity issue, we have two approaches. Endogeneity occurs because central banks almost always intervene in reaction to the market. It is therefore unclear if market movements are due to the market or to the action of the central bank. To deal with this, we first take an instrumental variables (IV) approach.

One IV approach takes advantage of the Bank of England's explicit exchange rate target during Bretton Woods, and uses the signed, squared, lagged distance of the exchange rate from target as an instrument for intervention. The motivation for this instrument is that the dealers working for the Bank of England, who were charged with intervening, may have been quicker to act if the exchange rate closed further from target the day before.

We also explore a second IV approach using lagged gold reserves as an instrument for intervention. The identifying assumption here is that lagged gold reserves reflect the entire history of shocks and intervention decisions, and are thus relatively orthogonal to current developments in financial markets. We obtain similar results (estimates of the same sign and magnitude) but much less precisely estimated due to low power in the first stage.

Finally, in addition to these two IV strategies, we also take an approach that identifies exogenous shocks to intervention as deviations from a policy rule estimated via an adaptive least absolute shrinkage and selection operator (lasso). Deviations from this rule may have an interpretation as exogenous shocks to intervention, but only if we can argue that the deviations are not taken in response to current developments in financial markets. To do so, we restrict attention to the deviations that occur on UK-specific holidays, during which the Bank of England was closed (and almost never intervened) while the pound continued to trade in New York, Zurich, and other world currency markets.

Les interventions stérilisées non annoncées ont-elles un impact sur le taux de change?

RÉSUMÉ

Bien que la plupart des banques centrales interviennent activement sur le marché des changes, la littérature sur le sujet offre des preuves mitigées de l'efficacité de ces interventions, et cela en particulier pour les interventions non annoncées. Nous utilisons de nouvelles données déclassifiées provenant des archives de la Banque d'Angleterre ainsi que les caractéristiques institutionnelles de la période de Bretton Woods pour estimer les effets des interventions sur le taux de change. Nous constatons qu'un achat de livres sterling équivalent à 1% de la masse monétaire entraîne une appréciation statistiquement significative de 4 à 5 points de base de la livre.

Mots-clés : Politique Monétaire, Marchés des Changes, Système de Bretton Woods

Les Documents de travail reflètent les idées personnelles de leurs auteurs et n'expriment pas nécessairement la position de la Banque de France. Ils sont disponibles sur publications.banque-france.fr

1 Introduction

Most developing and many advanced economies intervene in foreign exchange markets to manage volatility and unwanted exchange rate movements. Many central banks both sterilize their interventions and conduct them secretly, meaning without any announcement beforehand or acknowledgement after the fact.¹ Using recently-collected data on the Bank of England’s daily operations during the Bretton Woods era, we conduct a new analysis of such unannounced, never-acknowledged sterilized intervention and find statistically significant effects on the level of the exchange rate.

Our analysis informs an ongoing debate regarding whether sterilized foreign exchange intervention could meaningfully impact the exchange rate. In this context, “sterilized intervention” means market operations undertaken to influence the exchange rate while leaving the monetary base unchanged. This usually takes the form of a paired transaction in which the central bank buys (sells) domestic currency in foreign exchange markets while simultaneously selling (buying) domestic currency bonds. Policymakers generally believe that *unsterilized* intervention could work through impacting relative interest rates, and that public, *sterilized* intervention may work through a signaling channel. With sterilized, secret intervention these channels will be absent or muted, and policymakers exhibit less agreement on whether intervention may be effective in this context.²

The academic literature on intervention surveyed in e.g. Sarno and Taylor (2001) and Neely (2008) focuses disproportionately on the few central banks that intervene publicly and publish their intervention data. Even when circumstances have allowed for the study of other central banks, it is not always clear whether the operations were really secret or promptly sterilized.³ This renders disentangling the channels at play challenging.

¹From a recent survey of 22 “Emerging Market Economy” central banks, 17 reported “Never” or “Rarely” pre-announcing their intervention; when asked if they published data after the fact, 7 reported never publishing data at all and only 9 reported publishing data at a greater-than-monthly frequency (Mohanty and Berger, 2013); separately, most survey respondents reported routinely sterilizing their interventions.

²Specifically, Mohanty and Berger (2013) report that, when surveyed, most central bankers agree that the signaling channel of sterilized foreign exchange intervention is “effective” while exhibiting less agreement regarding the efficacy of other channels.

³Examples include Fratzscher et al. (2019), which includes 23 non-public datasets on daily intervention and likely includes many secret interventions (the authors found news coverage for only half of their intervention episodes) and which the contributing central banks affirmed were sterilized. Some recent

Finally, even with access to quality data, all studies of the effects of intervention must grapple with the issue of endogeneity, as intervention is far from randomly assigned. See Fratzscher et al. (2019) for a recent discussion of both of these issues.

By studying the Bank of England, we contribute a case study of a central bank that intervened frequently (on over 80% of trading days in sample), sterilized immediately, and operated with a high degree of secrecy. Relative to previous studies on the Bank of England (Naef, 2020, 2019) that presented mixed evidence for effectiveness based on correlations and event-studies, this paper presents causal point estimates of the effect of sterilized foreign exchange intervention on the exchange rate. We leverage the institutional setting of the Bretton Woods era to motivate three approaches to identification, including two instrumental variables (IV) approaches and a “Policy Rule” approach. This last approach proceeds by estimating a rule for determining the quantity of intervention normally conducted by the Bank of England, and treating deviation from it as a shock to intervention. The point estimates of all three independent approaches have the same economic interpretation and yield similar results.

To understand how these approaches deal with endogeneity, we appeal to a reduced-form model of the portfolio balance channel, as this theory traditionally garnered the most attention as an explanation for the efficacy of sterilized intervention absent information effects.⁴ The model informs our regression specifications and disciplines our discussion of identification issues. We note that ordinary least squares (OLS) estimates of the effects of intervention will be biased if central banks “lean against the wind.” For example, if the Bank of England attempted to strengthen the pound whenever it was weakening due to some fundamental shock, this would bias OLS estimates towards finding intervention unproductive (or even counterproductive). All three of our approaches yield results consistent with such a bias, despite relying on completely different identification

high-frequency studies on secret, intraday data on intervention in the market for the Czech koruna include Dominguez et al. (2013), who look at sales of reserves, and Scalia (2008), who studies sterilized interventions but without observing actual quantities of intervention, making inference instead based on intervention dates.

⁴We avoid framing our results as showing a portfolio balance channel in recognition of e.g. a market microstructure channel or other channels which might operate independently of the signaling channel, and which our empirical analysis will not rule out.

assumptions.

Our first IV approach takes advantage of the Bank of England’s explicit exchange rate target during Bretton Woods, and uses the signed, squared, lagged distance of the exchange rate from target as an instrument for intervention. The motivation for this instrument is that the dealers working for the Bank of England, who were charged with intervening, may have been quicker to act if the exchange rate closed further from target the day before. The identifying assumption is that the level of the exchange rate the day before does not impact the growth rate of the exchange rate, except through the (secret) actions of the central bank. We motivate this by noting that if our assumption did *not* hold, and the level of the exchange rate was useful for forecasting its growth rate, then market participants consistently “left money on the table” in a large and liquid market. Point estimates obtained from this approach are precisely estimated and robust to variations in specification and the time period of estimation. This identification assumption may not hold if there is mean reversion in fundamental shocks to the exchange rate, and the hope is that such mean reversion is small.⁵

We also explore a second IV approach using lagged gold reserves as an instrument for intervention. The identifying assumption here is that lagged gold reserves reflect the entire history of shocks and intervention decisions, and are thus relatively orthogonal to current developments in financial markets. We obtain similar results (of the same sign and magnitude) but much less precisely estimated due to low power in the first stage.

Finally, in addition to these two IV strategies, we also take an approach that identifies exogenous shocks to intervention as deviations from a policy rule estimated via an adaptive least absolute shrinkage and selection operator (lasso). Deviations from this rule may have an interpretation as exogenous shocks to intervention, but only if we can argue that the deviations are not taken in response to current developments in financial markets. To do so, we restrict attention to the deviations that occur on UK-specific holidays, during which the Bank of England was closed (and almost never intervened) while the pound

⁵Formally, an online appendix section [A.1](#) presents a simple model where the exclusion restriction nearly holds if the unobserved, fundamental shocks to the level of the exchange rate are almost a random walk.

continued to trade in New York, Zurich, and other world currency markets.⁶

We are not the first to estimate the effects of sterilized foreign exchange intervention. Menkhoff, Rieth, and Stöhr (2020) use a structural vector autoregressive model with external instruments to identify the effects of pre-announced interventions for the Bank of Japan. We use data on interventions that were never announced or made public, and take different approaches to identification. Several recent papers also present estimates using readily-available, low-frequency proxies for intervention.⁷ There is also a large event study literature which looks at the effect of intervention on a number of explicit success criteria, such as the direction of the exchange rate, which reports mixed results. For example, Fratzscher et al. (2019) finds that intervention is effective in up to 80% of cases, while Bordo et al. (2012) argue that the success rate for US interventions was historically no better than random.

This paper contributes to this literature by establishing the presence of nontrivial effects of sterilized intervention even absent a significant signaling channel. This finding at least partially rationalizes the decision of many central banks to conduct intervention in secret.

2 Historical and Institutional Context

The Bretton Woods system of pegged exchange rates lasted from 1944 to 1971, but our analysis begins in January of 1952 when the Bank of England reopened the foreign exchange market. This setting has three important features for our analysis: the Bank of England was charged with managing a clear exchange rate target; the sterilization of the foreign exchange operations we study was automatic; and interventions were secret.

In the system, the dollar was fixed to gold at \$35 an ounce and all other currencies

⁶The policy rule approach thus benefits from the fact that the Bank of England intervenes almost every day in our sample, so that the counterfactual intervention that we estimate on holidays is generally non-zero and non-trivial; it is by comparing the zero intervention observed on these holidays with the counterfactual implied by the rule that we obtain a shock measure.

⁷See e.g. Blanchard, Adler, and Filho (2015), who use changes in foreign exchange reserves observed at a quarterly frequency; Daude, Yeyati, and Nagengast (2016) who use changes in the ratio of reserves to M2 at a monthly frequency; and Adler, Lisack, and Mano (2019), who use changes in the central bank balance sheet at a monthly frequency.

were pegged to the dollar with a band of plus or minus 2%. The pound was fixed at the official price of \$2.80 per pound between 1949 and 1967, and at \$2.40 per pound between 1967 and the collapse of the system when President Nixon closed the “gold window” on August 15th, 1971. We use the pound/dollar exchange rate, and Figure 3 plots the exchange rate and target over time in these units. The explicit exchange rate target plays a role in both the construction of our instrument and the policy rule in our identification approaches below.

Another key feature of our setting is that the interventions we study were systematically sterilized, since they were all conducted through the Exchange Equalisation Account (EEA); Howson (1980) and more recently Allen (2019) establish that sterilization was a built-in feature of the EEA. By design, any operation of the EEA had a counterparty in UK Treasury bills, leading to automatic sterilization (note that the EEA is a government body technically independent from the Bank of England, which only manages the EEA). This makes us confident that we are indeed estimating effects of sterilized intervention and not simply picking up effects resulting from changes in the money supply.

A final notable feature of our dataset is that all interventions studied were conducted in secret. By “secret” we mean that in this period the Bank of England did not communicate their daily intervention operations or make public the data on their interventions at any point.⁸ A natural question is whether these operations were secret in practice, as obviously the Bank of England’s counterparties (which consisted of a small number of private banks) had to know when it was engaged in foreign exchange operations. We argue that intervention was likely secret for three reasons. The first was that not all of the central bank’s transactions in the foreign exchange market were associated with intervention, which would make it quite difficult in practice for counterparties to determine the bank’s intentions at short horizons. The Bank of England, nationalized in 1946, retained many private customers (including other central banks) and as a result frequently engaged in “customer operations” in addition to the intervention we study. These operations were substantial: on approximately 40% of our observed intervention days, the bank was also

⁸Public announcements accompanied interventions beginning in the 1980s.

engaged in customer operations. This would have made it difficult to disentangle the Bank's intention from its observed purchases and sales.

Second, the Bank of England outsourced some of its intervention to other central banks, reflecting the global nature of the foreign exchange market. Although most intervention was conducted in the London spot market, the Bank could request that the Federal Reserve, for example, intervene in the New York market and frequently did so (specifically, on just over 15% of all trading days).

Finally, anecdotal evidence confirms that secrecy was a goal from an early date, and that the Bank of England's dealers at least believed themselves to have been successful in this goal. In 1936, the senior official at the Bank of England in charge of foreign exchange matters, Harry Arthur Siepmann, noted that:

Experience has enabled some progress to be made in concealing or advertising the presence of the 'control', and this has led to masked intervention being resorted to more frequently and successfully. It is sometimes surprising to find how wide of the mark are the press reports of the EEA activity, as when on 6 April we bought nearly Fr.200 million but were reported by the financial news next morning as having "retired from the market soon after opening"... It is equally clear that, whatever precautions are taken, the presence of the 'control' cannot, as a general rule, escape observation, though guesses may be good or bad about the extent of its daily operations.⁹

The quote makes clear that while markets understood the Bank would intervene, day-to-day variations in this intervention could be quite difficult to discern. By the 1950s, when our sample begins, "masked" intervention was the rule, and secrecy an established policy goal. In a 1956 communication with the New York Fed, Roy Bridge, head dealer at the Bank of England, explained his strategy: 'I shall ask you to go into the market after lunch. ... Don't go before lunch. I thought it wise to change tactics a bit. It is a good thing.'¹⁰ In short, the Bank took pains to conceal its intervention, and believed

⁹Archives of the Bank of England, Harry Arthur Siepmann papers, reference C14/1, 1936.

¹⁰Telephone conversation with Mr. Bridge, Bank of England at 11:15 am, H. L. Sanford to file, 10 August 1956, New York, Archives of the Federal Reserve, box 617015.

these efforts to have been successful.¹¹

3 New Archival Data

We analyze a new, daily time series on the foreign exchange operations of the Bank of England taken from confidential reports sent from the Bank of England to the Treasury, which discriminates between “customer” operations and intervention meant to influence exchange rates (Naef, 2020, 2019). Figure 4 presents the daily series on intervention, deflated by UK M0 for ease of interpretation; note while the majority of this intervention was conducted directly by the Bank of England in the London pound/dollar spot market, the measure also includes intervention conducted by other central banks on the Bank of England’s behalf in offshore markets. A striking feature of this data is the sheer frequency of intervention: approximately 83.3% of the trading days in our sample see the Bank of England intervening in the spot market. For comparison, recent work by Fratzscher et al. (2019) using a sample of 33 central banks observed from 1995-2011 found an average frequency of intervention of 19.1% of trading days.

We also rely on gold reserve data from the Bank of England for one of our IV approaches, consisting of 5,117 daily observations.¹² Data on exchange rates comes from Accominotti, Cen, Chambers, and Marsh (2019). We also include various interest rate controls in some specifications, documented in online appendix section A.2.

4 IV Estimates of the Power of Unannounced, Sterilized Intervention

Let e_t be the pound/dollar exchange rate at the end of day t , plotted in Figure 3, and let Q_t be intervention undertaken to appreciate the pound defined as dollar sales as a share of UK M0, plotted in Figure 4. A naive attempt to estimate the marginal effect of

¹¹For more on the Bank of England intervention strategies, see Naef (2020).

¹²Our series for gold reserves ends in February of 1971, which is earlier than the data on interventions and explains the discrepancy in observations.

intervention on the exchange rate would be to estimate the following via OLS:

$$\ln e_t - \ln e_{t-1} = \beta_0 + \beta_1 Q_t + \epsilon_t, \quad (1)$$

where ϵ_t is an (unobserved) shock to growth in the exchange rate. Conventional wisdom suggests β_1 should be negative, as a sale of dollars (and purchase of pounds) should decrease the value of the dollar relative to the pound. But if Q_t is not randomly assigned, and the central bank “leans against the wind,” estimates of β_1 will be biased upward.

To surmount this, we instrument for the endogenous Q_t using the square of the distance from the exchange rate target at time $t - 1$, which we allow to take on negative values when below target. Formally, the distance instrument $Z_t \equiv (\ln e_{t-1} - \ln e_{t-1}^{target})^2 \times \text{sign}(\ln e_{t-1} - \ln e_{t-1}^{target})$, where the target is time-varying only because of the devaluation in sample. We motivate this instrument by arguing that if yesterday’s market closed far from the target, then regardless of today’s developments the dealers may be more aggressive in intervening.

Formally, exclusion requires that our instrument only impacts the growth of the exchange rate through its effect on the actions of the Bank of England, which were not observed directly by market participants at this time. To evaluate this, consider what it would mean for our exclusion assumption to *not* hold. This would imply that the level of the exchange rate was useful for forecasting its growth rate at very short horizons, and thus that traders consistently left money on the table in a large and liquid market.

A concern is that there may be predictable mean reversion at short horizons independent of the actions of the central bank, which would violate the exclusion restriction. In an online appendix section [A.1](#), we illustrate this concern by analyzing a simple first-order approximation of a reduced-form portfolio balance channel model, and note that mean-reverting behavior in (unobserved) fundamental shocks to the exchange rate would violate the exclusion restriction. However, we note that exclusion will nearly hold if the shocks to the exchange rate follow a nearly random walk (specifically, a stationary first-order autoregressive process with a near unit root).

We also explore IV results using lagged gold reserves as an instrument. Gold reserves

were kept secret and reflected the relative “strength” of the Bank of England with regards to its ability to defend the pound.¹³ The relevance argument here is that if endowed with greater reserves, the Bank of England would be more likely to intervene to support the pound all else equal. The excludability assumption is motivated by the fact that gold reserves at time $t - 1$ are the product of the entire history of shocks and intervention decisions, and thus relatively orthogonal to shocks at time t . In this approach, we also include a dummy for the post-devaluation period, which is necessary to account for the fact that the Bank of England both had less gold (as reserves were depleted in the run-up to devaluation) and intervened less after devaluing.

Table 1 presents estimates of β_1 in equation (1) comparing OLS to our two IV approaches. The results accord well with theory. When we estimate (1) by OLS, we find results consistent with severe upward bias as the coefficient is *positive* and significant, the opposite of what theory and the intuition of generations of central bankers suggests. However, when using any of our instruments, the sign flips, becoming negative and of reasonable magnitude. The interpretation of each coefficient is the increase (in percentage points) in the exchange rate that would result from a sale of dollars/purchase of pounds equivalent to 1% of British M0: the IV point estimates span the range of negative 2-10 basis points when using gold reserves or the distance approach, respectively.

We present the first stage of each regression in Table 2 to verify the economic intuition behind each approach. We note that the signs are as expected: when the pound is “too strong” relative to target yesterday, the Bank of England generally moved to weaken it (and vice versa when the pound was too weak), and higher gold reserves at the end of yesterday’s market close implies more intervention (dollar sales) the next day. We note the F-statistic and R-squared are low when using gold reserves, explaining the low power.

We next consider robustness to both time period of estimation and the inclusion of controls. We estimate our regressions with controls not only over the full sample but also over a sample which drops the entire month of the devaluation, and additionally

¹³Starting in the 1960s, gold reserves were published quarterly but with a lag and daily reserves were not available to market participants. See online appendix A.4 for details on the importance of gold as a reserve asset.

over a sample that drops data prior to 1959, as an important liberalization in UK capital markets occurred in late December 1958. This last exercise is particularly useful for understanding whether the presence of greater capital controls in the 1950s is driving our results, which does not appear to be the case. To motivate our choice of controls, we use a simple portfolio balance channel model, which suggests the following: let r_t (r_t^*) be the interest rate on riskless pound (dollar) bonds and let h be their maturity, then the exchange rate is given by

$$\ln e_t - \ln e_{t-1} = \beta_0 + \beta_1 Q_t + \beta_2 \Delta E_t \left[\ln e_{t+h} \right] + \beta_3 \Delta r_t + \beta_4 \Delta r_t^* + X_t + \mu_t, \quad (2)$$

where β_3 is negative, β_4 is positive, and the coefficient on the h -period forecast revision β_2 is unity in theory. In practice, we use futures markets to compute forecast revisions and changes in policy rates in both countries for r_t and r_t^* ; the vector X_t includes other interest rate controls, in addition to two lags of the dependent variable, as well as day-of-week, month and year dummies.¹⁴

Table 3 demonstrates that regardless of the sample period, our IV approach flips the sign of the OLS regression and yields a precise estimate of the effect of sterilized intervention within the two standard error bands of the Table 1 results: with the full sample, a sale of dollars/purchase of pounds equivalent to 1% of UK M0 would cause a four basis point appreciation of the pound. To give a sense of magnitude, a 1% intervention would be a large but far from abnormal daily intervention (see Figure 4), and the median daily change in the exchange rate (in absolute value) is 2.2 basis points in our sample. Thus, our results are consistent with the view that sterilized foreign exchange intervention was a useful tool for managing daily fluctuations.

¹⁴The full list of additional controls, not shown in Table 3, is the change in US 3-month treasury rates (available at a daily frequency) and the change in Treasury Bill Rates (available monthly). The additional UK controls include changes in consol yields, commercial paper rates, and UK M0, all available at a monthly frequency.

5 Treating Holiday-Driven Deviations from a “Policy Rule” as Shocks to Intervention

In this section, we estimate a policy rule for central bank intervention based on non-holiday trading days, and use this rule to calculate a counterfactual for the quantity of intervention that would have occurred on each holiday if the bank had been open as normal. Similarly, we estimate an exchange rate forecasting equation on non-holiday trading days and use this to create a counterfactual for exchange rate growth. Then we can regress the deviation of the exchange rate from its counterfactual on the deviation of intervention from its counterfactual and obtain an estimate of the effect of intervention.

We restrict our attention to holidays because we know on these days that the deviation from the policy rule was due to the bank being closed, and thus unrelated to developments in world currency markets. Specifically, we restrict attention to the deviations that occur on UK-specific holidays, during which the Bank of England was closed (and rarely intervened) while the pound continued to trade in New York, Zurich, and other world currency markets. For example, throughout our sample the last Monday of August is a secular holiday called the “Late Summer Bank Holiday” where all British markets and banks close while the rest of world traded as usual. We also include a second secular bank holiday in the winter and Good Friday in addition to Easter Monday. The results are consistent with our earlier IV results, again of the same sign and magnitude, and again despite relying on a very different identification assumption.

Formally, we will report point estimates from the following regression: denote \hat{Q}_t^i as predicted intervention using some policy rule i (which we will discuss below). Similarly, let \hat{e}_t^i be a forecast for the exchange rate. Then we estimate the following β^i via OLS:

$$\underbrace{(\ln e_t - \ln e_{t-1}) - (\ln \hat{e}_t^i - \ln e_{t-1})}_{\text{Forecast Error for the Growth in } e} = \beta^i \times \underbrace{(Q_t - \hat{Q}_t^i)}_{\text{Deviation from the Policy Rule } i} + \gamma_t^i \quad (3)$$

where γ_t^i is an error term, and we can interpret β^i as the effect of intervention, which has the same economic interpretation and units as the coefficient estimated in our IV

regressions above.¹⁵

In practice, our forecasting procedure is as follows: we use adaptive lasso to choose the policy rule from up to ten lags of the dependent variables and ten lags of all included and excluded instruments used above, in addition to various dummies and time trends. We use adaptive lasso as recent evidence suggests it performs well in time series contexts (Medeiros and Mendes, 2016).

We use lasso because simple rules do not predict either exchange rates or intervention well, and complicated rules require discipline, as it is not *a priori* obvious what belongs in the policy rule.¹⁶ Unlike with conventional monetary policy, where the arguments of the central bank’s policy rule are well understood, contemporaries were vague on the determinants of day-to-day operations even in their secret, internal communications. As Harry Siepmann unhelpfully wrote in 1936, in a section labeled “tactics”:

The tactics and management of the EEA naturally attract a good deal of attention and comment, but the fact is that the technique of day-to-day operations is not susceptible of much development or variation. Once the objectives have been set by policy, the question of method is a matter for practical judgment and opportunism, which necessarily depends upon the state of the market. In the press and elsewhere an attempt is occasionally made to propound some kind of theory of management. . . . All such hypothetical arguments have the advantage that, by their very nature, they cannot be disproved.

While it is possible that operations could have become more systematic in the period studied here, we conclude that an atheoretic approach has some appeal. Finally, using adaptive lasso to estimate the policy rule (instead of OLS) mitigates concerns of overfitting. If we overfit, this will effectively add “noise” to our policy shock measure, biasing

¹⁵Note that using a forecast error on the left hand side is formally almost identical to simply including the variables chosen by the adaptive lasso as controls on the right hand side.

¹⁶To see why simple policy rules have little power, note the first stages of our IV regressions in Table 2 have R-squared values below .05; fitting parsimonious rules based on these instruments would thus leave us with little power. Use of Lasso allows us to make nontrivial predictions and raise the R-squared values without concerns of overfitting (the Lasso models described below are capable of explaining 20-25% of the variance in-sample for intervention). Note that this approach benefits heavily from the fact that in our setting the central bank is intervening almost every day, so that a policy rule can be meaningfully estimated.

estimates of β^i toward zero.

Note that even having chosen adaptive lasso as our estimator, we still have some freedom over its implementation. Accordingly, we present results from two different forecasting procedures that yield distinct models, labelled according to the information criterion involved in the implementation: either AIC (Akaike Information Criterion) or BIC (Bayesian Information Criterion). In practice it is not clear which model we should favor in our context, which is why we present both; online appendix section [A.3](#) discusses the details of estimation. The results of estimating β^i in equation (3) via OLS given the different forecasts from the two models are largely consistent, and presented in Table 4 estimated over three different subsamples. Note that the coefficients on intervention have the same interpretation as previous tables, and we thus compare them directly.

The first two columns present results for all non-holiday trading days, suggesting that a sale of dollars equivalent to 1% of UK M0 actually depreciates the pound by 3 basis points. We include these columns to show that use of a policy rule alone is not helpful in achieving identification and simply recovers the positive OLS estimates in the first columns of Table 1 and Table 3. As the Bank of England official Harry Siepmann stated above, day-to-day operations respond in real time to changes in market conditions, meaning that deviations from the rule on the right-hand-side in our setting are generally endogenous to any shocks driving exchange rate movements.

Columns (3) to (6) restrict our sample to holidays, when we know deviation from the policy rule is driven by the closure of the Bank of England and not current developments in financial markets. Here we obtain results of the same sign and magnitude as the IV results in Table 3. These results suggest that a sale of dollars equivalent to 1% of UK M0 appreciates the pound by 3-8 basis points, depending on the specification.

6 Conclusion

This paper established the presence of nontrivial effects of sterilized intervention even absent a significant signaling channel. Our results suggest that a sterilized, unannounced

sale of dollars equivalent to 1% of UK M0 causes a 4-5 basis point appreciation of the pound. Given that the median absolute change in the exchange rate was 2.2 basis points during this period, our estimates are consistent with the view that the Bank of England's interventions were useful in offsetting day-to-day fluctuations in the exchange rate.

While the context of the Bank of England during Bretton Woods is different from many central banks today, our results may still prove relevant to modern policymakers. Many modern central banks manage exchange rate pegs, even if their bands are often broader than those studied here, and intervene in foreign exchange markets. Our results at least partially rationalize the decision of many central banks to both intervene in secret and sterilize their interventions by demonstrating that such interventions can still have economically significant effects on the exchange rate. Our use of historical data affords us a relatively rare opportunity to study the track record of systematic, secret, sterilized intervention over a long period of time, confident in the knowledge that the data has not been manipulated prior to publication or selectively provided.

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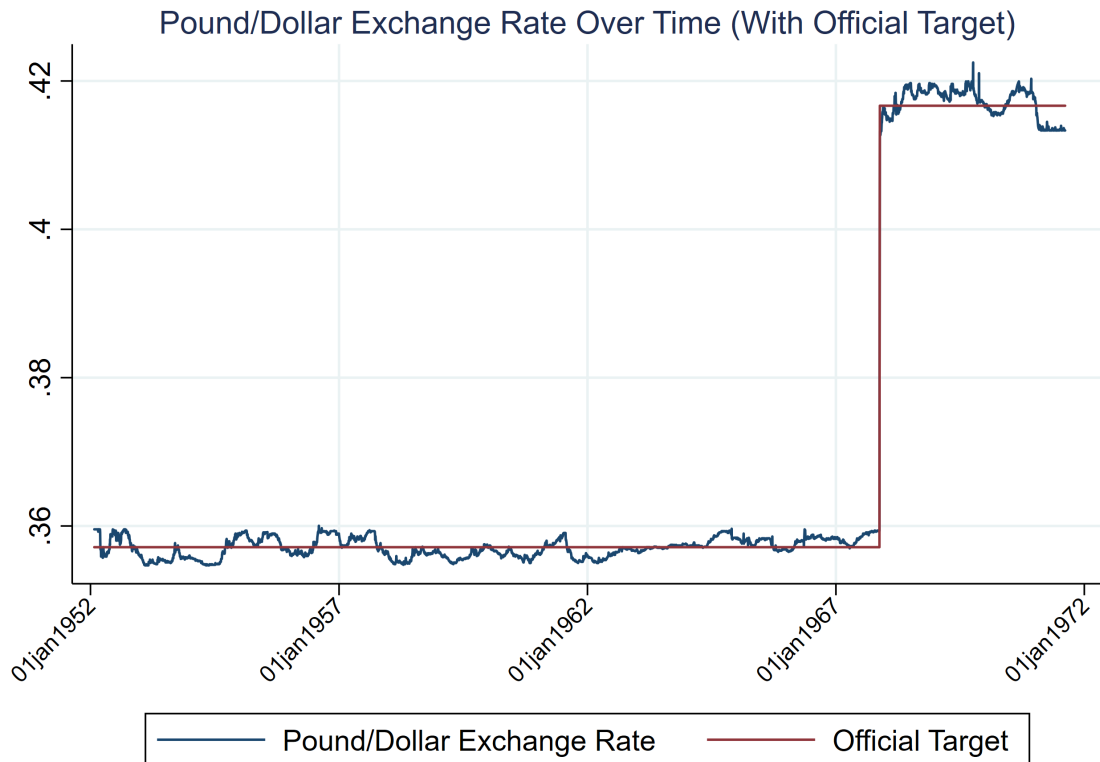


Figure 1: Above, the Pound/Dollar exchange rate is plotted over time. Note the devaluation of the pound in late November of 1967. See text for source.

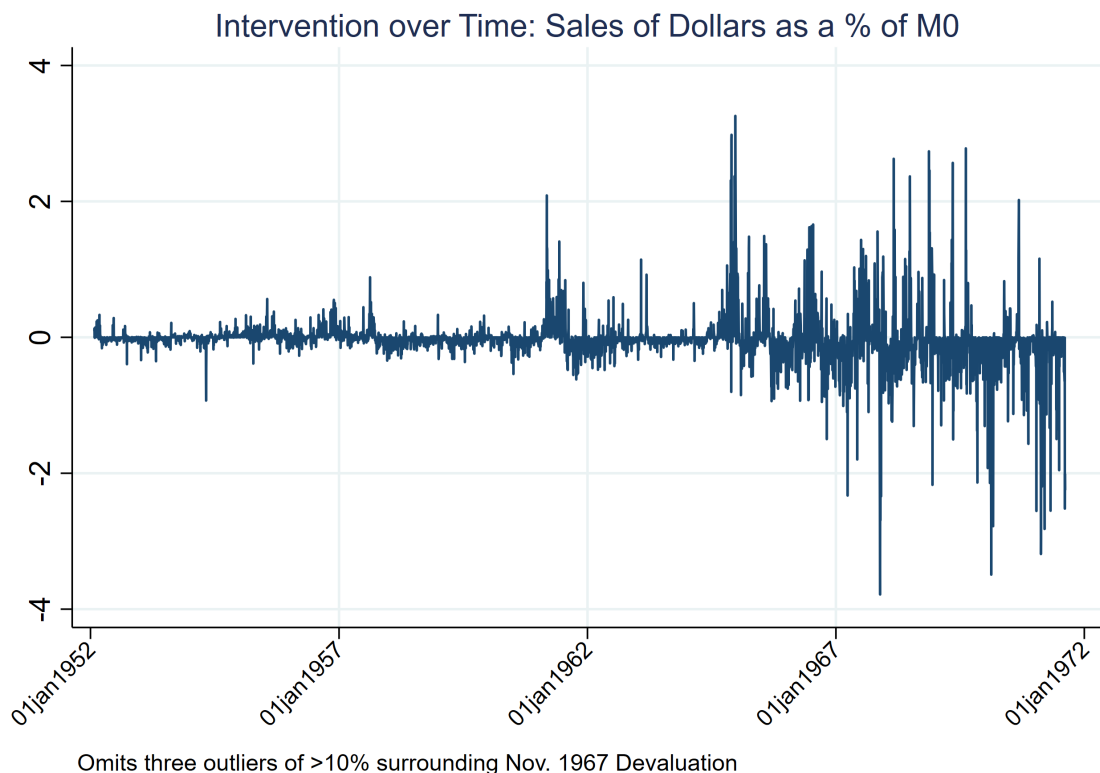


Figure 2: Intervention over time, deflated by UK M0 to ease interpretation. Positive values indicate sales of dollars by the Bank of England, understood as attempts to appreciate the pound vis-a-vis the dollar. This is the key right-hand-side variable in all our regressions below. See text for source. 18

Table 1: Effect of Intervention on the Change in the Exchange Rate [1952-1971]

	(1)	(2)	(3)
	OLS	IV: Distance	IV: Gold
Intervention	0.02*** (0.01)	-0.10*** (0.03)	-0.02 (0.04)
Observations	5244	5244	5115

Notes: Heteroskedasticity-robust standard errors in parentheses. The dependent variable is the log growth in the value of the dollar relative to the pound, and “Intervention” is the daily quantity of dollar sales by the Bank of England (divided by UK M0) undertaken to appreciate the pound. Columns (2) and (3) present IV results using the instruments described in the text, each of which demonstrates the bias in OLS and suggest that an intervention equivalent to 1% of UK M0 appreciates the pound by between 2-10 basis points, depending on the specification (though note the large standard errors). All regressions include day-of-week, month and year dummies and drop the first trading day after the November 1967 devaluation.

Stars indicate: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$

Table 2: First Stage Regressions: Effect on Intervention (Dollar Sales)

	(1)	(2)
	Distance	Gold
Lagged, Squared Distance from Target	0.33*** (0.04)	
Lagged Gold Reserves/M0		0.06 (0.11)
Dummy for After Devaluation		-0.12*** (0.03)
Constant	-0.03*** (0.01)	-0.02 (0.03)
Observations	5244	5115
R^2	0.041	0.019
F	90.47	27.24

Notes: Heteroskedasticity-robust standard errors in parentheses. The dependent variable is the daily quantity of intervention (measured as dollar sales divided by UK M0). The signs confirm the economic intuition underlying the relevance assumption of each approach: when the lagged distance from target instrument is positive, the pound is “too weak” relative to target and the Bank of England acts to strengthen it, and higher gold reserves at the end of yesterday’s market close implies more intervention (dollar sales) the next day. All regressions drop the first trading day after the November 1967 devaluation.

Stars indicate: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$

Table 3: Effect of Intervention on the Change in the Exchange Rate [1952-1971]

	OLS		IV: Distance		IV: Gold		
	(1) Full Sample	(2) Full Sample	(3) Drop Nov. '67	(4) After 1958	(5) Full Sample	(6) Drop Nov. '67	(7) After 1958
Intervention	0.01* (0.00)	-0.04*** (0.01)	-0.05*** (0.01)	-0.04*** (0.01)	-0.03 (0.02)	-0.08 (0.10)	-0.02 (0.02)
L.FX Growth	-0.12** (0.04)	-0.07 (0.04)	-0.06 (0.04)	-0.09* (0.04)	-0.08* (0.04)	-0.03 (0.11)	-0.12* (0.05)
L2.FX Growth	-0.07*** (0.02)	-0.05* (0.02)	-0.04 (0.02)	-0.05* (0.03)	-0.05* (0.02)	-0.02 (0.06)	-0.06* (0.03)
Change in US Policy Rate	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)
Change in UK Policy Rate	-0.05*** (0.00)	-0.05*** (0.01)	-0.05*** (0.01)	-0.06*** (0.01)	-0.05*** (0.01)	-0.06*** (0.01)	-0.05*** (0.01)
1-mo. Exp. Revision	0.59*** (0.05)	0.64*** (0.05)	0.65*** (0.05)	0.62*** (0.06)	0.63*** (0.05)	0.68*** (0.11)	0.59*** (0.06)
Observations	4227	4227	4209	3105	4103	4085	2981

Notes: Heteroskedasticity-robust standard errors in parentheses. The dependent variable is the log growth in the value of the dollar relative to the pound, and “Intervention” is the daily quantity of dollar sales by the Bank of England (divided by UK M0) undertaken to appreciate the pound. We also present point estimates for two lags of the dependent variable, changes in both the UK “Bank Rate” and the effective Federal Funds rate, and one month ahead expectation revisions read from futures markets. The IV results are estimated over the full sample and two others: one which drops the entire month of the devaluation, and another which keeps only the period after an important liberalization in UK capital markets. All regressions include day-of-week, month and year dummies, as well as additional interest rate controls described in the text, and drop the first trading day after the November 1967 devaluation.

Stars indicate: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$

Table 4: Effects of Sterilized Intervention on the Log Growth in the Value of the Dollar using Policy Rules and Forecasts Estimated via Adaptive Lasso: Results by Model and Sample Period

	All Dates		Holidays		Holidays (After 1958)	
	(1) AIC	(2) BIC	(3) AIC	(4) BIC	(5) AIC	(6) BIC
Intervention: AIC	0.03*** (0.01)		-0.08* (0.04)		-0.05** (0.02)	
Intervention: BIC		0.03*** (0.01)		-0.04 (0.03)		-0.03 (0.02)
Observations	3177	3930	38	54	32	45
R^2	0.047	0.056	0.110	0.035	0.145	0.040

Notes: Heteroskedasticity-robust standard errors in parentheses. The dependent variable is the log growth in the value of the dollar relative to the pound, and “Intervention” is the daily quantity of dollar sales by the Bank of England (divided by UK M0) undertaken to appreciate the pound, each given as a deviation from a forecast computed using the adaptive lasso and either the AIC or BIC as an information criterion (see online appendix A.3 for details on computation). The table compares the results using just holiday dates to the results using all dates in columns (1) and (2). With all dates we replicate the OLS results, while with holidays we recover results consistent with the IV columns observed in Table 3. Note we are missing some holidays because forecasts could not be computed (due to missing data) and that this explains the smaller number of observations when using the less-parsimonious AIC model.

Stars indicate: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$

A Appendix (for online publication)

A.1 A Reduced-Form Portfolio Balance Channel Model of Sterilized Foreign Exchange Intervention¹⁷

We use a simple model to discipline our regression specifications (including the choice of controls) and illustrate a case where the distance instrument’s exclusion restriction only holds “approximately” due to the presence of mean-reverting fundamental shocks to the level of the exchange rate.

Define e_t as the exchange rate in terms of the home currency (pounds) per unit of foreign currency (dollars), so that an increase in e is a depreciation of home’s currency. World demand for home (pound) bonds is determined by some function D which is increasing in their excess return over foreign (dollar) bonds. Letting R_t and R_t^* denote gross interest rates on h -period home and foreign currency bonds,

$$\text{World Demand For Home Bonds} \equiv \chi_t D \left(R_t - R_t^* \left(\frac{E_t[e_{t+h}]}{e_t} \right) \right).$$

This is a standard reduced-form model of UIP deviations.¹⁸ We assume that the log of the demand shifter χ_t follows a stationary AR(1) process:

$$\ln \chi_t = \rho \ln \chi_{t-1} + \delta_t$$

where $\rho < 1$ and δ_t is a white noise process. We assume the supply of bonds available for the private sector to hold is given by total home (UK) government debt, denoted B_t , less central bank holdings, denoted A_t . Given the supply of home currency bonds, equilibrium in the market for home debt is achieved through the exchange rate adjusting today, given gross interest rates and expectations of the exchange rate. The intuition is

¹⁷This is sometimes also called the “imperfect asset substitutability” or “risk premium” channel.

¹⁸See e.g. microfounded models such as Gabaix and Maggiori (2015), who obtain a similar demand function assuming incentive-compatibility constraints prevent risk-neutral investors from arbitraging away UIP deviations. It is also a standard model used in undergraduate texts; see e.g. Krugman, Obstfeld, and Melitz (2015), where D is motivated by aggregating over the idiosyncratic demands of individual, risk-averse investors.

simple: if the expected returns on the two bonds are unchanged, their relative price must adjust when the central bank alters the supply. This is achieved through exchange rate adjustment.

Setting supply equal to demand and log-linearizing yields a framework for our regressions. Then, since we do not observe the size of the bank's balance sheet at a daily frequency, but only the changes, we first difference. In what follows, for any variable Z_t , we use \bar{Z} to denote the steady state of Z_t ; writing $\ln R = \ln(1+r) \approx r$, and letting Δ be one period differences over t , we obtain

$$\Delta \ln e_t = E_t[\ln e_{t+h}] - E_{t-1}[\ln e_{t+h-1}] - \frac{\bar{R}}{\bar{R}^*} \Delta r_t + \Delta r_t^* - \phi \Delta \ln A_t + \epsilon_t \quad (4)$$

where ϵ_t collects unobserved structural errors, and ϕ is a positive, uninteresting collection of steady-state values.¹⁹ The sign accords with intuition regarding sterilized foreign exchange interventions, as ΔA_t in this model corresponds with the sterilized intervention data collected (which we then divide by M0 to obtain the variable Q_t used in the text, to ease interpretation).²⁰

Now consider the error term: this contains both a term related to daily changes in the stock of government debt B_t , which we abstract from, and the fundamental shock term:

$$\epsilon_t \equiv \frac{D'(\bar{R} - \bar{R}^*)\bar{B}}{\bar{B} - \bar{A}} \Delta \ln B_t + \frac{D'(\bar{R} - \bar{R}^*)}{\bar{R}^*} \Delta \ln \chi_t$$

Since the distance instrument contains a lag of the exchange rate, it contains the shock χ_{t-1} . It will generally only be orthogonal to the error term if $\Delta \ln \chi_t = (\rho - 1) \ln \chi_t + \delta_t$ is i.i.d. which is only the case if $\rho = 1$ and the demand shifter is a random walk. Thus, we note that if ρ is close to one then the exclusion restriction will be almost satisfied.

Regarding our specification with controls, we estimate the following version of the

¹⁹Formally, $\phi \equiv D'(\bar{R} - \bar{R}^*) \frac{\bar{A}}{\bar{B} - \bar{A}}$; the marginal effect of intervention depends both on the share of home bonds held by the central bank and the steady-state "slope" of the demand curve, which is increasing in the excess return on home bonds (and hence positive).

²⁰To see the correspondence between the "dollar sales" variable Q_t and the change in the central bank's holding of pound bonds $\Delta \ln A_t$, consider an example where the Bank of England (the home country) sells dollars and buys pounds. When the Bank of England buys home bonds to sterilize the intervention, A_t increases.

above equation:

$$\Delta \ln e_t = \beta_0 + \beta_1 Q_t + \beta_2 \Delta E_t [\ln e_{t+h}] + \beta_3 \Delta r_t + \beta_4 \Delta r_t^* + X_t + \mu_t \quad (5)$$

where $\Delta \ln A_t$ has been replaced by Q_t and X_t includes day-of-week, month and year fixed effects, two lags of the dependent variable and various interest rate controls. We use changes in one month forward rates to proxy for $\Delta E_t [\ln e_{t+h}]$, and policy rates in each country as our measures of r_t and r_t^* . Note that from the model’s perspective, ideally we would use changes in risk-free h -month rates, but these are not always available at daily frequencies (an exception is the US 3-month treasury rate which is available at a daily frequency from FRED). We thus also include various changes in available interest rates at monthly frequencies as described in the next section of the Appendix.

A.2 Data Sources

For exchange rates, we rely on data collected by Accominotti et al. (2019) from the *Financial Times*, and patch in missing data from Global Financial Data (GFD).²¹ We also take one-month forward premiums from this same source, which we use to construct the forecast revision $\Delta E_t [\ln e_{t+h}]$ in equation (5). All other interest rate controls and UK M0 are downloaded from the Federal Reserve Economic Database (FRED), except for the UK policy rate which is taken from the Bank of England.

For our intervention variable, we deflate by the previous months UK M0. We also include the following monthly changes as controls in some specifications (with FRED series names): changes in UK M0 (MBM0UKM); changes in US Treasury Bill rates (INTGSTUSM193N); changes in 3-month Treasuries (TB3MS); changes in UK console yields (YCLTUK); and changes in UK commercial paper rates (DRSTPUKM). For daily interest rates, changes in the Bank Rate were downloaded from the Bank of England’s

²¹We prefer to use the Accominotti et al. (2019) data from *Financial Times* since it is better documented, and patch in for dates when data is missing due to e.g. bad scans of the *Financial Times*. In particular we also use the GFD data to obtain prices for holiday dates when the world market was still trading. In practice, on the days when they overlap, the correlation between the *Financial Times* data and the GFD data is effectively one.

web site; we also included changes in the US policy rate as captured by the effective Fed Funds rate (DFF) and changes in 3-month treasury rates (DTB3), though these series only begin in 1954.

One non-trivial data cleaning issue bears mentioning: foreign exchange markets in Europe were open on Saturdays from April 15th, 1955 to October 17th, 1964, and the Bank of England intervened over the weekend as a result. However, the Bank of England recorded its intervention for both Friday and Saturday jointly, so that we do not observe how much intervention occurred on each day. Rather than impute, we instead treat Friday and Saturday as one trading day for the purposes of estimation, and construct changes from end-of-day Thursday to end-of-day Saturday when creating our controls and non-intervention variables. All references to the number of observations made in the text account for this, and count both Friday and Saturday as one day.

A.3 Adaptive Lasso Implementation

We use the [lassopack](#) package in Stata provided by Ahrens, Hansen, and Schaffer (2020) to implement adaptive lasso, using default values for implementation, and note the importance of the choice of information criterion.

We allow for up to ten lags of the following: intervention as a fraction of M0, gold reserves as a fraction of M0, lagged squared distance from target (i.e. the instrument used in our earlier IV regressions), growth in the exchange rate, forecast error revisions, changes in the Bank of England policy rate and changes in the Fed Funds rate. We also allow for a linear time trend, a time trend with a break after the devaluation, a dummy for being post-devaluation, day-of-week, month and year dummies, and all of our previous interest rate controls (which were available at a monthly frequency).

Adaptive lasso is a shrinkage estimator; formally, we pick parameters λ and ω_j and solve the resulting optimization problem:

$$\hat{\beta} = \arg \min_{\beta} \frac{1}{2n} \sum_{i=1}^n (y_i - \mathbf{x}_i \beta')^2 + \lambda \sum_{j=1}^p \omega_j |\beta_j|$$

where y_i is either the growth in the exchange rate or intervention as a fraction of UK M0, and x is a vector of p potential predictors. Adaptive lasso uses a set of initial OLS estimates to pick the ω_j . To pick λ , the optimization problem is solved for multiple potential values given a pre-specified grid. We then pick from the resulting models using either the AIC or BIC; the BIC yields a more parsimonious model, while the AIC has a greater in-sample fit and produces more substantial forecasts.²² In Table 4 of the main text, we presented results for both approaches.

To obtain the coefficients shown in Table 4, we regress the forecast error for exchange rate growth on the forecast error for intervention (i.e. the deviation from the policy rule). Denote \hat{Q}_t^i as predicted intervention using either the $i = BIC$ or $i = AIC$ model. Similarly, let \hat{e}_t^i be the forecast for the exchange rate. Then we estimate the following β^i for each model via OLS:

$$\underbrace{(\ln e_t - \ln e_{t-1}) - (\ln \hat{e}_t^i - \ln e_{t-1})}_{\text{Forecast Error for the Growth in } e} = \beta^i \times \underbrace{(Q_t - \hat{Q}_t^i)}_{\text{Deviation from the Policy Rule } i} + \gamma_t^i$$

where γ_t^i is an error term. As Table 4 shows, in this step it is critical to restrict t to be in the set of dates which are holidays: there, we know the deviations from the policy rule on the right-hand-side are plausibly exogenous. Note the economic interpretation of β^i is similar to our IV regressions with controls and we should expect similar point estimates if both approaches are truly identifying as-good-as-random variation in Q_t .

A.4 Relative Reserves and the Importance of Gold

Our second IV approach relies on the use of gold as a proxy for the strength of the Bank of England’s reserve position. We use gold as it was the leading reserve asset at the time; see Figure 3 which presents data from Naef (2021a) on Bank of England reserves. Gold clearly played a major role during most of the Bretton Woods period. While dollars were useful as a liquid asset that could immediately used for intervention, they were not seen

²²The software package we use also produces estimates based on alternative versions of these information criteria, but this is the only distinction which matters in practice.

as a safe reserve asset and excess dollar reserves were often converted into gold. At the end of the Bretton Woods period, however, the dollar became more important. This was mainly due to the growing importance of swaps with the Fed and other short term dollar loans which increased the dollar position. The spikes at the end of Figure 3 are due to short term swap contracts that were meant to manipulate the true reserve position as shown by Naef (2021b). Other reserve currencies played a minor role relative to the dollar, as visible in Figure 4; Avaro (2020) has shown that the dollar dominated as a major reserve currency in the reserve portfolio of most major central banks during the Bretton Woods period.

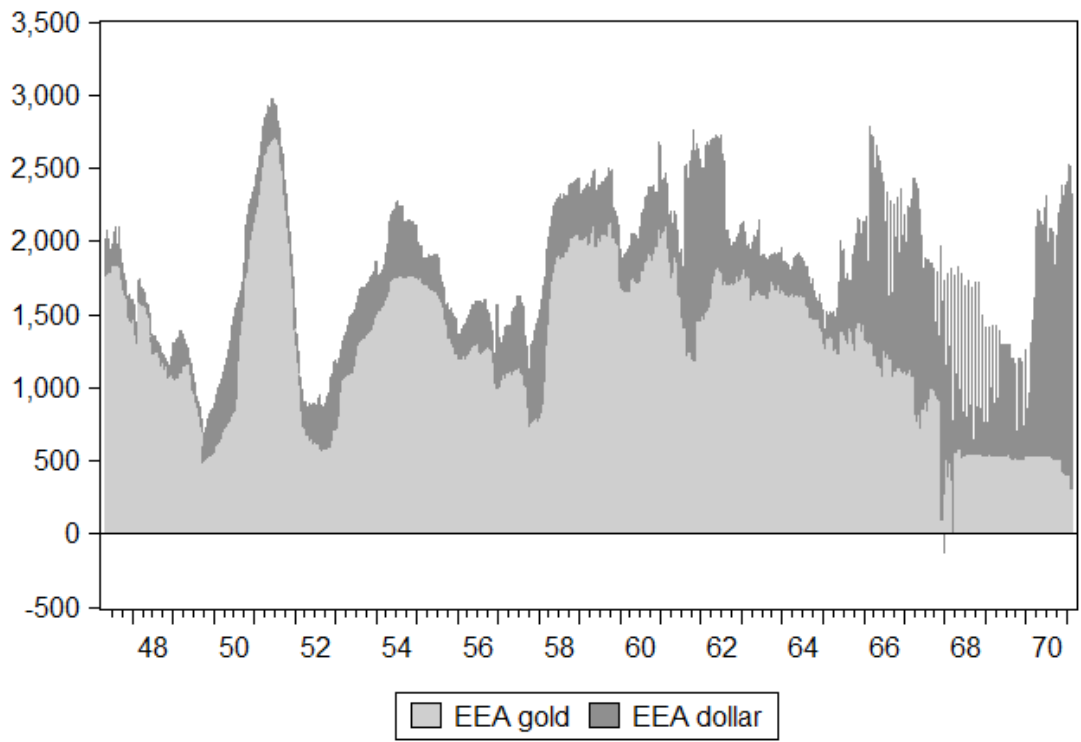


Figure 3: Exchange Equalisation Account gold and dollar reserves.

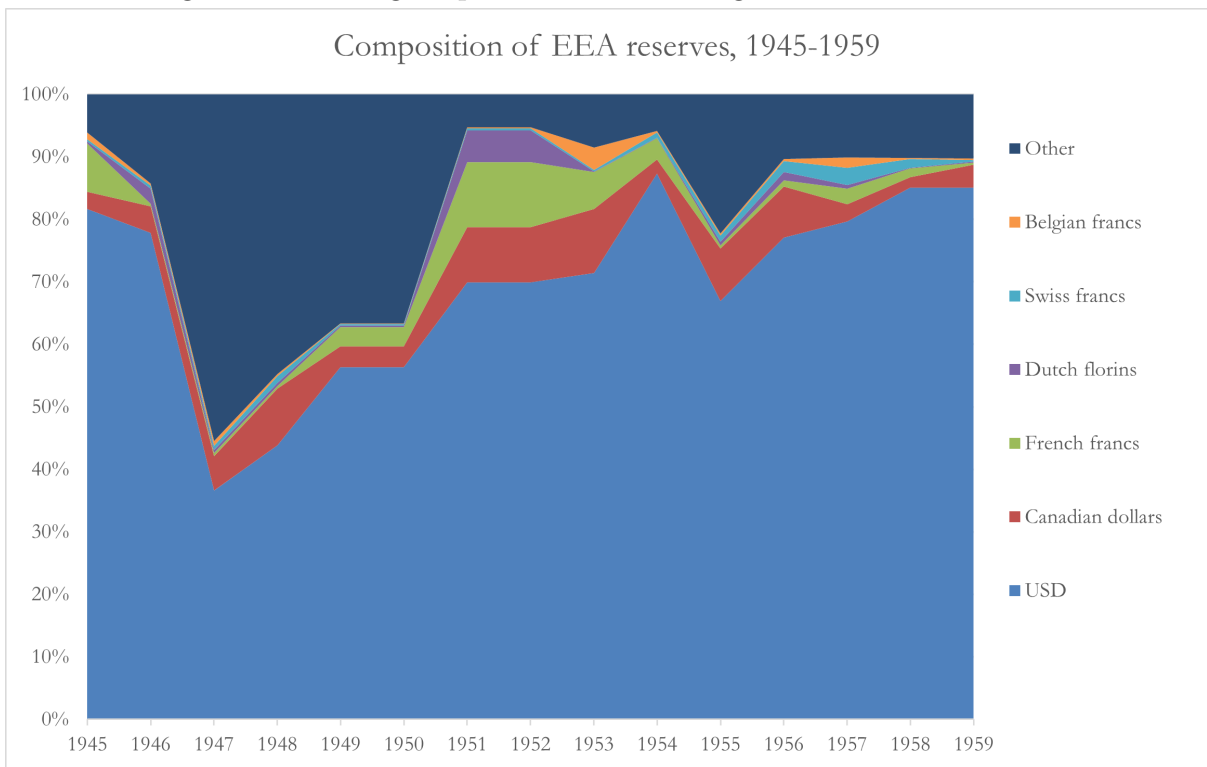


Figure 4: Relative importance of currencies in reserves of the Bank of England archives, reference T 233/2117.