An Early Experiment with "Permazero"[1]

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Abstract: We investigate a regime of persistent, near-zero policy interest rates ("permazero" in the terminology of Bullard 2015). This regime was implemented by a prominent early central bank, the Bank of Amsterdam (or "Bank") in 1683 and continued until the Bank's collapse in 1795. The Bank's policy rate, an administered lending rate, was fixed at one-half percent over this period for the most common type of collateral.

We employ archival data to provide a new reconstruction of the Bank's activities over 1736-1791. The data indicate that "permazero" worked well for long portions of the sample. This can be attributed in part to the Bank's open market interventions, which dampened fluctuations in liquidity arising from use of the Bank's lending facility.

The data also yield insights into episodes of major policy failures by the Bank. These are 1756-1763 (the Seven Years' War) and 1781-1790 (the Fourth Anglo-Dutch War and its aftermath). In the first instance, speculative inflows overwhelmed the Bank's ability to offset these through open market operations. This episode culminated in a Lehman-like financial crisis in late 1763. In the second instance, market participants abandoned the Bank's lending facility en masse, again overwhelming the Bank's defensive open market operations. This failure was followed by an attempted recapitalization of the Bank in 1791 and its full collapse in 1795.

This case study thus provides a mixed verdict on the sustainability of a "permazero" policy. On the favorable side, the Bank was able to maintain its policy for long periods through skilled quantitative balance sheet management. Less favorably, however, vulnerabilities in the Bank's policy were eventually put to test by large shocks, with adverse results.

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1. Introduction

The art of monetary policy has changed, quantitatively and qualitatively, since September 15, 2008. Post-Lehman economic weakness has led many central banks to push their policy rates close to, and in some cases, a bit beyond the zero lower bound. The prospect of a binding ZLB (or ELB) has also led central banks to engage in extensive asset purchases, as an alternative channel for implementing monetary policy. The resulting policy environment is often described as "unconventional" and temporary, but as it persists, a scenario of continued low policy rates has become empirically relevant for many economies. Increased chances of such an outcome (termed "permazero" by Bullard 2015) have in turn increased fears of collateral damage, including persistent below-target inflation and substandard growth on the one hand (see e.g., Bullard 2010), and inflationary surges on the other (e.g., Bassetto and Phelan 2015). Such fears are rejected by "Neo-Fisherians" (e.g., Cochrane 2016) who argue that the main consequence of keeping interest rates low will only be to anchor inflation rates at correspondingly low levels.

Can economic history contribute to this debate? Central banks' post-2008 policies are often described as "unprecedented," but few monetary phenomena are truly lacking in historical precedents. The central bank analyzed below, in particular, offers an extended case study of a perma-(near-)zero policy regime. The central bank in question, the Bank of Amsterdam (or "Bank") set its annualized lending rate at one-half percent in 1683, and maintained this rate up until its collapse in 1795. The Bank's commitment to this policy was unwavering, and there is no evidence that any change in this rate was ever contemplated over the period when it was in place. The Bank's money, known as the *bank florin* or *bank guilder*, was a dominant currency in much of Europe for much of this time, so this was a policy with substantial economic consequences.

This study uses data from the Bank's archives to reconstruct and analyze its balance sheet over 1736-1791, a sample that covers much of the low-policy-rate episode.[1] Analysis of the data shows that while the Bank did not vary its policy rate over this period, it was oftentimes far from passive. More specifically, Bank engaged in quantitative management

[1] This sample period is dictated by data availability. For details see section 4 below.

of its balance sheet in the form of frequent, large, and persistent rounds of open market interventions. Monthly operations of one to two million florins occur throughout the sample, and each such operation was roughly 5 to 10 percent of the Bank's size, equivalent in value to 9-18 metric tons of silver. The most extensive sequence of operations occurred over the 1750s, and these involved a monetary tightening on the order of 15 million bank florins or at least 6 percent of contemporary Dutch GDP, equivalent to about $1 trillion in modern U.S. terms. This is a modest intervention by post-2008 standards, but close to what the capacity of the Bank allowed.

What were the consequences of the Bank's policies? Modern-style macroeconomic indicators do not exist for the eighteenth-century Dutch Republic, but the data that do exist suggest a period of lackluster economic performance. Dutch output was, on a per-capita basis, probably the highest in Europe over much of this time, but available indicators suggest a stagnation or gradual decline in aggregate output (De Vries and Van der Woude 1997, Chapter 13). Reconstructed price indices indicate that inflation was virtually nonexistent over this period, averaging one-half percent annually or less (Van Zanden 2013).[2]

The Dutch Republic's stable prices did promote Amsterdam's role as a financial center, however. For much of the period we study, Amsterdam was home to the most liquid credit market in Europe (Gillard 2004, Flandreau et al. 2009, Carlos and Neal 2011, Dehing 2012). Payments activity through the Bank was correspondingly intense. Turnover in Bank accounts was about 388 million florins in the early 1760s (Dehing 2012, 82 and 140), equal in value to almost 4,000 tons of silver, or 1.5-2 times annual Dutch GDP. As a standard of comparison, an analogous ratio for the Federal Reserve (annual value of Fedwire payments/ U.S. GDP) comes in at 2.5 at the peak of the Bretton-Woods era (1955 figures from Bank for International Settlements 1980, 265). Such intensive use of central bank liquidity was made possible by the Bank's low policy rate.

Amsterdam's popularity as a financial center masked vulnerabilities in the Bank's policies, however, and our data reconstruction reveals how these weaknesses were tested by

[2] This low inflation rate can be in part attributed to the policies of the Bank, but also to a comprehensive 1694 coinage reform that reduced previous incentives for Dutch mints to debase the circulating coinage; see Polak (1998).

financial markets. Fiscal constraints imposed on the Bank by its owner, the City of Amsterdam, introduced a fundamental asymmetry into the Bank's operations. Easing was always possible, but the Bank's tightening operations were limited by the availability of collateral to sell into the money market. Binding collateral constraints are manifested as sudden halts in the Bank's open market operations, and these are particularly evident over 1756-1763 (the Seven Years' War) and 1781-1790 (the Fourth Anglo-Dutch War and its aftermath). Both of these periods witnessed policy failures on the part of the Bank. The first period was characterized by an unstable value of the Bank's money, an ensuing credit bubble, and ultimately a Lehman-like money panic (De Jong-Keesing 1939, Schnabel and Shin 2004, Quinn and Roberds 2015). The second period saw the Bank lapse into "policy insolvency" as a prelude to its collapse in 1795 (Van Dillen 1964b, Quinn and Roberds 2014b).

Our case study thus delivers a mixed message on the sustainability of low policy rates. On the positive side, skillful open market interventions by the Bank allowed it to maintain a near-zero policy rate over long periods without serious difficulty. Inflation remained stable over these periods, and bank credit provided at this rate demonstrably supported contemporary financial markets: sizeable amounts of such credit were dispensed by the Bank up until about 1780, and this credit matches or exceeds the Bank of England's discount credit over the first part of our sample.

On the negative side, however, the Bank's policy approach was not resilient to large shocks. The reconstructed data show how the Bank tried to, but could not contain the market pressures arising from wartime conditions experienced during the early 1760s and early 1780s. In the first instance, surging demand at the Bank's lending facility overwhelmed the Bank's ability to sterilize this credit creation. In the second instance, market participants abandoned the Bank's lending facility en masse, spawning another shock that the Bank could not offset, and ultimately rendering the Bank's policy rate irrelevant.

What implications does this eighteenth-century experience have for modern central banks? As will be explained below, the Bank of Amsterdam operated on a different model from modern central banks, so answers to this question must acknowledge the differences

between then and now. In place of today's monetary policy goals, the Bank's overriding policy goal was seemingly straightforward: to ensure a predictable metallic value for its money. Nonetheless, the key tradeoff faced by Bank would seem relevant for modern central banks. This was the difficulty in maintaining both a low policy rate and a stable monetary value in the face of large, unforeseen shifts in market sentiment. The shortcomings of the Bank's approach to managing this challenge remained hidden for decades, only to be quickly revealed in the face of disruptive events.

The rest of this paper is organized as follows. Relevant literature is surveyed in Section 2. Section 3 describes the structure of the Bank and explains how it implemented policy. Section 4 presents the data and Section 5 presents some descriptive econometrics. Section 6 concludes.

2. Connections to the literature

The analysis below draws on a large literature on the history of the Bank of Amsterdam, and particularly on contributions by Mees (1838), Van Dillen (1925, 1934, 1964a,b), Gillard (2004), and Dehing (2012). As in other work (Quinn and Roberds 2014a, b, 2015) we extend this literature by reconstructing the Bank's balance sheet for the sample considered.

<to be completed.>

3. The Bank of Amsterdam

The Bank of Amsterdam (*Amsterdamsche Wisselbank*) was a prominent early public bank, founded in 1609 and liquidated in 1820. The Bank was chartered and owned by the City of Amsterdam, and its main purpose was to provide a stable money for the settlement of bills of exchange drawn on Amsterdam merchants. This was a vital function at the time, since bills of exchange were the predominant form of short-term commercial finance, and, for much of the period we study, Amsterdam was home to Europe's largest and most liquid bill market.

A "stable money" in this era meant only one thing: that the money in question could be readily converted, at a predictable price, into coin with a high precious metal content. Following a 1683 policy change, however, the Bank's money evolved into a de facto fiat money, in the sense that it carried no inherent right of redemption: the metallic value of the bank florin was what the market determined it to be (see e.g., Van Dillen 1934, 1964a; Dehing 2012; Quinn and Roberds 2014a). As a publicly owned manager of a fiat money, the Bank was a true "central bank." The Bank was nevertheless able to maintain a stable value for its money by employing techniques that resemble those used by central banks today. These are described in the next section.

3.1 Basic structure of the Bank

Table 1 gives a stylized balance sheet for the Bank during our period of interest.

Table 1: Balance sheet of the Bank of Amsterdam (18th century)

Assets	*Liabilities + equity*
Coins under receipt (those eligible for repurchase) E	Account balances M
Unencumbered coins (not eligible for repurchase) U	Equity ε
Loans L	

Inspection of the table reveals some noteworthy differences between the structure of the Bank and that of modern central banks. The monetary liabilities (denoted M) of the Bank existed only as balances in Bank accounts, since the Bank never issued circulating currency. These accounts correspond to "reserve accounts" at modern central banks; every merchant bank and most large merchants in Amsterdam had such an account.[3] On the asset side, the bulk of the Bank's portfolio consisted of silver (and to a lesser extent, gold) coin rather than government securities favored by today's central banks. This was a practical choice for the time, since the Dutch Republic had no unified national debt (Gelderblom and Jonker 2011), and the government securities that did exist tended to be rather

[3] In principle anyone, not just banks, could open an account at the Bank. Deposit banking did exist but was underdeveloped in Amsterdam until the nineteenth century (Jonker 1996). In practice, accounts were used only by those parties likely to deal with bills of exchange: the very wealthy and public institutions. At its mid-eighteenth-century peak, the Bank maintained about 3,000 accounts as compared to Amsterdam's population of 200,000 (Dehing and 't Hart 1997).

illiquid (Van Bochove 2013). Following the Bank's own accounting system, we divide the Bank's holdings of coins into two categories, *E* and *U*, according to whether they were subject to options known as *receipts.*

3.1.1 The receipt window

Modern central banks commonly interact with financial markets via repurchase (repo) transactions. The Bank of Amsterdam employed a functionally similar interaction with the markets, through the issue of receipts. An account holder at the Bank who wanted to convert "trade coin" to bank money could sell the coin to the Bank at a posted official price, receiving in return 1) credit to his Bank account and 2) a receipt for the coin sold.[4] A receipt was, in modern terminology, an American call option on the type of coin sold (and no other coin) with an expiration date of six months after the sale, and a strike price slightly above the original sale price.

Take for example a transaction from February 25, 1737. Jan Albert Vos sold coins called *ryxdaalders* to the Bank, and this increased the Bank's account liabilities by 1,920 florins with a corresponding increase in assets. The transaction used the Bank's official value of the coins purchased; see Table 2 below.[5]

Table 2: Balance sheet effects of a sale of trade coins to the Bank

Assets	*Liabilities + equity*
+ 1920 florins in 800 encumbered *ryxdaalder* coins	+ 1920 florins in account balances

Source: Amsterdam Municipal Archives 5077/297 folio 1308 and AMA 5077/1378 folio 47.

Coins held in the Bank's vault that had outstanding receipts (denoted *E*) were in effect "encumbered," i.e., subject to exercise of the call option embedded in the receipt. For

[4] Trade coins were high-denomination coins with high precious metal content, e.g., Dutch *ryders* or Spanish pieces of eight. Such coins had special liquidity value as means of settlement in foreign markets where the Dutch Republic had persistent trade deficits, e.g., Asia (De Vries and Van der Woude 1997, 84). The market value of trade coins in Amsterdam tended to fluctuate in response to shocks such as the arrival of silver fleets in Spain or the outbreak of war.

[5] *Ryxdaalders* (a.k.a. rixdollars) were silver Dutch coins worth 2.4 bank florins each. The transaction involved four sacks of 200 coins each.

convenience we will sometimes refer to sales of trade coins against receipts as "deposits." These were not however deposits in the modern sense of generalized demandable debt claim against the Bank. Instead, such sales generated a negotiable claim against only a specific type of collateral, i.e., a receipt.

For silver trade coins that constituted the bulk of the Bank's receipt business, the "strike price" of a receipt was always one-fourth percent higher than the sale price. For a few favored domestic silver coins, this margin fell to one-eighth percent, and it rose to one-half percent for gold coins. Receipts were fully negotiable as bearer instruments and could be rolled over at the same cost as for redemption.[6]

The great majority of the time, the call option inherent in a receipt was "in the money," i.e., the price for repurchasing the coin listed on the receipt was below its market value, so that the receipt was eventually redeemed. The function of a receipt was thus much like a modern central bank (term) repo, providing liquidity to the money market against liquid collateral at a policy interest rate.[7] From the beginning of the receipt system in 1683, the Bank's implied policy interest rate was simply the redemption fee of *one-fourth percent per six months, or about one-half percent annualized.* Such a low rate was feasible because inflation during this period was effectively zero, and the quality of the collateral involved (trade coins) was such that the issue of receipts entailed little risk to the Bank.

Despite the parallels, there are also some noteworthy differences between the receipt system and modern central bank repos. One is that the policy interest rate inherent in the receipt system was an administered rate rather than a target for market rates, as is preferred by many central banks today. In modern terminology, the receipt system was a "standing facility" whereby the Bank offered as much credit as the market demanded. One reason for this structure seems to have been that there was no corresponding private market, because only the Bank was able to issue receipts *qua* call options on trade coins. The exact

[6] Contemporary accounts of the Amsterdam money market, such as those found in Le Moine de L'Espine and Le Long (1763) and in *The Wealth of Nations* (Smith 1937) describe an active secondary market in receipts. Unfortunately very few records of such transactions survive.

[7] The use of the Bank's receipt window as a form of repo liquidity is described at length in a popular eighteenth century trading manual for Amsterdam merchants (Le Moine de L'Espine and Le Long 1763, 197-202; see Appendix C). This is an eighth edition of a book that was originally published in 1694, which suggests that such use of receipts was a well-established practice over our sample.

reasons for this are unclear. Mees (1838, 136-140) suggests that the receipt contract placed the Bank in an extremely strong position as a creditor, meaning that it could always hang on to coins whose receipts had expired. This was a privilege that Amsterdam may have only been willing to extend to a prestigious public institution.

Another difference between the receipt transaction and modern repos is that the second "leg" of the transaction was structured as an option that expired after six months if not exercised or rolled over. Since receipts were usually "in the money" and could be easily traded in the secondary market, expirations were relatively rare. There are however a number of instances in our dataset where for example, the value of certain coins was reduced, so that their receipts went "out of the money" and market participants allowed these receipts to expire. In such instances, the trade coins in question lost their encumbrance and became owned by the Bank. Since a receipt was just an option to exchange Bank money for coin, expiration of a receipt had no effect on the stock of Bank money.

3.1.2 Operations in unencumbered coin

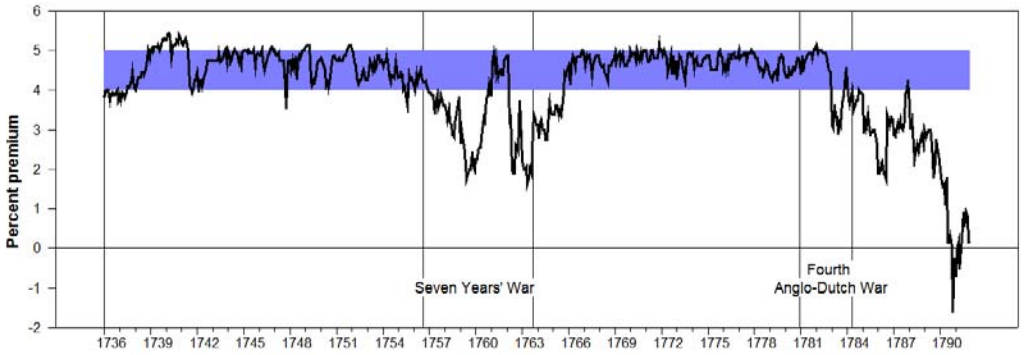
Another way for Amsterdam merchants to acquire Bank funds was to purchase them from people with accounts at the Bank. This was often done through brokers who were active in a secondary market that took place every morning in front of the Bank. In this market, circulating coins could be converted to bank florins and vice versa, at bid-ask spreads of one-eighth percent or lower.[8] Circulating money was denominated in a separate unit of account known as the *current florin* or *current guilder*. The market price of bank money was recorded as an *agio* or premium of bank florins over current florins, i.e., a price of 1.05 current florins per bank florin was recorded as an agio of five percent. As a shorthand, we will use "florin" for bank unit of account and "guilder" for current unit of account. The notation a_M will be used to denote the market agio.[9]

[8] This market was also used by merchants without a Bank account to trade bank florins through specialized brokers.

[9] In pre-Napoleonic Europe it was fairly common for the unit of account of a public bank to become decoupled from that of locally circulating money. Hamburg and Venice were two other cities where such separation became a long-lasting feature of the monetary environment; see Roberds and Velde (2016). Recently there have been some proposals to similarly separate the units of account for circulating currency and funds

Figure 1 plots monthly values of a_M from January 1736 to December 1791. The agio stays between four and five percent for most of the sample except during the Seven Years War (1756-1763), and during the period of the Bank's decline from the Fourth Anglo-Dutch War (1780-1784) onward.

Figure 1: Market agio, 1736:1-1791:12
(Percent premium bank florin over current florin)



Sources: Gillard (2004) and Schneider, Schwarzer, and Schnelzer (1991). The shaded band represents the Bank's unofficial target band. The Seven Years' War period is taken as August 1756 (the first Prussian campaign of the war) through July 1763 (the outbreak of the postwar financial panic in Amsterdam). The Fourth Anglo-Dutch War period is taken as December 1780 (declaration of war) through May 1784 (signing of the Treaty of Paris).

The Bank routinely intervened in this secondary market, buying and selling large quantities of coin at the going market price (rather than at an official price as with the receipt window), in the same way as modern central banks buy and sell securities in open market transactions. No receipts were granted for these "outright" transactions, which during our era of interest were often conducted in small-denomination coins with one-guilder face value called *gulden*. These were not considered trade coins and were ineligible for the receipt window. The Bank's purchase operations, together with trade coins whose receipts had expired, gave rise to a stock of unencumbered coin U in the Bank's vault.

For an example, we return to 1737. On March 15, the Bank purchased 25,945.375 current guilders (in the form of *gulden* coins) from Arnoud Borchers at an agio of $3\frac{15}{16}$ percent. Borchers got 25,000 bank florins with a corresponding increase in coin held by the Bank

in central bank accounts, as a way of circumventing ZLB constraints; see e.g., Agarwall and Kimball (2015) or Goodfriend (2016).

(see Table 3). To simplify accounting, purchased coin was carried on the Bank's books at a fixed agio, usually five percent. Any difference between this value and the market value of coins bought or sold was resolved through a one-time adjustment to the Bank's equity. Purchased coins were not "marked to market." Coin acquired by the Bank in this fashion was not subject to receipt claims and could be readily sold back into the market.

Table 3: Balance sheet effects of a purchase of one-guilder coins by the Bank

Assets	*Liabilities + Equity*
+ 24,709.875 florins in 25,945.375 unencumbered *guldden* coin	+ 25,000 florins in account balances -290.125 florins in equity (loss from adjusting to a 5 percent agio)

Source: AMA 5077/1378 folio 44.

As noted above, the Bank also occasionally acquired unencumbered coin through the expiration of receipts. Such expirations did not change the stock of the Bank's money, but only shifted the stock of its assets from one category (encumbered) to another (unencumbered).

3.1.3 Loans

The Bank's charter excluded it from making loans—other than granting credit through the receipt window, which was not considered lending. In practice, however, the Bank routinely engaged in lending activity throughout its existence. The great bulk of the Bank's loans were made to two privileged borrowers, the Dutch East India Company ("Company", also known by its Dutch initials VOC) and the City of Amsterdam ("City"). The differences in how the Bank accounted for the two types of loans is indicative of the political economy within which the Bank operated.

The Company frequently borrowed balances on short-term from the Bank against unsecured notes known as *anticipations*, which were to be repaid by the sale of goods in transit from Asia to the Netherlands. These and other loans to the Company show up in the Bank's balance sheet as increases in loan assets (denoted *L*) and increases in account

liabilities *M*. For example, a March 13, 1737, loan of 100,000 florins to the Company increased the stock of Bank ledger money by the same amount (Table 4). Such short-term borrowing allowed the Company to outfit one year's trading fleet and pay out dividends to its stockholders, while awaiting the return of a previous year's fleet. Interest on such loans was an important source of income to the Bank (Uittenbogaard 2009), and most of these loans appear to have been granted automatically, on an as-needed basis.

Table 4: Balance sheet effects of a loan to the East India Company

Assets	*Liabilities*
+ 100,000 florins in loan principal	+ 100,000 florins in account

Source: AMA 5077/297 folio 1503

Since the City owned the Bank, its status as a borrower was different from the Company's. Until the 1780s, loans extended to the City carried no interest, were operationalized through the removal of unencumbered coin *U* from the Bank's vault. These had no direct effect on the amount of bank florins outstanding. The City attended to these "loans" when and how (write-down or repay) it wanted, so they functioned as adjustments to the Bank's equity (denoted *E*), similar to when the City took the Bank's residual profits as a seigniorage dividend. If such loans are treated more realistically as takings (and recapitalizations when repaid), then the Bank had negative equity for the entire sample studied.[10]

City loans enter this paper's sample of account transactions only when the City began to borrow bank balances in 1782. The City directed most of these new bank florins to a new municipal lending agency (*Stadsbeleeningkamer* or "loan chamber") that the City used to disperse loans to individuals.[11] The loan chamber did reliably repay the bank with 2 per-

[10] Negative equity is not unheard of for central banks, which as a rule tend to be thinly capitalized (see Archer and Moser-Boehm 2013 for a survey of central bank accounting). A more valid indicator of a central bank's health is usually given by its *net worth*, which is its equity augmented by the "franchise value" of discounted future seigniorage earnings (see e.g. Fry 1993, Stella 1997, 2005, Stella and Lönnberg 2008, Del Negro and Sims 2015). The net worth of the Bank of Amsterdam was positive until about 1780.

[11] The City also experimented with repaying loans to the city treasury with interest. In 1783, the City repaid with interest 800,000 of a 1.4 million-florin line of credit. Then the City gave up the effort, and its remaining 600,000-florin loan balance became permanently non-performing.

cent interest, but the chamber continuously re-borrowed to do so. It is unclear whether the Bank was even permitted to ration the supply of credit to the chamber.

3.2 Mechanics of policy implementation

As a conceptual device, it is convenient to think of the Bank's balances as an amalgam of two institutions, one stable in value and the other not. The stable-value portion of the Bank consisted of account balances that were matched by trade coins held under receipt. This was a 100 percent reserves institution, and people could undo these balances at any time through the execution of receipt options. The market for receipts allowed for the easy reallocation of the right to redeem balances. In contrast, accounts with no corresponding receipt had only fractional metallic backing. Those balances could not be withdrawn, but their price (the agio) could be bid down. As a result, the first part of the Bank was stable when the market supplied consistent funding to the Bank via the receipt window, and the second part was stable when the agio was level over time.[12]

This device allows us to (conceptually) divide the Bank's account liabilities *M* into those fully backed by coins under receipt M_E and the others M_U, which are fractionally backed with no right of redemption:

$$M = M_E + M_U$$

Our decomposition modifies the Bank's balance sheet as shown in Table 5. "Encumbered" account balances M_E are identically equal to coins under receipt *E*. The remaining account balances M_U are assigned to a fractional reserve bank offering fiat monetary liabilities. As an accounting identity, these balances plus the bank's equity must be matched by the Bank's unencumbered coin plus its loans:

[12] This structure somewhat resembles that of the Bank of England following the passage of Peel's Act in 1844. Peel's Act famously split the Bank of England into Banking and Issue departments, constrained the banknote issue of the former, and enforced a 100 percent marginal metallic backing requirement for notes issued by the latter (Clapham 1970). Our decomposition, unlike Peel's, is purely conceptual since the Bank's ledgers never distinguish between "backed" and "unbacked" balances. Another major difference is that the right to redeem the Bank's money was always bound to the receipts issued by the Bank, rather than to the Bank's money itself.

$$M_U + \varepsilon = U + L$$

The Bank did not divide balances this way because no individual account was "encumbered" until that account holder used a receipt to withdraw coins. Yet acknowledging that a portion of accounts were subject to receipt redemptions allows us to identify both the level of liabilities that could be withdrawn on demand and, by definition, the level of the Bank's market funding under its permazero policy.

Table 5: Subdivided balance sheet of the Bank of Amsterdam (18th century)

Assets	*Liabilities + equity*
Coins under receipt E	*Fully Backed Portion* "Encumbered" account balances (redeemable on demand) M_E
Unencumbered coins U Loans L	*Partially Backed Portion* "Unencumbered" balances (no right of redemption) M_U Equity ε

The discretionary policy operations of the Bank consisted of its sales and purchases of its unencumbered metallic assets in the daily, secondary market for bank money. The Bank's charter contained no guidance as to how such transactions should be carried out, and indeed it is not clear that the Bank ever had formal legal authority to conduct its open market operations. The extent of these transactions, like the other details of the Bank's balance sheet, was never public information. Given their often massive size, however, the existence of these operations must have been known to market participants and at least informally sanctioned by the City.

The Bank could use these transactions to offset fluctuations in the stock of Bank money arising from the "autonomous factors" of demand at the receipt window and the credit extended to the Company. An upsurge in receipts, for example, could be offset with a sale of *gulden* coins, leaving the net stock of bank florins unchanged. Under this scenario, participants in the Amsterdam money market would then have temporarily swapped one form of highly liquid collateral (trade coins) for a perhaps slightly less liquid form of collateral (say, *gulden* coins). Similar situations occurred when the Bank sterilized inflows

of silver coins into the receipt window with sales of gold coins. These scenarios may be compared to situations, say, where a modern central bank offsets liquidity created via repos in one class of assets by outright sales of another.

Benchmark results such as Wallace's (1981) Modigliani-Miller theorem raise the question of why the Bank's open market operations might have mattered for market allocations. One answer to this question may be found in the different liquidity values associated with various types of coin. Gold and large-denomination silver coins were preferred in large-value transactions in distant markets, while the small-denomination coins such as the one-guilder *gulden* coins were more useful in local, everyday commerce. Changes in market price of gold and silver would also have impacted market preferences. Directly converting one coin to another would have entailed mint charges of around one percent in each direction (for silver coins, see Polak 1998) as well other transaction costs. Use of the receipt window and the Bank's compensating OMOs allowed the market cheap access to its preferred form of collateral.

At a somewhat deeper level, the Bank's open market interventions mattered because they shifted the relative size of the fully backed (stable-value) and fractionally backed (fiat) portions of the Bank: open market purchases increased the size of the latter and increased the Bank's stock of unencumbered coin, which then became subject to seizure by the City. Recent theoretical findings (Sims and Del Negro 2015, Benigno and Nisticò 2015) suggest that these shifts might have been less consequential if the Bank had enjoyed full fiscal guarantees from the City. In practice, however, the fiscal relationship between Bank and the City was highly exploitative and the extent of the Bank's fiscal backing was ambiguous. Eventually, at the very end of our sample in 1791, the City opted to inject capital into the distressed Bank (Quinn and Roberds 2014b). By this point, however, the Bank's international reputation had been largely destroyed.

3.3 Policy constraints

The Bank's first and foremost policy goal was to maintain a stable value for its money; indeed this was the reason that the Bank came into existence in the early seventeenth cen-

tury. The universally acknowledged barometer of the bank florin's monetary value was the market agio. While an explicit "target band" for the actual, secondary market agio is not mentioned in the Bank archives until 1782 (Van Dillen 1925, 433-434) policies adopted by the Bank appear to have kept the market agio within its implicit band over the stable periods of our sample. Since the metallic content of Dutch silver coinage was largely constant during this time, a stable agio also implied a stable metallic value for the bank florin. The Bank however never formally committed to an agio "peg," in a modern sense.

The target level derived from the coinage laws of the Dutch Republic. Each domestic trade coin *C* had an implicit agio a_C, defined by

$$a_C = 100 \times \left(\left(\frac{\text{legal value of } C \text{ in current guilders}}{\text{legal value of } C \text{ in bank florins}} \right) - 1 \right)$$

For example, ordinances declared that the *ryxdaalder* coins deposited by Mr. Vos in Table 2 to be worth 2.5 current guilders each outside the Bank, versus 2.4 florins within the bank.[13] Acquiring *ryxdaalder* coins and then depositing them created an implicit agio of $a_{ryxdaalder} = 100\left(\left(2.5/2.4\right)-1\right) = 4.167$ percent. Each trade coin had a slightly different implicit agio because bank florin and current guilder values varied slightly (see Polak 1998). These implicit agios formed a natural target range of 4 to 5 percent because they acted as an anchor.

To connect the elements of Amsterdam's monetary system, Table 6 summarizes the relationship between balances in the Bank and two forms of money outside the Bank: *gulden* coins and trade coins. The latter two monies each have their own channels to Bank money, i.e., the receipt windows (for trade coins) leading to the fully backed portion of the Bank and the agio spot market (for *gulden*) leading to the partially backed portion. To connect the monies outside the bank, the table adds the exchange of trade coins for current guilders. People could route current guilders through trade coins to realize an implic-

[13] A coin's market price could be even higher if the value of the coins' silver content was sufficiently above the ordinance value.

it agio and create a specie-flow process. For example, a high market agio relative to a coin's implicit agio encourages sales of trade coins (discourages receipt redemptions) that increase the stock of bank florins and push down the agio.[14] As with other specie-flow examples such as the classical gold standard, these incentives can prove weaker than the other reasons people exchange money. Still, the anchoring effect of implicit agios helps explain why the Bank apparently targeted market agios between 4 and 5 percent.

Table 6. Relationship of different monies within Amsterdam

Monetary instrument (unit of account)	Bank balances (bank florins)	*Gulden* coins (current guilders)	Trade coins (florins/guilders)
Bank balances (bank florins)		Open mkt. operations (*current guilders/ bank florin*)	Receipt window (*bank florins/ trade coin)*
Gulden coins (current guilders)	*		Ordinance values *(current guilders/ trade coin)*
Trade coins (florins / guilders)	*	*	

The structure of receipts complicated the anchoring process. A market agio below range of the implicit agios encouraged receipt redemptions, but one had to have a receipt to take advantage. Receipts could be purchased from other people, so Dehing (2012, 124-6) argues that receipt prices had an inverse relationship to the market agio. While there is insufficient data to confirm the strength of this relationship, paying more to acquire a receipt (or forgoing the sale of the same) reduces the gains from using receipts. Similarly, the ability to sell a valuable receipt undermines the disincentives to sell trade coins to the Bank when the agio is low. In contrast, receipts have little value when the agio is above the target range, so incentives are less affected. In the extreme, receipts could have so little value that people do not pay to roll them over. As a result, the anchoring properties of the system are asymmetric, stronger for agios above the target than below.

The connections in Table 6 also mean that Bank operations could alter receipt window behavior. Open market operations act directly on the level of bank florins to pressure the

[14] There is a parallel here with a famous proposal by Merton Miller (1998), that Hong Kong stabilize its currency through the issue of securities with embedded put options. The Bank of Amsterdam's receipts operationalized Miller's proposal some three centuries earlier.

market agio a_M, but changing a_M also alters its relationship with each trade coin's implicit agio a_C. A stronger (weaker) a_M increases (decreases) incentives to use the alternative channel of the receipt window to acquire bank money. Such feedback mitigates the response to quantitative easing, and it does so by altering the encumbered portion of the Bank.

The centrality of an exchange rate (the market agio) in the Bank's operations invites a comparison to more recent monetary institutions, e.g., the central banks that operated under the classical gold standard, or modern central banks operating under an exchange rate peg. Such comparisons have some validity, since eighteenth-century Amsterdam had no capital controls, and the Bank was, like these institutions, fully subject to the stresses of the Mundell-Fleming "impossible trinity." One key factor that distinguishes the Bank of Amsterdam from these later examples is the Bank's approach to managing the trilemma, which was wholly restricted to quantitative operations. A modern central bank would be reluctant to adopt such an approach, particularly in light of unfavorable twentieth-century experiences with fixed exchange-rate regimes (see e.g., Bordo and James 2014). The Bank of Amsterdam, by contrast, seems to have been largely unconcerned until close to the end of its existence.

One reason for this lack of concern may have been incomplete understanding. The idea that a central bank should manipulate its policy interest rate in order to manage its exchange rate was not well developed at the time: the Bank of England, to cite another contemporary example, moved its policy rate (the Bank Rate) only a few times in the eighteenth century, and then only within a relative narrow range of 4-6 percent (Homer and Sylla 2011, Table 14).[15] A second reason for the Bank's relative indifference to the trilemma may have been the relative informality of its commitment, which meant that the Bank could tolerate some volatility in the agio during periods of stress. This accords with modern central banking experience, in the sense that central banks that enforce looser ex-

[15] A preference for quantitative balance sheet management seems to have persisted up to the early twentieth century. Sayers (1970, 1976) and Ugolini (2015), for example, show that during the period of the classical gold standard, the Bank of England relied heavily on open market operations, and preferred to change its Bank Rate only when OMOs proved insufficient.

change rate pegs tend to enjoy more monetary autonomy (Klein and Shambaugh 2015). Finally, contemporary descriptions of the Bank express faith in the receipt window as an anchoring mechanism, with any deviations from the official value of the agio seen as being subject to corrective specie flows.

Ultimately the receipt window proved vulnerable to two modes of speculative attack. In the first form of attack, pessimistic receipt holders (including people who had purchased receipts on the open market) could simply redeem their receipts *en masse*. This occurred over 1781-1783 when people feared the Bank might renege on receipt obligations. The Bank could (and did) attempt to sterilize the resulting monetary contraction through open market purchases, but doing so drastically increased the relative size of the fractionally backed portion of the Bank. Restoring the credibility of the restructured Bank then required a sizeable capital injection, which the City was reluctant to provide.

Our data suggest that the Bank was subject to a second and subtler form of speculative pressure during the Seven Years' War (1756-1763). At that time, market participants apparently retained faith that the Bank would honor receipt obligations. However participants with a negative outlook for the bank florin found it attractive to sell trade coins to the Bank through the receipt window. The proceeds could then be used to purchase foreign currency (bills drawn on foreign markets), in anticipation of a depreciating value for the florin. The receipts granted by the Bank would then have functioned as put options on the domestic value of the bank florin, ensuring that the receipt window remained popular even though the market agio was low (see Appendix C for some illustrative calculations). The resulting inflow of trade coin through the receipt window then tended to increase the stock of Bank money, exerting further negative pressure on the bank florin and reinforcing negative market sentiment. Volatility of the agio also increased at this time (see Appendix B), which would have worked to increase receipts' value. To defend against the weakening of the florin in foreign and domestic markets, the Bank lacked the option of

raising its policy rate. It could however sell unencumbered metal into the market, but such activity could not always be sustained.[16]

Another complicating factor was the changes in the price and quality of coins. In the seventeenth century, debasement of silver coins created dramatic challenges for the Bank (Quinn and Roberds 2007). In the eighteenth century, the value and quality of Dutch silver coin had become very stable, but gold coins had not. Dutch gold coins circulated at values that varied with the price of gold, and this price could vary sharply over the short term. These forces brought waves of gold into the Bank's window. In the extreme, the receipts for gold coins became "out of the money," and people abandoned their right to withdrawal. Under this scenario, significant amounts of gold fell into the outright ownership of the Bank, creating stocks of unencumbered gold coin for the Bank to manage.

4. Data

To examine the history of the Bank's market, its policy operations, and their interactions, we reconstructed each transaction that altered the amount of bank florins from January 1736 through December 1791.[17] Records of these transactions exist because the Bank was owned by the city of Amsterdam, and the city maintains the ledgers in its municipal archives. We begin in 1736 when the Bank simplified its internal accounting processes, and end with the last year with complete records. The Bank maintained meticulous double-entry records, so the Bank's master account contains the relevant transactions, a total of 73,479 entries.[18]

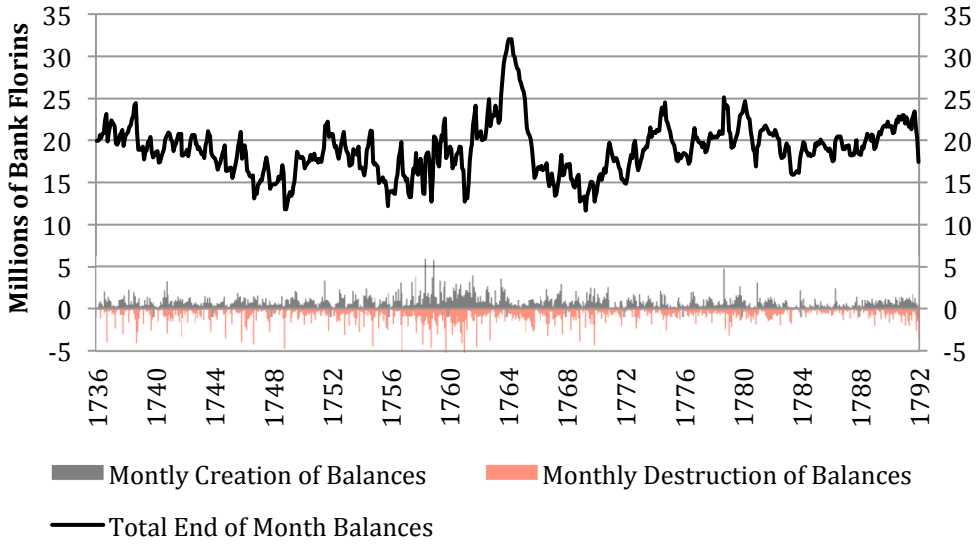
[16] The market pessimists' fears were confirmed in early August 1763, when the market agio briefly fell below zero following the failure of a prominent merchant bank (De Jong Keesing 1939, 165). The Bank responded by declaring unminted silver bullion eligible for the receipt window, although at a steep haircut. This policy response shored up the liquidity of market participants, broke the negative psychology of the panic, and allowed the agio to recover to its normal range (Quinn and Roberds 2015).

[17] The Bank was closed for several weeks each January to reconcile account activity over the previous year, so these records encompass "banking year" data over 1736-1791.

[18] The master account was called the *specie kamer* ("coin room"), and we photographed those account folios within dedicated ledgers (AMA 5077/1338-1349) when available, or else within regular ledgers or *grootboeken* of the Bank (AMA 5077/192-609). This master account may be compared to the System Open Market Account at the Federal Reserve and analogous accounts at other modern central banks. A portion of this data (1781-1792) was employed in an earlier paper (Quinn and Roberds 2014b).

Aggregating to the month, Figure 3 gives our construction of the total level of account balances along with the amounts added and subtracted over 673 months. In terms of the balance sheet (Table 1), this is the level and monthly changes in the Bank's total monetary liabilities *M*, and that level is stable over long periods of time. The series stays between 15 and 25 million florins for 88 percent of the months. The only major deviation is the peak surrounding the crisis of 1763. This stability is in no small part explained by active policy on the part of the Bank, but to see that we must disaggregate by the purpose of each transaction.

Figure 2. Level of monetary liabilities, monthly from 1736:1-1792:1



Source: Amsterdam Municipal Archives and authors' calculations.

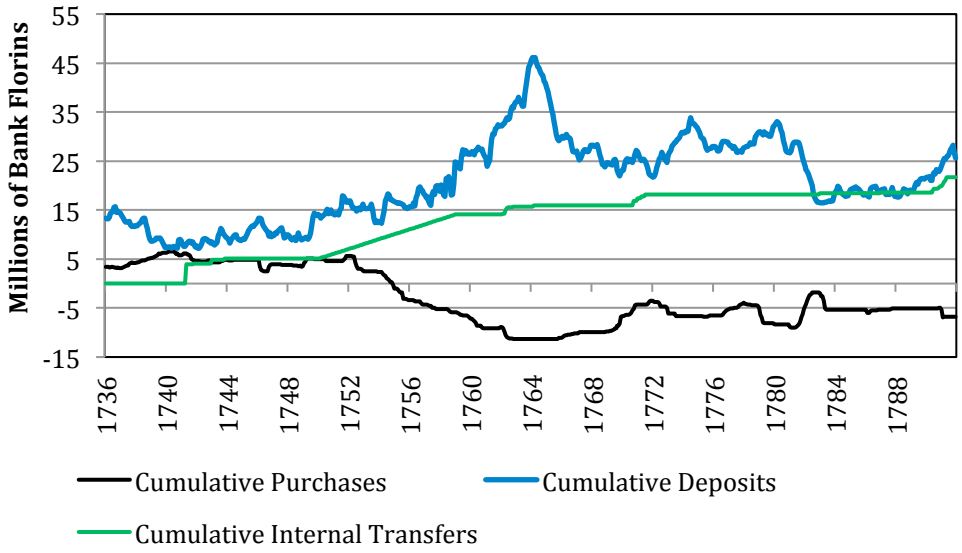
The Bank's account ledgers, while informative, do not detail the other side of these transactions, i.e., whether changes in Bank balances stem from a deposit/withdrawal (i.e., a change in encumbered coin *E*), a loan/repayment (change in *L*), a purchase/sale (change in *U*), or an adjustment in equity ε such as from fees and interest payments. That information mostly resides in another set of books that records flows of metal and related fees.[19] Referring again to Bank's balance sheet in Table 1, these "cash books" track changes in coins on the asset side of the balance sheet. Through the arduous reconciliation of the two sets, it is possible to identify coin-related changes in monetary liabilities

[19] These ledgers are called *kasboeken* ("cash books": AMA 5077/ 1355-1387). They do not detail transactions unrelated to metal such as loans and transfer fees.

and to further subdivide those into changes in balances encumbered by receipts and those unencumbered. In other words, monetary liabilities can be separated into the two constituent parts of the Bank of Amsterdam suggested in Section 3: accounts fully-backed by coins under receipt and accounts back by fractional reserves owned outright by the Bank.

The cash books are available from 1736 through 1791, with gaps. Some years (1747-1760) lack a cash book, so we deploy filters using regularities identified from the years that we do have. Appendix A details how we did this and our robustness checks. Other years (1738, 1742, 1778, and 1780) lack complete account ledgers, so we derive account transactions from cash books. Fortunately, all years in our sample have either an account ledger or a cash book, so it is possible to construct a continuous and generally accurate record of the Bank's operations.[20] Figure 3 provides an overview of this reconstruction.

Figure 3. Cumulative balances from net purchases and from net deposits, 1736:1-1792:1



Source: Amsterdam Municipal Archives and authors' calculations.

The figure shows an estimated series of cumulative account balances generated by net purchases, starting at the Bank's level of unencumbered accounts in January 1736. This line is *not* the level of metal *U* owned outright by the Bank. For example, most years the

[20] An earlier paper (Quinn and Roberds 2014a) decomposes the Bank's seventeenth-century ledgers using a "Furfine" algorithm, which necessarily results in misclassification of some transactions. The techniques used here are more accurate in general and almost error-free for years in which complete records exist; see Appendix A.

Bank engaged in operations to acquire coin outright. The Bank then used the coin to pay its annual dividend to the City. The purchases are recorded here, because they created bank florins. The dividend payments are not, because they did not destroy bank florins. On the balance sheet, the dividends were offset by reductions in equity. This figure only reconstructs changes in the Bank's monetary liabilities.

The purchases series also shows that the Bank engaged in large open market operations, but the activity was nonlinear. Monthly operations of one to two million florins (5 to 10 percent of the Bank's balance sheet) are spread throughout the sample. Also, two purchasing operations of about 7 million occur around 1770 and again around 1781. Dominating the series, however, is a sequence of sales operations that collectively unloads 15 million florins' worth of metal from 1752 to 1761. Taken together, these would have been equal to at least 6 percent of contemporary Dutch GDP (≈ 260 million bank florins in the more prosperous year of 1742; see De Vries and Van der Woude 1997, 702). This pattern poses a puzzle: why and how did the Bank sell off nine million more than its already substantial stock of purchased metal?

The "how" of this puzzle is explained by the fact that in 1741 and during the 1750s, the Bank came to possess a great deal of unencumbered gold with which to conduct open market sales: 14 million florins' worth of gold that it did not buy outright. Instead, the gold had been sold to the Bank through the receipt window, and then the receipts expired. In contemporary parlance, the gold "fell into the Bank." This means that gold coins moved balance sheet categories from assets under receipt to assets owned outright, and the corresponding monetary liabilities shifted from being encumbered by a receipt to being unencumbered. The shift did not change the overall level of bank florins. Figure 4 shows this process of cumulative internal transfers.[21] The series is a stair step in the 1750s because we lack the guidance of cash books for those years. Instead, we distributed the overall change evenly among the years in question.[22] This pace does supply the Bank

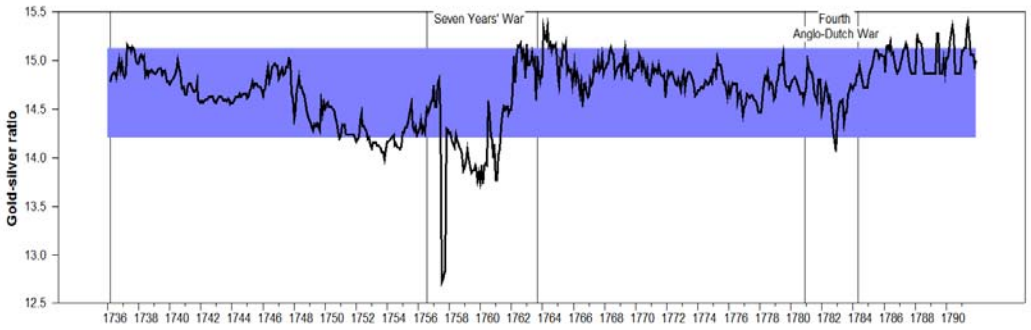
[21] Even with the cash books, the Bank rarely documented exactly when coins "fell" into the Bank. Instead, the change in status from under receipt to outright ownership has to be deduced. For example, in 1741, 3.9 million in Dutch gold *ducatons* became owned by the Bank. The last receipt was paid April 12 and the first open market sale was May 4, so we date the fall as May 4.

[22] We are currently in the process of reconstructing an accurate series for internal transfers over this period.

with enough gold to meet the volume of open market sales.

People may have deposited so much gold during this period because the price of gold fell to the lowest levels of the eighteenth century (Nogués-Marco 2013, 471). We lack a gold price series for Amsterdam, but a gold-to-silver ratio for Hamburg, one of Amsterdam's close trading partners, is indicative.[23]

Figure 4. Hamburg Gold-to-Silver Ratios, 1736:1-1791:12



Source: Authors' calculations from contemporary financial publications (*Preis Couranten*) held in the Hamburg State Archives; see Appendix B for details. These data were generously shared by François Velde. The shaded band shows the arbitrage bounds derived by Nogués-Marco (2013).

Figure 4 plots the Hamburg ratio over our sample period, and it fell to lows between 1750 and 1760. Two direct observations are available for Amsterdam prices of a domestic gold trade coin accepted by the Bank, the gold *dukaat.* These prices, for July 1750 and November 1751, produce ratios of 14.45 and 14.52 that are similar to Hamburg's 14.51 and 14.23 respectively.[24] The low ratios observed in the 1750s tended encourage the minting of "cheap" gold, and production of gold coins by Dutch mints surged at this time (Polak 1998, 103-64).

An alternative way to exploit low gold prices would have been to sell coins to the Bank. Figure 5 shows that over 1750-1752 and 1757-1758, the Bank overvalued the *dukaat*, which would have encouraged gold inflows. In both cases the Bank eventually responded

[23] This series is derived from contemporary financial publications (*Preis Couranten*) held in the Hamburg State Archive, generously shared by François Velde.
[24] The first observation from the *Opregte Groninger Courant* is on July 11, 1750, for 5.15 current guilders per gold *dukaat*. That produces a ratio of 14.45: as 5.15*70.99 coins per mark fine/25.3 current guilders per mark fine of silver *guldens* (Polak 1998, 67, 76). The last observation is November 12, 1751, for 5.175.

by slightly devaluing the *dukaat*, in May 1750 and again in July 1758). This would have caused receipts on *dukaten* already sold to the bank go even farther out of the money, effectively stranding these coins at the Bank.

Figure 5. Amsterdam Prices of a Gold *Dukaat*, 1736:1-1791:12

Sources: Amsterdam Municipal Archives; Hamburg State Archives; Schneider, Schwarzer, and Schnelzer (1991). Amsterdam "market prices" are Hamburg prices converted at the sight exchange rate.

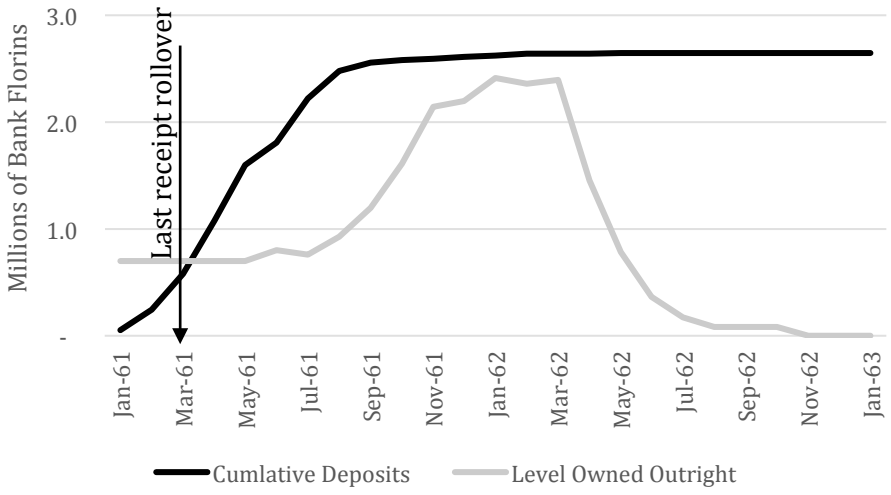
The "why" of the Bank's massive sale at this time may be an effort to offset expansionary effects of rapid deposit growth. To see this, note that Figure 3 starts with the level of account balances encumbered by receipts in January 1736. The series then adds deposits matched by a receipt and subtracts similar withdrawals to generate a level of cumulative net deposits. This series does is not adjust for internal transfers, but one can see the approximate level of encumbered accounts as the difference between deposits and internal transfers.[25] The 1750s saw net deposits increase by about the same 15 million florins that the Bank sold. Circumstances thus suggest that the Bank sought to sterilize the deposit inflow.

Figure 6 details this process for a period when the cash books exist. The figure plots the process of gold deposit, abandonment, and sale during 1761 and 1762. The story begins in early 1761 when 2.5 million bank florins' worth of Dutch gold *dukaten* surged into the Bank, encouraged by a dip in gold prices. The cumulative deposits of gold *dukaten* start at zero in January 1761. The rapid inflow slows by August 1761 and trickles to a stop in early 1762. Few of the resulting receipts were used for subsequent withdrawals and even

[25] It is not identical because it includes fees that, on a monthly basis, are very small (due to the Bank's "permazero" policy). When summed over decades, they bias downward the late years of the sample.

fewer were rolled over. None were renewed after March 1761. As a result, we can approximately time the abandonment of these receipts.[26]

Figure 6. Gold dukaten at the Bank, 1761-2



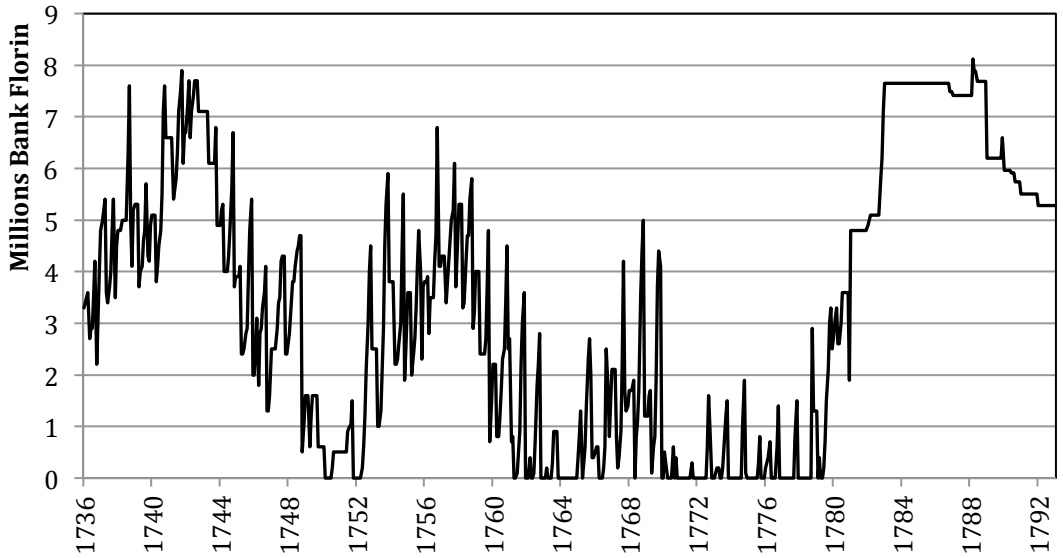
Source: Amsterdam Municipal Archives and authors' calculations.

Figure 6 adds these "fallen" coins to the 700,000 florins of gold *dukaten* that the Bank already owned outright in January 1761. The level owned by the Bank was 2.4 million in March 1762 when the Bank began selling the coins. All the coins were sold by November, with the result that Bank undid the inflows of the previous year, to the extent it could. The nonlinearity of the Bank's open market activity is also evidenced by the long periods where such activity comes to a full stop, e.g., 1763-1765 and 1783-1790. The determinants of the Bank's decisions to engage in OMOs will be more fully investigated in the next section.

The last major channel by which bank florins were created and destroyed is through borrowings by the Dutch East India Company, shown in Figure 7.

[26] We measure abandonment as the amount held under receipt that is neither withdrawn nor rolled over after six months. The measure has a downward (conservative) bias because it does not exclude withdrawals of new deposits and because it double counts receipts that are renewed and withdrawn within the six months.

Figure 7. Cumulative balances from Dutch East India Company loan principal, 1736:1-1792:1



Source: Amsterdam Municipal Archives and authors' calculations.

The seasonality of the anticipations is evident, but the figure also shows that sometimes the Company rolled over its short-term loans into multi-year positions. A very different pattern begins in 1781 when the Company's debt slips into non-performance after the disastrous Fourth Anglo-Dutch War. This regime change corresponds with a collapse of the Bank's market funding through the receipt window (Figure 3), the end of receipts as an effective anchor, and the permanent drop by the agio out of its policy range (Figure 1). The power of this section's monetary decomposition is that none of these patterns is evident from the aggregate series in Figure 2.

Putting the pieces together, Figure 8 applies the decomposition of liabilities in Table 5 to the level of bank florins *M* in Figure 3. The figure plots balances that are "encumbered" by a receipt, M_E , and "unencumbered" balances M_U, further subdivided into two components: M_L and M_R. M_L ("Loans" in the figure) denotes account balances backed by credits to the Company:

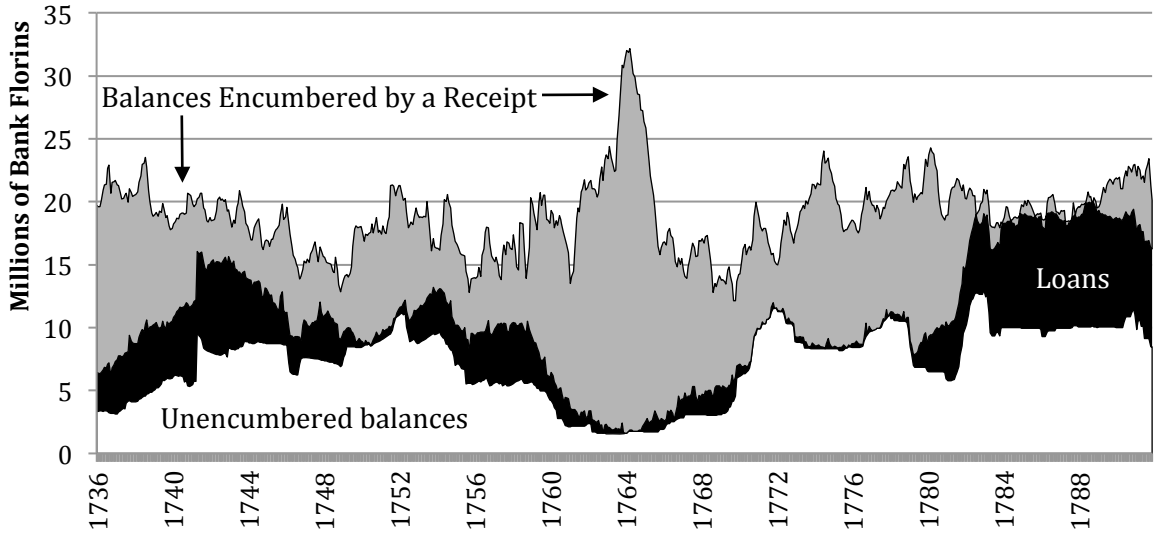
$$M_L = L$$

M_R ("Unencumbered balances"), which is the residual, discretionary component of unencumbered Bank money, is defined as

$$M_R = M_U - M_L = U - \varepsilon$$

where the last equation is an accounting identity. Policy operations by the bank are reflected in movements in M_R, which is "backed" by unencumbered coin *U* and (the negative of) Bank equity $-\varepsilon$.

Figure 8. Decomposition of Bank money *M*, 1736:1-1792:1



Source: Amsterdam Municipal Archives and authors' calculations. The M_L or "loans" series is seasonally adjusted for visual clarity, as described in Appendix B.

The dominating feature of Figure 8 is the magnitude of the variations in M_E . Compared to the agio in Figure 1, or the stock of Bank money in Figure 3, the Bank's level of market funding was not stable. The most extreme fluctuations occurred during the Seven Years' War. Between 1756 and early 1763 there is a net inflow of over 15 million florins, pushing the agio well below its target range. An additional 10 million flows into the Bank following the outbreak of a panic in August 1763, and the tide of metal does not begin to recede until the agio starts to return to its normal range in mid-1764.

Figure 8 also suggests that a goal of the Bank's open market interventions was a stabilization of the overall level of balances, as a channel through which the Bank pursued its policy goal of agio stability. As noted above, this view is supported by the extensive tightening operations observed over the 1750s, and also by the Bank's easing operations over 1781-1783, which add 7 million florins in an attempt to counteract a mass redemption of

receipts. The general determinants of the Bank's open market operations are analyzed in the following section.

5. Econometric analyses

To gain a more precise understanding of the Bank's approach to monetary policy, we fit several econometric models to the reconstructed data series. The models allow for non-linearity of the Bank's open market operations, by splitting the sample into three regimes of "tightening" (months where the Bank conducted metal sales), "easing" (months with purchases), and "no intervention." Tightening (easing) was defined as a monthly rate of open market sales (purchases) in excess of 25,000 florins. The 25,000-florins breakpoint was chosen because the Bank often conducted small purchases to balance the contractionary effects of the fees it charged for receipts, and likewise sold small amounts of precious metals to supply jewelers and similar users. The 25,000-florins limit filters out months where only such routine, "maintenance"-type of transactions occurred.

The sample Markov transition matrix π for the three regimes (tighten, ease, no intervention) is given by

$$\pi = \begin{bmatrix} 0.532 & 0.0484 & 0.419 \\ 0.0423 & 0.655 & 0.303 \\ 0.129 & 0.106 & 0.765 \end{bmatrix},$$

where π_{ij} gives the probability of transition from regime *i* to regime *j*. The corresponding steady-state distribution over regimes is $\{0.185, 0.212, 0.603\}$, i.e., the Bank intervened during about 40 percent of our sample (266 out of 671 months), with interventions roughly evenly split between sales and purchases. Regimes are persistent, and it is rare for the Bank to go directly from tightening to easing or vice versa.

5.1 Dynamics within regimes

Our first exercise was to fit unconstrained VARs to the three regimes.[27] Because the regimes are observable, this can be done by estimating separate models for each regime using OLS. The OLS estimates were then used to construct posterior distributions of the model parameters under a standard diffuse-prior specification.

The VARs encompass five variables. These are 1) market agio, and 2) the projected annualized return on bills of exchange circulating between Amsterdam and London (see Appendix B), and three components of Bank money balances: 3) balances generated by Company (VOC) loans (see Figure 7), which were deseasonalized, 4) cumulative balances generated by deposits against receipts ("cumulative deposits" in Figure 3) and 5) cumulative balances generated by open market activity ("cumulative purchases" in Figure 3).. We chose to work with the "raw" balance series shown in Figure 3 rather than the "adjusted" monetary series in Figure 8 because we currently lack a precise understanding of the internal transfers needed to construct the adjusted series.[28]

Dynamics among the five data series seem well captured by a VAR specification with two monthly lags.[29] The financial market variables (agio, bill rate) come first in the (Choleski) orderings shown below, the intuition being that these would react quickly to changes in international conditions and market sentiment. The monetary variables (Company loans, deposits, and purchases) come second, the intuition being that these would be somewhat slower to react than market prices. Estimated impulse responses are robust to changes in orderings within the two classes of variables.

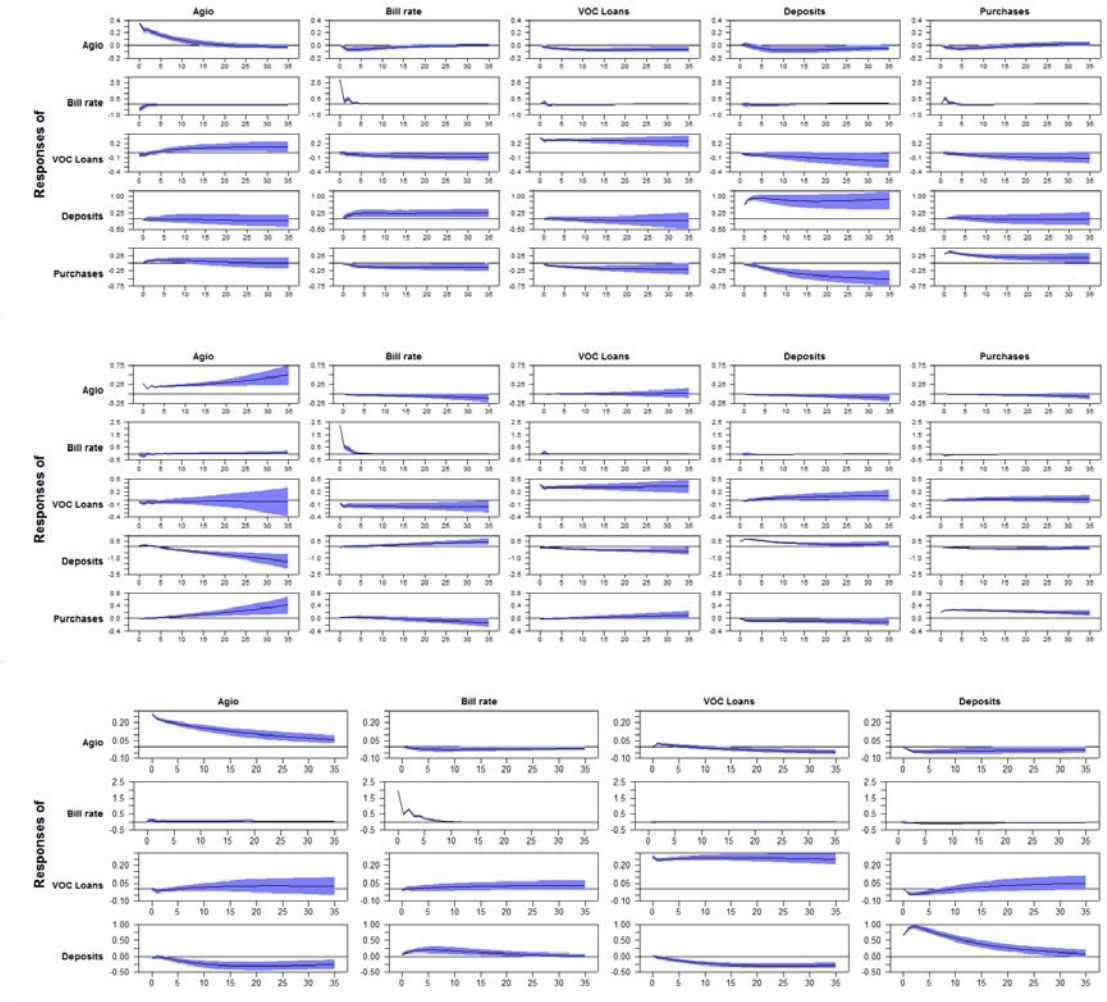
[27] Standard likelihood ratio tests strongly reject constancy of VAR parameters across different regimes. Possible non-stationarity of the estimated representations means that the usual asymptotic justification for these tests may not apply, however. Future versions of the paper will present appropriate Bayesian tests for parameter constancy.

[28] We plan to employ the Figure 8 series this once we have reconstructed a full series of the Bank's internal transfers.

[29] The choice of two lags was again motivated by standard tests, whose asymptotics may not apply here. This modeling choice will be confirmed by more rigorous tests.

Figure 9 presents 36-month impulse responses[30] for the tightening, easing, and no-intervention regimes. Units in the figures are percent for financial variables and millions of bank florins for the monetary variables. Posterior mean responses and 70 percent error bands are shown. Because the purchases series is close to deterministic in the no-intervention regime, the VAR for that regime was estimated only in the first four variables for that regime.

Figure 9: Impulse responses over tightening, easing, and no-intervention regimes



Source: authors' calculation. Responses to 1-standard deviation shocks are shown. Units are percent for prices and millions of bank florins for quantities.

[30] Impulse responses are presented as convenient representations of dynamics within regimes. In actuality it was uncommon for the same regime to persist over long periods of time.

The dynamics in the figure are reasonably intuitive and confirm the asymmetries that confronted the Bank. Under tightening, shocks to the agio lose momentum within a year's time. Under easing, the agio tends to drift, and shocks to the agio induce persistent or possibly explosive responses in purchases and deposits.[31] Such purchases would have built up the Bank's war chest of unencumbered metal for either "borrowing" by the City or future tightening. During the tightening regime, however, sales by the Bank (i.e., the negative of purchases) respond primarily to shocks to deposits. Under both the tightening and easing regimes, sales (purchases) displace around 50 percent of a deposit inflow (outflow) within that regime.

For the no-intervention regime, the key dynamic interaction is between Company loans and deposits, with an increase (decrease) in loans being somewhat offset by a deposit outflow (inflow). Agio shocks are also short-lived in this regime, though they persist longer than under tightening.

5.2 Transitions across regimes

What motivated the Bank of Amsterdam to intervene? To investigate this question, we fit discrete choice (multinomial logit) models to each of the three regimes in the sample.[32] The models estimate the probability of transitioning to a regime of {tightening, easing, or no intervention} during the following month, as a function of variables observed during the current month. These include the current month's regime (i.e., a separate model is estimated for each regime), and two lags each of bill rates, VOC loans, and deposits. The current month's agio is also included, but since most agio observations fall within a fairly narrow range, we reduced the agio series to indicators for a "low" (below 3.7 percent: 25th percentile) and for the no-intervention regime, "high" (above 4.8 percent: 75th per-

[31] The spectral radius (largest autoregressive root) is greater than one for the VARs estimated over the tightening and easing regimes, and the 3-regime system is not mean-square stable under Markov chain dynamics (Farmer, Waggoner, and Zha 2009, 1855) at the point estimates. Both of these facts suggest potential nonstationarity of the estimated system. Estimates shown in Figure 9 are robust to potential nonstationarity, however.

[32] Estimates reported in Table 6 were calculated using the BMRS package in the R programing language (cran.r-project.org/web/packages/brms/vignettes/brms.pdf). Diffuse priors over model coefficients were employed for each estimation.

centile) agios.[33] In months where tightening or easing occurs, the size of the intervention is also included in the explanatory variables. Because open market operations were constrained by the Bank's stock of unencumbered metal, this was included as an explanatory variable. For transitions from the "no intervention" state, the metal stock variable was split into two variables, according whether a low agio (<3.7) was prevalent or not.

Table 7: Multinomial logit models of transition probabilities: Posterior means (standard deviations) of coefficients

		Next month's regime					
Current month's regime	Explanatory variable	Tightening		Easing		No intervention	
Tightening	Constant			-0.157	(4.569)	0.522	(1.674)
	Agio < 3.7%			-2.092	(2.445)	-1.143	(0.690)
	Bill rate			**0.850**	(0.467)	0.171	(0.122)
	Bill rate (-1)			**0.850**	(0.491)	0.099	(0.139)
	VOC Loans			0.413	(1.774)	-0.183	(0.648)
	VOC (-1)			-0.366	(1.783)	0.240	(0.651)
	Deposits			-0.896	(1.006)	-0.176	(0.332)
	Deposits (-1)			0.481	(0.987)	0.174	(0.337)
	Metal stock			**-0.919**	(0.473)	-0.198	(0.137)
	Amount sold			3.303	(1.848)	**-2.735**	(1.025)
Pseudo- R^2 (Estrella measure) = .172							
Easing	Constant	**-9.550**	(4.910)			-0.142	(1.433)
	Agio < 3.7%	5.558	(3.462)			0.429	(1.101)
	Bill rate	**1.382**	(0.619)			-0.097	(0.157)
	Bill rate (-1)	0.237	(0.283)			0.078	(0.134)
	VOC Loans	0.789	(1.362)			0.077	(0.603)
	VOC (-1)	-0.993	(1.353)			-0.033	(0.613)
	Deposits	-0.040	(0.889)			0.263	(0.361)
	Deposits (-1)	-0.189	(0.892)			-0.266	(0.359)
	Metal stock	0.669	(0.417)			-0.052	(0.107)
	Amt purchased	**-9.623**	(5.463)			**-2.742**	(1.399)
Pseudo- R^2 = .137							
No intervention	Constant	-1.960	(1.282)	0.700	(1.372)		
	Agio < 3.7%	**-3.321**	(1.827)	**-2.514**	(1.285)		
	Agio > 4.8%	-0.840	(0.428)	**0.910**	(0.426)		
	Bill rate	**-0.248**	(0.111)	-0.010	(0.111)		
	Bill rate (-1)	0.230	(0.118)	-0.020	(0.113)		
	VOC Loans	-0.122	(0.580)	-0.472	(0.605)		
	VOC (-1)	0.082	(0.581)	0.509	(0.613)		
	Deposits	0.090	(0.229)	-0.434	(0.282)		
	Deposits (-1)	-0.124	(0.227)	0.374	(0.280)		
	Metal*(agio<3.7)	**1.109**	(0.456)	-0.021	(0.432)		
	Metal*(agio≥3.7)	**0.246**	(0.112)	**-0.340**	(0.115)		
Pseudo- R^2 = .172							

Note: a coefficient in **boldface** indicates that the 95% credible interval ("Bayesian confidence interval") for that coefficient does not contain zero.

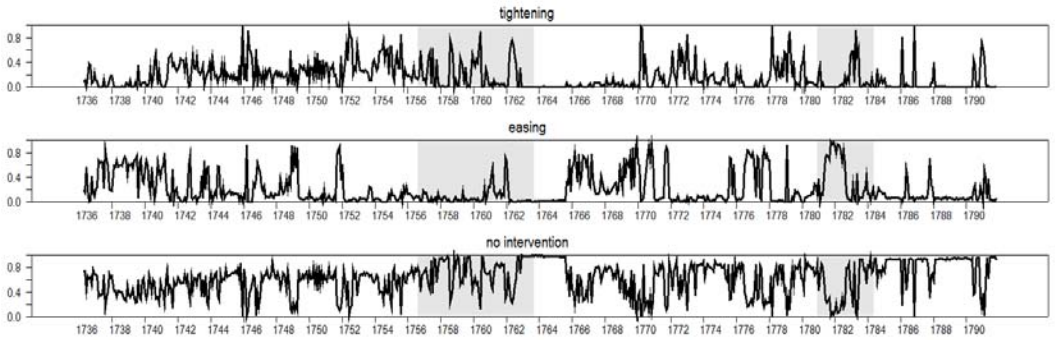
[33] For the tightening and easing subsamples, the coefficient on the high agio dummy is not well identified, so it was excluded as an explanatory variable.

Estimates of the choice models are presented in Table 7. For each model, the "default choice" (necessary due to the usual incomplete identification of logit model parameters) was taken to be the current month's regime. The results again seem intuitive, although the explanatory power of the models is generally low as measured by pseudo-R^2. When the initial regime is no intervention, the Bank seems to be keying off the stock of unencumbered metal: a large unencumbered metal stock increases the chance of tightening, but diminishes the chance of easing. Tightening is particularly likely when a large metal stock is combined with a low agio. Absent the interaction with the metal stock, a low agio is estimated to reduce the chance of tightening. On the other hand, a high agio increases the chances the Bank will ease.

When the current regime is tightening (or easing), the most significant coefficients are on the size of the Bank's operations, which diminish the probability of transition to the no-intervention regime. In other words, the Bank apparently preferred to distribute its open market interventions over a period of time, a familiar practice in modern central banking.

Figure 10 plots the evolution of the 1-month-ahead transition probabilities implied by the logit models (at the posterior mean coefficients).

Figure 10: One-month-ahead transition probabilities, 1736:2-1791:12 (in-sample estimates)



Source: authors' calculations. Shaded intervals are the Seven Year's War and the Fourth Anglo-Dutch War.

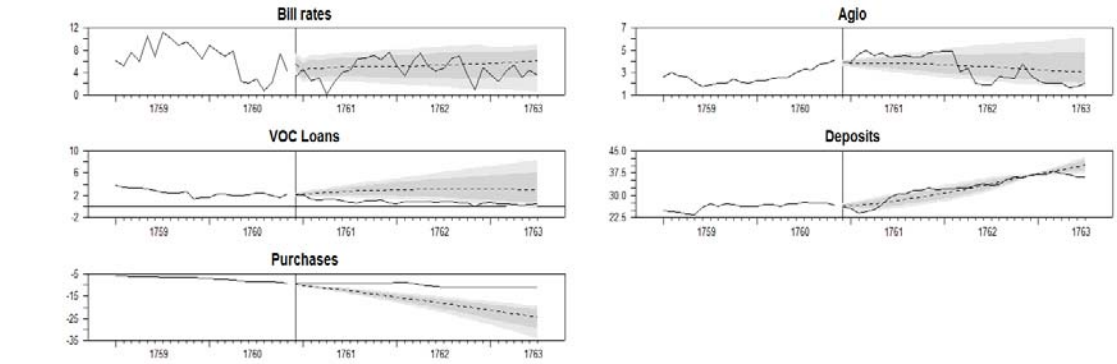
The chart is consistent with the idea that the Seven Years' War was a turning point for the Bank. Tightening in particular is fairly likely over the first part of the sample but becomes very improbable from late 1762 through 1770 and again from 1783 onward. From about

1760 onward, the Bank appears to increasingly rely on the receipt window to maintain a stable market agio.

5.3 Counterfactual scenarios

For our final econometric exercise, we analyzed counterfactual scenarios over two policy-failure intervals. The first interval runs from December 1760 through July 1763, when the Bank's pace of metal sales slowed despite continued strong war-related demand at the receipt window.[34] In the counterfactual scenario, the "tightening" VAR model was used to construct out-of-sample forecasts over this period (1760:12-1763:7), while constraining the path of deposits to match their yearend 1762 level. The conditional forecast gives an indication of what might have happened, if the Bank had continued in its traditional tightening mode over this period and the deposit inflow had continued unabated. The conditional forecast distributions are plotted in Figure 11.

Figure 11: Conditional forecasts versus actual series, 1760:12-1763:7



Notes: forecast distributions are calculated using Algorithm 1 of Waggoner and Zha (1999, 642). Shown are the median (dotted lines), the middle 50 percent (dark gray), and middle 70 percent (light gray) of the forecast distribution for each variable, together with the actual data series (solid lines). Units are percent (prices) and millions of bank florins (quantities).

The forecasts indicate that a monumental sequence of interventions would have been necessary for the Bank to maintain a tightening stance over this interval, on the order of 10 million florins at the median forecast.[35] This amount would have greatly exceeded the unencumbered metal the Bank had available, e.g., only 1.4 million florins at the end of

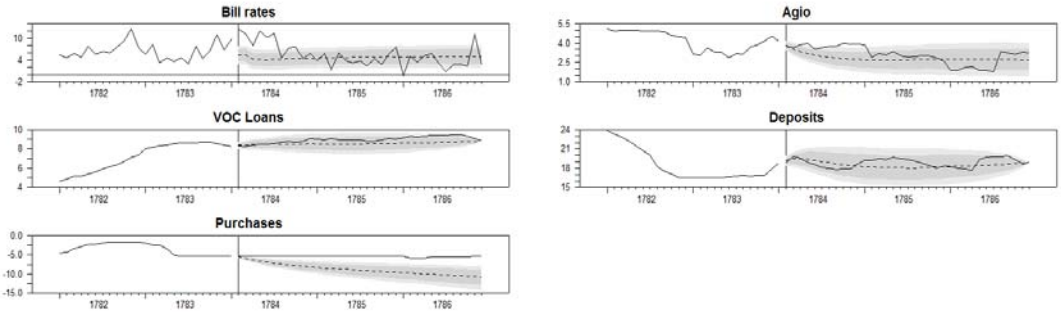
[34] Another market dynamic begins in August 1763, with the outbreak of a financial panic in Amsterdam.
[35] Median forecasts are shown rather than means, due to skewness of the conditional forecast distributions.

1760. And even a selloff of this size does is not predicted to return the agio to its 4-5 percent target range, in part because it is counteracted by a an expansion in lending to the VOC (about 1.5-2 million florins), together with continued growth in deposits over early 1763 (another 2 million).

This exercise is subject to the usual Lucas-critique qualifications: if the Bank had tightened as firmly as these estimates suggest, then the Bank's customers might have reacted by slowing their deposits and the agio might have adjusted in different way. The projections in Figure 11 seem at least plausible, however. These imply a net reduction in Bank money of about 7 million florins by July 1763, which would have reduced the total stock of Bank money to 18.5 million florins, close to average for our sample (cf. Figure 3).

Figure 12 plots the second policy-failure interval, which runs from February 1784 through December 1786. This period was characterized by another "sudden stop" in a sequence of asset sales that the Bank began in January 1783, in an apparent attempt to counteract a drop in the market agio.[36] The counterfactual scenario is constructed as a conditional forecast beginning in 1784:2 that constrains deposits to match their yearend 1786 level, while keeping the Bank in "tightening" mode. Because the finances of the VOC were by this time largely under political control (De Korte 1984), the path of VOC loans is also constrained to match its level at yearend 1786.

Figure 12: Conditional forecasts versus actual series, 1784:2-1786:12



Notes: forecast distributions are calculated using Algorithm 1 of Waggoner and Zha (1999, 642). Shown are the median (dotted lines), the middle 50 percent (dark gray), and middle 70 percent (light gray) of the forecast distribution for each variable, together with the actual data series (solid lines). lines). Units are percent (prices) and millions of bank florins (quantities).

[36] Our scenario stops well before 1788, when some trade coins begin to trickle back into the Bank.

As with the previous episode, the conditional forecast suggests a strong pace of sales would have been necessary for the Bank to continue tightening over this interval: about five million florins at the median forecast. Again this amount exceeds the Bank's available stock of unencumbered metal: 4 million florins in February 1784. It also appears unlikely that this intervention would have returned the agio to its target range of 4-5 percent. A predicted intervention of 5 million florins seems realistic, given that the City eventually (in 1791) was compelled to inject even more (6 million) into the Bank to keep it temporarily afloat.

5.4 Summary

Taken together, the results in this section suggest the following narrative of the Bank's open market operations. The key "intermediate target" guiding the Bank's decisions to intervene seems to have been its stock of unencumbered metal (Table 7, panel 3). If this was sufficiently high (low), then the Bank would opportunistically sell (purchase) metal on the open market if conditions were right: a low agio for sales, or high agio for purchases. Once the decision was made to enter the market, interventions were made in a smooth fashion (Table 7, panels 1 and 2), and these leaned against the prevailing flow of deposits (Figure 9). This cautious approach to intervention met its limits during the Seven Years' War, when the Bank lacked adequate unencumbered metal to respond to large deposit inflows (Figure 11). The Bank became less active in the second half of the sample (Figure 10). Passivity worked for a while but could not control the Bank's loss of credibility in the wake of the Fourth Anglo-Dutch War (Figure 12).

This twenty-first century characterization of the Bank's operations is necessarily somewhat anachronistic, and we cannot dismiss the possibility that the Bank's managers were guided primarily by profit-taking rather than public policy motives. Whatever their intent, the practical effect of these operations is clear: in its role as a central bank, the Bank functioned well when its interventions could control liquidity creation, and less so when it could not.

6. Conclusion

The data presented above indicate that even in the eighteenth century, it was no simple matter to manage a "permazero" policy regime. The Bank of Amsterdam did not just fix a low policy rate and hope for the best. Instead, the data show that liquidity created through the Bank of Amsterdam's lending facility (i.e., its receipt window) was heavily managed by means of the Bank's open market operations.

Adherence to a low policy rate brought with it advantages and disadvantages. On the one hand, the Bank depended on its lending facility and its attractive interest rate to anchor the value of its money. On the other hand, market utilization of this facility could be volatile, particularly when the market price of Bank money (i.e., the agio) was low, or its outlook uncertain. Demand for Bank credit was also subject to fluctuations in bimetallic ratios, the outcome of wars, and similar exogenous factors. There is clear evidence that the Bank's open market operations counteracted the resulting fluctuations in the stock of Bank money, but the effectiveness of the Bank's sales operations was limited by its level of unencumbered assets. As a result, the value of the Bank's money proved vulnerable to a combination of pessimistic expectations and low levels of owned assets.

A permazero policy was thus both a source of the Bank's great success and a contributor to its ultimate demise. Cheap access to credit made the Bank's lending facility popular and promoted agio stability over long periods, yet this same popularity could also undermine stability or fail altogether. Large-scale open market sales were the Bank's primary tool available to address problems with its lending facility, but the Bank did not sacrifice immediate stability and profitability to maintain a sufficient precautionary stock of assets. In the end, the Bank failed because it did not anticipate the degree of tightening necessary to support the credibility of its policy framework. That would seem a useful lesson for later generations of central banks.

References

Agarwal, R. and M. Kimball. 2015. “Breaking Through the Zero Lower Bound.” IMF Working Paper 15/ 224.

Archer, D. and P. Moser-Boehm. 2013. “Central bank finances.” Bank for International Settlements Papers no. 71 (April).

Bassetto, M., and C. Phelan. 2015. “Speculative Runs on Interest Rate Pegs.” *Journal of Monetary Economics* 73: 99-114.

Benigno, P. and S. Nisticò. 2015. “Non-Neutrality of Open Market Operations.” LUISS Guido Carli/ School of European Political Economy, Working paper no. 5/ 2015.

Bordo, M. D. and H. James. 2014. “The European Crisis in the Context of the History of Previous Financial Crises.” *Journal of Macroeconomics* 39(B): 275-284.

Bullard, J. 2015. “Permazero.” Remarks at the Cato Institute Conference “Rethinking Monetary Policy,” November 12.

Bullard, J. 2010. “Seven Faces of ‘The Peril.’ ” *Federal Reserve Bank of St. Louis Review* 92(5): 339-52.

Carlos, A. M. and L. Neal. 2011. “Amsterdam and London as financial centers in the eighteenth century.” *Financial History Review* 18(1): 21-46.

Clapham, J. 1970. *The Bank of England, a history, volume II.* Cambridge: Cambridge University Press.

Cochrane, J. H. 2016. “Do Higher Interest Rates Raise or Lower Inflation?” Mimeo.

Dehing, P. 2012. *Geld in Amsterdam: Wisselbank en wisselkoersen, 1650-1725*. Hilversum: Uitgeverij Verloren.

Dehing, P., and M. ‘t Hart. 1997. “Linking the fortunes, currency and banking, 1550-1800.” In *A Financial History of the Netherlands,* ed. M. ‘t Hart, J. Jonker and J. L. van Zanden, 37-63. Cambridge: Cambridge University Press.

De Jong-Keesing, E. E. 1939. *De Economische Crisis van 1763 te Amsterdam.* Amsterdam: N.V. Intern. Uitgevers en h. Mij.

De Korte, J.P. 1984. *De Jaarlijkse Financiële Verantwoording in de Verenigde Oostindische Compagnie*. Leiden: Martinus Nijhoff.

Del Negro, M. and C. A. Sims. 2015. “When Does A Central Bank’s Balance Sheet Require Fiscal Support?” *Journal of Monetary Economics* 73: 1-19.

De Vries, J., and A. van der Woude. 1997. *The First Modern Economy: Success, failure and perseverance of the Dutch economy, 1500-1815.* Cambridge: Cambridge University Press.

Estima. 2010. *RATS Version 8 Reference Manual.* Evanston, Illinois: Estima.

Farmer, R.E.A., D.F. Waggoner, and T. Zha. 2009. “Understanding Markov-switching rational expectations models.” *Journal of Economic Theory* 144: 1849-1867.

Flandreau, M., C. Galimard, C. Jobst and P. Nogués-Marco. 2009. "Monetary Geography before the Industrial Revolution." *Cambridge Journal of Regions, Economy and Society* 2 (2): 149-171.

Fry, M. J. 1993. "The Fiscal Abuse of Central Banks." International Monetary Fund Working Paper no. 93/58 (July).

Gelderblom, O. and J. Jonker. 2011. "Public Finance and Economic Growth: The Case of Holland in the Seventeenth Century." *Journal of Economic History* 71(1): 1-39.

Gillard, L. 2004. *La Banque d'Amsterdam et le florin européen au temps del la République Néerlandaise (1610-1820).* Paris: École des hautes-études en sciences sociales.

Goodfriend, M. 2016. "The Case for Unencumbering Interest Rate Policy at the Zero Lower Bound." Paper presented at the Jackson Hole Economic Policy Symposium.

Hodrick, R. and E. Prescott. 1997. "Post-War U.S. Business Cycles: An Empirical Investigation." *Journal of Money, Credit, and Banking* 29(1): 1-16.

Homer, S. and R. Sylla. 2011. *A History of Interest Rates, 4th Edition.* Hoboken, NJ: John Wiley & Sons.

Jonker, J. 1996. *Merchants, Bankers, Middlemen: The Amsterdam Money Market during the First Half of the 19th Century*. Amsterdam: NEHA.

Klein, M. W. and J. C. Shambaugh. 2015. "Rounding the Corners of the Policy Trilemma: Sources of Monetary Policy Autonomy." *American Economic Journal: Macroeconomics* 7(4): 33-66.

Le Moine de L'Espine, J. and I. Le Long. 1763. *De Koophandel van Amsterdam*. Rotterdam: Ph. Losel, J.D. Beman, H. Kentlink, J. Bosch, N. Smithof, d'wed. J. Losel en J. Burgvliet.

Mees, W. C. 1838. *Proeve eener Geschiedenis van het Bankwezen in Nederland geduerende den Tijd der Republiek.* Rotterdam: W. Messcuert.

Miller, M. H. 1998. "The current Southeast Asia financial crisis." *Pacific-Basin Finance Journal* 6, 225-233.

Nogués-Marco, P. 2013. "Competing Bimetallic Ratios: Amsterdam, London, and Bullion Arbitrage in Mid-Eighteenth Century." *Journal of Economic History* 73(2): 445-76.

Polak, M. 1998. *Historiografie en Economie van de "Muntchaos."* Amsterdam: NEHA.

Quinn, S. and W. Roberds. 2007. "The Bank of Amsterdam and the Leap to Central Bank Money," *American Economic Review Papers and Proceedings* 97: 262-5.

Quinn, S. and W. Roberds. 2014a. "How Amsterdam Got Fiat Money." *Journal of Monetary Economics* 66(1), 1-12.

Quinn, S. and W. Roberds. 2014b. "Death of a Reserve Currency". Federal Reserve Bank of Atlanta Working Paper no. 2014-17 (September).

Quinn, S. and W. Roberds. 2015. “Responding to a Shadow Banking Crisis: the Lessons of 1763.” *Journal of Money, Credit, and Banking.*

Roberds, W. and F. R. Velde. 2016. “Early Public Banks I: Ledger-Money Banks.” In D. Fox and W. Ernst, eds. *Money in the Western Legal Tradition.* Oxford: Oxford University Press.

Sayers, R. S. 1970. *The Bank of England Operations 1890-1914.* Westport, Connecticut: Greenwood Press.

Sayers, R. S. 1976. *The Bank of England 1891-1944, Volume 1*. Cambridge: Cambridge University Press.

Schnabel, I. and H.S. Shin. 2004. “Liquidity and Contagion: The Crisis of 1763.” *Journal of the European Economic Association* 2(6): 929-968.

Schneider, J., O. Schwarzer, and P. Schnelzer. 1991. *Historische Statistik von Deutschland. Band XII: Statistik der Geld- und Wechselkurse in Deutschland und im Ostseeraum (18. Und 19. Jahrhundert).* St. Katharinen: Scripta-Mercuratae-Verlag.

Smith, A. 1937. *The Wealth of Nations*. New York: Modern Library.

Stella, P. 1997. “Do Central Banks Need Capital?” International Monetary Fund Working Paper no. 97/83 (July).

Stella, P. 2005. “Central Bank Financial Strength, Transparency, and Policy Credibility.” *IMF Staff Papers* 52(2).

Stella, P. and Å. Lönnberg. 2008. “Issues in Central Bank Finance and Independence.” International Monetary Fund Working Paper no. 08/37 (February).

‘T Hart, M. 2009. “Corporate Governance.” In *The Bank of Amsterdam*, ed. M. van Nieuwkerk, 144-55. Amsterdam: Sonsbeek.

Ugolini, S. 2015. “Liquidity Management and Central Bank Strength: Bank of England Operations Reloaded, 1889-1910.” University of Toulouse

Uittenbogaard, R. 2009. “Lending by the Bank of Amsterdam (1609-1802).” In *The Bank of Amsterdam*, ed. M. van Nieuwkerk, 120-131. Amsterdam: Sonsbeek.

Van Bochove, C. 2013. “Configuring Financial Markets in Preindustrial Europe.” *Journal of Economic History* 73(1): 247-278.

Van Dillen, J. G. 1925. *Bronnen Tot de Geschiedenis der Wisselbanken*. The Hague: Martinus Nijhoff.

Van Dillen, J. G. 1934. “The Bank of Amsterdam.” In *History of the Principal Public Banks*, ed. J. G. van Dillen, 79-124. The Hague: Martinus Nijhoff.

Van Dillen, J. G. 1964a. “Bloeitijd der Amsterdamse Wisselbank 1687-1781,” in J. G. van Dillen, ed. *Mensen en Achtergronden, Studies uitgegeven ter gelegenheid van de tachtigste jaardag van de schrijver.* Groningen: J.B. Wolters.

Van Dillen, J. G. 1964b. “Ondergang van de Amsterdamse Wisselbank 1782-1820,” in J. G. van Dillen, ed. *Mensen en Achtergronden, Studies uitgegeven ter gelegenheid van de tachtigste jaardag van de schrijver.* Groningen: J.B. Wolters.

Van Zanden, J. L. 2013. “Prices and wages and the cost of living in the western part of the Netherlands, 1450-1800.” Visited online at the International Institute of Social History, www.iisg.nl.

Waggoner, D. F. and T. Zha. 1999. “Conditional Forecasts in Dynamic Multivariate Models.” *Review of Economics and Statistics* 81(4): 639-651.

Wallace, N. 1981. “A Modigliani-Miller Theorem for Open-Market Operations.” *American Economic Review* 71(3): 267-274.

Appendix A: Construction of Bank of Amsterdam balance sheets

The cashbooks (*kasboeken*) for 1747 through 1760 are not extant, so we do not have starting levels of

- collateral
- withdrawals and prolongations by collateral
- purchases and sales by collateral
- payments to the city treasury
- expenses

Therefore, we cannot directly connect these to master (*specie kamer*) account transactions. For each account entry, however, we do have date, name, amount, and sequential position. The challenge is to use this information to best assign a purpose to each ledger transaction. This appendix sets out our filtering process.

I. Dutch East India Company Loans

Using name information and annual totals, we know Dutch East India Company loan principal and interest payments. These ledger transactions are readily sorted out, and their totals can be confirmed by fiscal year (see Van Dillen 1925: 979-984).

II. Annual Transaction Fees

At the end of each fiscal year, account holders had to pay a fee assessed on the number of debit transactions. The Bank deducted the total of all these fees from the master account (*specie kamer*) as the last transaction of the fiscal year. It was labeled *partygeld* and is readily identifiable.

The remaining transactions are (usually) either deposits/withdrawals of coins, prolongations of coins, or purchase/sales of collateral that is not under receipt.

III. Deposits and Purchases

The Bank had a long-standing tradition of channeling deposits through receiver accounts. Receivers than transferred cumulative deposits to the debit side of the master account (*specie kamer*). In contrast, the Bank accounted for purchases directly with its counterparty. This accounting convention bifurcates deposits (receiver as counterparty) from purchases (other people as counterparty).

IV. Withdrawals and Prolongations

The credit side of the master account, however, has no such separation. Withdrawals, prolongations, and sales are mingled. The major tool for identifying withdrawals and prolongations comes from regularities in how the receipt window operated. Van Dillen observed that deposits, withdrawals and prolongations occurred in a unit called a sack that

had a highly consistent value over time (Van Dillen 1925: 883-884). We have confirmed this through reconstruction of extant *kasboeken* for numerous years. The Bank of Amsterdam seems to have migrated to units of sacks in the early 1700s.

- For Dutch coins, the value of a sack is the value of each coin in bank florin multiplied by the number of coins per sack.
- For foreign coins, the value of a sack is the bank florins per mark of the silver or gold in bank florin multiplied by the number of marks per sack.

Withdrawal and prolongation fees were assessed per sack at a consistent rate. Hence, from the perspective of sacks of coins, withdrawals and prolongations occur in discrete bank florin increments as reported in the table below.

Table A.1. Withdrawal and Prolongation Values in Bank Florins: 1736-1769

	Sack Content	Sack Value in bank florin	Fee Rate	Withdrawal with Fee in bank florin	Prolongation Fee in bank florin
Dutch Coins					
Ryxdaalder (Silver)	200 coins	480	1/4%	481.2	1.2
Silver Ducatons	200 coins	600	1/8%	600.75	0.75
Staten Drie Gulden (Silver)	200 coins	565	1/8%	565.7	0.70625
Goude Ducaaten (Gold):	1,000 coins				
1736 through 1746		4,950	1/2%	4,974.75	24.75
1747 through 1749		4,975	1/2%	4,999.875	24.875
1750 into 1756		4,950	1/2%	4,974.75	24.75
1756 through 1769		4,975	1/2%	4,999.875	24.875
Foreign Coins					
SILVER (approximately 92.5% fine): Pylaaren, Mexicaanen, and Siviliaanen (Spanish dollars of various origins); Franse Croonen (French); Navarre Croonen (French); Engelse Croonen (English);	100 marks (weight)	2,200	1/4%	2,205.5	5.5
GOLD (approximately 22 carats fine: 91.67%) Goude Crusados (Portuguese); Goude Guignes (English); Goude Franse Schild Pistoolen (French); Goude Brabantse Soveryne (Brabant)	22 marks (weight)	6,820	1/2%	6,854.1	34.1
GOLD (approximately 21.33 carats fine: 88.89%) Goude Franse Pistoolen (French)	22 marks (weight)	6,600	1/2%	6,633	33

Using this regularity to label account transactions is complicated by a few details.

1. The bank florin value per sack can change. This happened to gold *ducaton* sometime between 1746 and 1761. To address this, we treat gold *ducaton* as two coins: one at the 1746 value and one at the 1761 value.
2. Some types of coin have the same bank florin value, so they are indistinguishable in account terms. To address this, we combine coin types of the same bank florin value into one category.
    - Spanish, French, and English silver become "Foreign Silver Coins" at 2,200 bf per sack with a fee rate of ¼%.
    - Gold coins with 22 carat fineness aggregate into "Foreign Gold Coins" at 6,820 bf per sack with a fee of ½%.
3. Some values are multiples of others. Multiples do not stop our identification of transactions as withdrawals or prolongations, but they do confuse identification of which coin was withdrawn or prolonged.
    - Withdrawal multiples are rare. Examining all combinations in 1746 where neither coin exceeds 100 sacks, we identified only two multiples for withdrawals. One is the highly unlikely withdrawal amount of 308,434.5 bf being either 62 sacks of gold ducaton (1746) or 45 sacks of foreign gold coins. The other is the far more common 26,466 bf being either 55 sacks of Ryxdaalders or 12 sacks of Foreign Silver Coins. This outcome may have to become its own category should it arise and no additional information is available.
    - Prolongation multiples are more common. For example, 6 bf could prolong either 8 sacks of silver ducatons or 5 sacks of ryxdaalders. This is an ambiguity we will likely be unable to resolve with confidence, but it does not impede our ability to categorize a transaction as a prolongation.
4. The Dutch silver coin called the "*Staten Drie Gulden*" has a rounding problem. They have a per-sack fee of 0.70625 bf, but the Bank only handled increments of 0.025 bf ($1/40^{th}$). Examination of *staten drie gulden* transactions from 1761 through 1764 (there were none in 1746), suggests the Bank usually rounded to the nearest $1/40^{th}$. However, the Bank would sometimes round up when rounding down was slightly more appropriate. As a result, we look for expected *drie gulden* values and known rounding deviations.

Although all coins using receipts were transacted in sacks, the Bank's account system operated in bank florins rather than sacks. As a result, the sack-based accounting of coins did not always lead to a unique bank florin entry.

For example,

- A withdrawn sack of foreign silver could be paid by one transaction of 2,205.5 bf. Or, two people could split the payment, i.e. one pays 1,205.5 and the other pays 1,000. Alone, neither corresponds to a sack withdrawal or prolongation derived from Table A.1.
- Alternatively, a person could pay 2,205.5 to withdraw one sack of foreign silver and, separately, pay 481.2 to withdraw one sack of *ryxdaalders*. Or, a person could combine them into one payment of 2,686.7. The combination does not corresponds to a sack withdrawal or prolongation derived from Table A.1.

Such splits and combinations interfere with the simple translation of account transactions into collateral transactions. To ascertain the extent of these problems, we matched all account transactions in 1746 and 1761 (our bookend years) with collateral transactions.

1. We found no examples of combining. We know this does happen in later decades, but it may not be happening at mid-century.
2. Prolongations of a given coin type were not split, so prolongations should be readily identifiable.
3. Withdrawals of the same coin type were sometimes split. This problem is surmountable because splits were all booked on the same day and because the elements of those splits were recorded (often in sequence) in the accounts ledger. For example, on 24 November 1746, Elias Barents withdrew 6 sacks of Spanish silver coins worth 13,200 bank florin in principal. He also had to pay 33 bank florins in fees. This withdrawal was paid for by a sequence of consecutive transactions reported in Table A.2. The “voor idem” means that an entry was made on behalf of Elias Barents.

Table A.2. Changes in Bank of Amsterdam Balance Sheet from a "Split" Withdrawal

ASSETS		LIABILITIES	
6 sacks of Spanish pylaaren coin to:		Account Balances from:	
Elias Barents	-13,200	Elias Barents	-6,025
		Eliazar Barents voor idem	-850
		Barent Symons voor idem	-3,000
		Gerrit Muller voor idem	-3,358
		NET WORTH (Profit)	
		Profit from:	
		Withdrawal fee	33
TOTAL CHANGE	-13,200		-13,200

Sources: (5077/1387, f. 65), (5077/1344, f. 89)

Applying these insights form the *kasboeken* creates a highly effective filter for withdrawals and prolongations for the years 1747 through 1760.

V. Test of the Filter

Before applying the withdrawal/prolongation filter (Section IV above) to the years 1747-1760, we applied it to the three years with *kasboeken*. We then compared the filter result to the actual record. Table Y gives the results. Overall, the filter mis-identified 9 out of 2,955 transactions. That makes for an error rate of 0.30 percent measured by transactions and 0.24 percent measured by bank florins.

Over the three years, the test incorrectly rejected 47 transactions that were in fact withdrawals/prolongations. Most of that was human error in not accepting that very large prolongations as such. This was corrected when applying the filter to the gap years. The remaining 8 rejection errors were from combining withdrawal and prolongation (thrice), aggressive rounding of *staten drie gulden* coins (thrice), an unexplained fee error, and a fee error that was later corrected. Over the three years, the test incorrectly accepted one sale transaction. A 125 bank florin transaction was labeled as the prolongation of *staten drie gulden* when it was really part of the sale of gold coins.

Table A.3. Results of Filter Test on the Years 1744-1746.

ACTUAL SPECIE KAMER CREDITS BY CATEGORY

BY TRANSACTIONS	1744	1745	1746	Total
Withdrawals and Pro-longations	698	885	1,131	2,714
Sales	76	19	146	241
Total	774	904	1,277	2,955

BY BANK FLORINS	1744	1745	1746	Total
Withdrawals and Pro-longations	3,845,428.825	4,016,138.750	9,004,322.30	16,865,889.875
Sales	183,644.125	25,824.400	2,404,616.20	2,614,084.725
Total	4,029,072.950	4,041,963.150	11,408,938.50	19,479,974.600

INCORRECT REJECTIONS OF A CREDIT AS A WITHDRAWAL OR PROLONGATION

BY TRANSACTIONS	1744	1745	1746	Total
Human Error	1	15	23	39
Filter Error	2	4	2	8
Total	3	19	25	47

BY BANK FLORINS	1744	1745	1746	Total
Human Error	627.00	63,880.18	281,618.30	346,125.48
Filter Error	15,471.50	12,812.25	18,102.80	46,386.55
Total	16,098.50	76,692.43	299,721.10	392,512.03

INCORRECT IDENTIFICATIONS OF A CREDIT AS A WITHDRAWAL OR PROLONGAITON

BY TRANSACTIONS	1744	1745	1746	Total
Human Error	0	0	0	0
Filter Error	0	0	1	1
Total	0	0	1	1

BY BANK FLORINS	1744	1745	1746	Total
Human Error	0	0	0	0
Filter Error	0	0	125	125
Total	0	0	125	125

SHARE OF CREDIT ENTRIES MISIDENTIFIED BY THE FILTER

BY TRANSACTIONS	1744	1745	1746	Total
Withdrawals and Pro-longations	0.29%	0.45%	0.18%	0.29%
Sales	0.00%	0.00%	0.68%	0.41%
Total	0.26%	0.44%	0.23%	0.30%

BY BANK FLORINS	1744	1745	1746	Total
Withdrawals and Pro-longations	0.40%	0.32%	0.20%	0.28%
Sales	0.000%	0.000%	0.005%	0.005%
Total	0.38%	0.32%	0.16%	0.24%

Source: Authors' calculations.

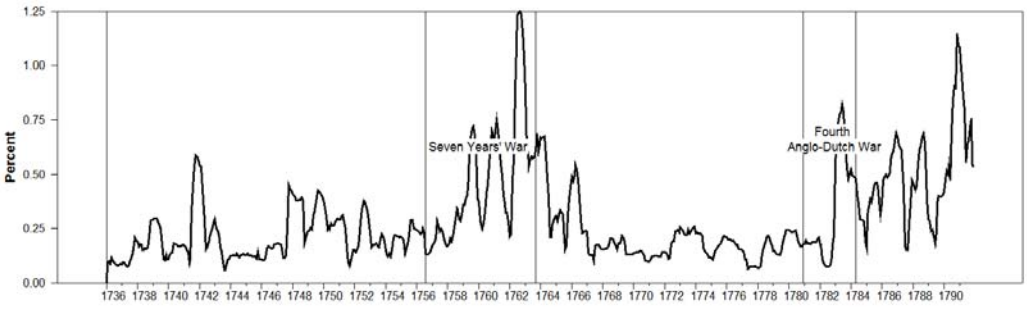
Appendix B: Additional details of data series

B.1 Agio

The data for agio series consist of monthly observations taken from on the market agio of the bank florin, i.e., the percent premium of the bank florin over the current florin. When multiple observations were available for a given month, we averaged observations. Our dataset begins in January 1736 and run through December 1791.

The volatility of the agio follows a roughly inverse pattern from its level, i.e., volatility increases whenever the agio falls out of its target range. This pattern is shown in Figure B.1., which plots 12-month rolling standard deviations of the agio series in Figure 1:

Figure B.1. Volatility of the agio, 1736:1-1791:12
(12-month rolling standard deviations)



B.2 Interest rates

There is no single reference short-term market interest rate for Amsterdam during our sample that would correspond to the rate on short-term government debt (e.g., 90-day T-bill rate) used in modern macro studies. A type of interest rate that is commonly used for this era is the "bill rate." In our case the bill rate is the return available to a merchant in Amsterdam from purchasing a bill of exchange drawn on a reputable merchant in another city (most commonly, London), then repatriating the funds to Amsterdam by drawing a London bill on an Amsterdam merchant. Because bills of exchange were payable in foreign currency, they always entailed foreign exchange risk. And, even when they were drawn on the best credits, they also involved some credit risk. Bills could be refused (fail

to be accepted) by a drawee or an accepted bill could be defaulted on. Nor could a bill be formally bound to collateral. To compensate bill holders for these risks, the bill rate was typically much higher than the one-half percent charged by the Bank of Amsterdam at its receipt window (the average ex post bill rate in our sample is about 4.3 percent) and this rate was also volatile (the sample standard deviation is 2.9 percent).

To construct a bill rate series, we used data on London prices of bills drawn on Amsterdam, taken from a dataset generously provided by Larry Neal, and Amsterdam prices of bills drawn on London, taken from Schneider, Schwarzer, and Schnelzer (1991).[37] Both of these series were originally collected from "price currents," local financial newspapers that appeared once or twice a week. The Amsterdam on London series is available only on a monthly basis, where the monthly observation was derived from the first available observation of that month. To construct a corresponding series for London, we took the nearest corresponding price observation, correcting for England's belated adoption of the modern calendar in September 1752. We again employed data from January 1736 through December 1791.

In both London and Amsterdam, bills on the other city were customarily drawn at multiple maturities, including "sight" (de facto 7-day) and 2-month (60-day) bills. We used 2-month bill prices to construct our interest rate series because they are many more observations available for these than for the sight bills, particularly for Amsterdam on London. Prices are recorded as "bank shillings" (= .3 bank florins) per pound sterling. Our interest rate thus corresponds to the return on a 4-month transaction: purchasing a 2-month bill on London in Amsterdam, then a 2-month bill on Amsterdam in London. The (measured) annualized ex post interest rate on such a transaction, expressed in percentage terms, is

$$r_t = 300\left(L_{t+2} - A_t\right)$$

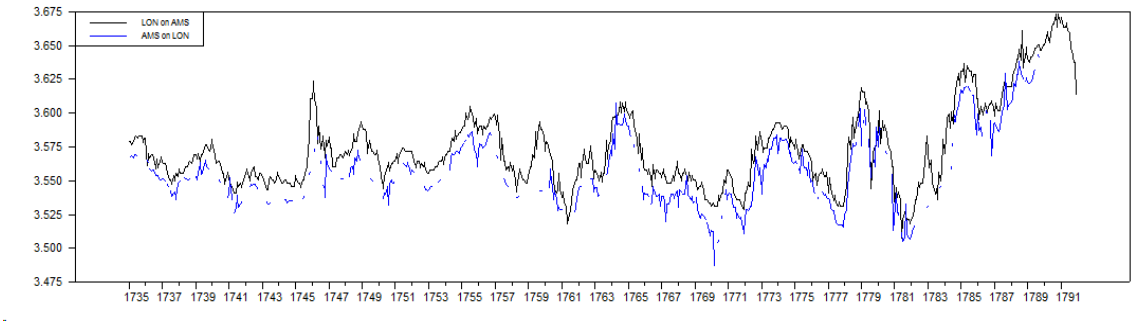
[37] We used London price data because Amsterdam-London was the densest market of its day. At the cost of additional complexity, our strategy could be adapted to take into account bill prices on additional markets.

where L_{t+2} is the log of the 2-month ahead London price of a 2-month bill drawn on Amsterdam, and A_t is the log of the current month Amsterdam price of a bill drawn on London. The literature traditionally calculates the ex ante bill rate as

$$300\,(L_t - A_t)$$

under the implicit assumption that bill prices (and the London price in particular) approximately follow a random walk. There are two potential problems with the traditional methodology in the present case. The first is that while the London on Amsterdam price series is complete, many of the Amsterdam on London prices are missing (301 observations or 45 percent of the sample) including all data after 1789. The second is temporal misalignment of the two bill price samples due to variation in calendars and irregular publication dates of the price currents. The data issues are compounded by the underlying informality of price currents' data. The data gaps in particular are evident in figure B.2, which plots the two bill price series.

Figure B.2: Bill price data series, 1736:1-1791:12
(100 x logs of raw series, bank shillings per pound sterling)



Visual inspection of figure B.2 indicates that the two bill price series are smooth and highly correlated, which suggests that a variation on the traditional method that can be used to resolve the data issues. To this end, we employed a simple state-space model, following the basic strategy of the well-known stochastic trend model of Hodrick and Prescott (1997).

In our model, there are two underlying state variables, x_t and z_t, both of which are postulated to follow univariate random walks; innovations in *x* and *z* may be contemporaneously correlated.[38] The observed (demeaned) Amsterdam on London bill price series is postulated to follow

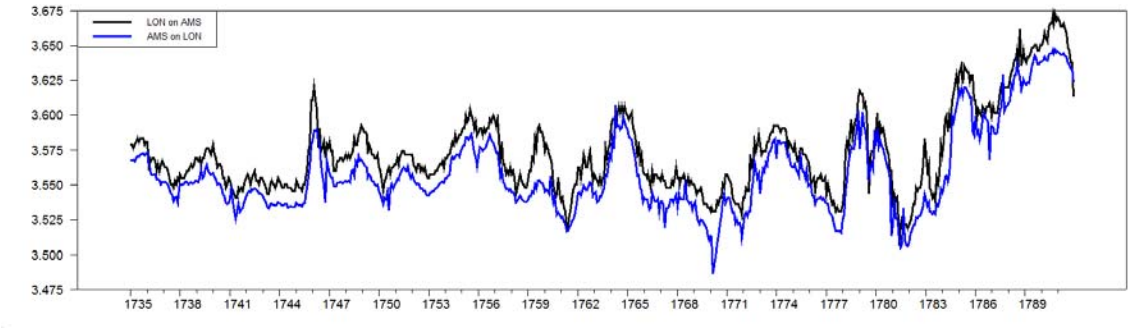
$$A_t = x_t \ ,$$

and the (demeaned) London on Amsterdam bill price similarly follows

$$L_t = x_t + z_t \ .$$

The model is easily fit to the bill price data via maximum likelihood estimation of the Kalman smoother.[39] Figure B.3 plots the smoothed data series. Note that the smoothed London on Amsterdam series replicates the original data series.

Figure B.3: Smoothed bill price data series (100 x logs), 1736:1-1791:12



With the smoothed series in hand, we then calculated ex ante bill rates $\hat{r}_t$ as

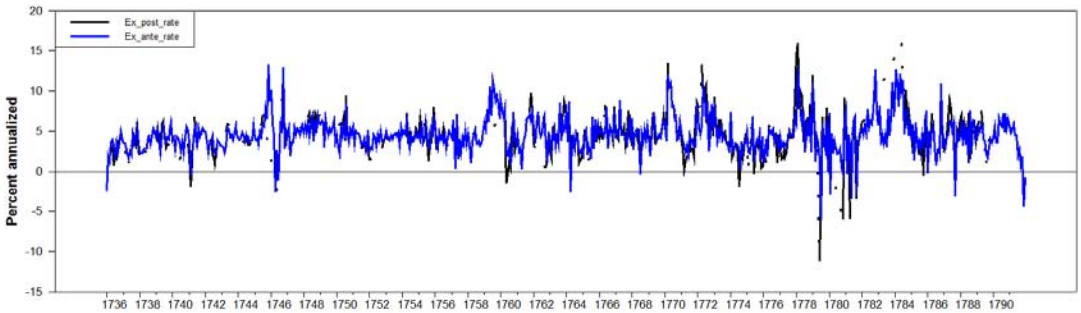
$$\hat{r}_t = 300\left(\hat{L}_{t+2} - \hat{A}_t\right)$$

where $\hat{A}_t$ is the smoothed value of the log of the Amsterdam on London bill price, and $\hat{L}_{t+2}$ is the 2-month ahead projection of the log price of London bills on Amsterdam. Our

[38] As in many implementations of the Hodrick-Prescott filter, the random walk structure is used here as a convenient filtering device rather than as a precise description of the stochastic properties of the data.
[39] Our estimated model allowed for measurement errors in the observed bill rates. The estimated variance of these error terms was however so small as to be negligible, so we set them to zero.

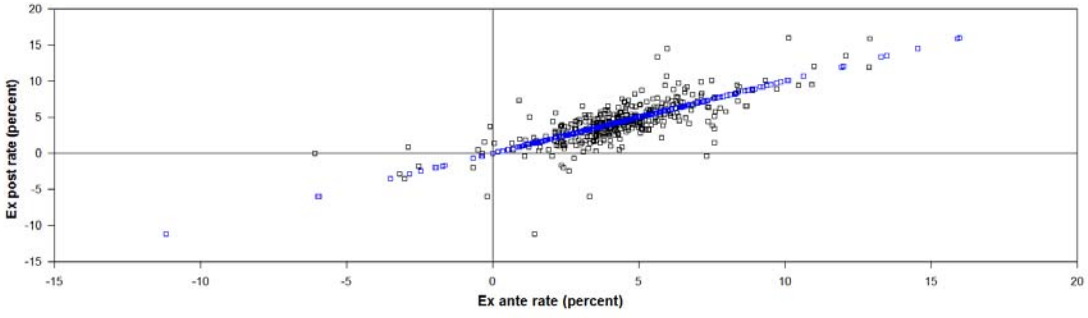
method thus follows the traditional approach in that each bill price is approximated as a random walk. What is new is that we assume the difference between the two prices is also approximated by a random walk, as a way of filling in the missing observations. Figure B.4 below plots the measured ex post rate r_t and our calculation of the ex ante rate $\hat{r}_t$ over the data sample.

Figure B.4: Ex post and ex ante bill rates, 1736:1-1791:12
(Data versus smoother-implied rates)



The ex ante rate tracks the ex post rate (the simple correlation of the two series is .73) except during periods of extended market volatility. An X-Y plot of the two series (Figure B.5) shows that the ex post rate is generally well predicted when ex ante rates are close to their mean. Our filtering approach does less well, however, at very high rates or for the subset of the sample when the round-trip returns on bills are negative.

Figure B.4: Ex post and ex ante bill rates
(Data versus smoother-implied rates)

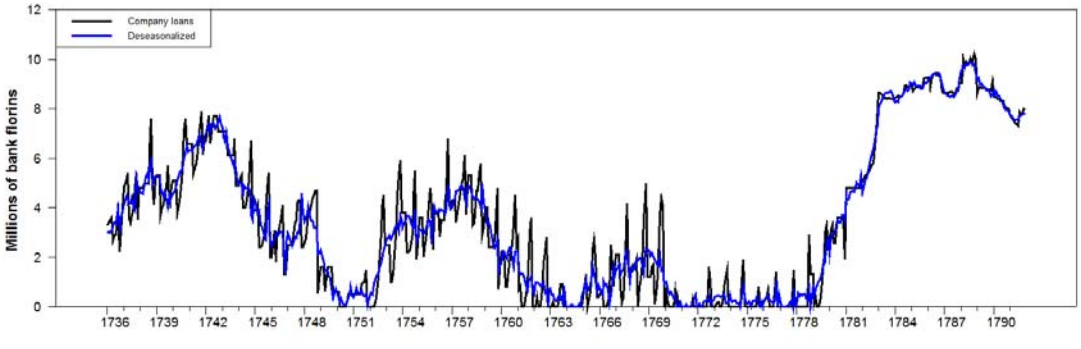


B.3 Seasonal adjustment of the Company loans series

For some of the analyses, the Company loans series in Figure 8 was deseasonalized using the procedure described in Estima (2010, 438). To implement this procedure, the loans

series was prefiltered by demeaning, tapering at both ends, and padding with zeros out to 6144 observations. A band-pass filter was then applied to the finite Fourier transform of the prefiltered series. The filter masks out harmonic frequencies associated with annual cycles and adjacent frequencies. The initial prefiltering steps were then reversed to obtain the seasonally adjusted series. For a few observations where the original series was at or near zero, "ghosting" distortions from the band-pass filter caused the adjusted series to go slightly negative. The negative observations have no economic significance and were set equal to zero. Figure B.5 plots the original and adjusted series.

Figure B.5: Original and deseasonalized Company loans series, 1736:1-1791:12



B.4 Construction of the gold price series

The gold-silver ratio shown in Figure 5 was constructed as follows. The Hamburg *Preis Couranten* report in each issue a current range of prices for Dutch gold *dukaten*, expressed as percentage deviations from their "par" value of six Bank of Hamburg marks per *dukaat.* The price per gram of gold in Hamburg can thus be expressed as

$$P_g = \left(\text{Hamburg marks per } dukaat\right)/3.4173$$

since each *dukaat* contained 3.4173 grams of gold. The *Preis Couranten* also report the market price of a Cologne mark of fine silver, expressed in Bank of Hamburg marks. (Note that a "Cologne mark" here refers to a unit of weight, while the "Bank of Hamburg mark" refers to a currency unit.) The price per gram of silver in Hamburg can thus be expressed as

$$P_S = (\text{Hamburg marks per Cologne mark of silver})/233.85$$

where the denominator gives the weight in grams of a "Cologne mark" as it was interpreted in Hamburg. Taking the ratio of P_G to P_S gives the series in Figure 5.

To form the market gold price series in Figure 6, we converted the Hamburg price of *dukaten*, expressed in Bank of Hamburg marks per *dukaat*, into Amsterdam bank florins using the sight Amsterdam on Hamburg exchange rate series given in Schneider, Schwarzer, and Schnelzer (1991). Because the latter series is incomplete, it was interpolated using the Hamburg on Amsterdam sight exchange rate series from the same source, in precisely the same manner as described above for the Amsterdam on London series.

Appendix C. The use of receipts

C.1 Description in a contemporary merchants' manual[40]

Since this business [with receipts] is known to only a few people, we will illustrate it with an example. Suppose that you had 1000 French Louis d'Or that you wanted so sell. These normally go for 11.4 to 11.7 florins each, but suppose you could not sell them for more than 11.4 florins. Since this price is too low and unprofitable for you, you bring these coins into the Bank, which dispenses in return for these [coins] 10,700 florins bank money, at 10.7 florins a coin, which you then have at your disposal for six months at a cost of ½ percent, six months being the usual maturity of receipts. If the coins in question appreciate in the meantime, and come up to a price where you find it profitable to sell, then you can withdraw these from the Bank and sell them at the going price; or, you can sell your receipt, if somebody wants to buy it at the corresponding price.

If, however, the coins in question do not appreciate within six months' time, and you are nevertheless of the opinion that they will go higher during the following six months, then you can prolong the receipt, provided you bring it into the Bank and transfer the 53.5 [bank] florins, that is, the ½ percent, from your account to the Specie Kamer [the Bank's master account], which you would be obliged to pay to the Bank for having stored your coin, according to the receipt agreement. After which it would be written on the receipt, *prolonged for six months on date* … . Then, after the passage of six more months, if you again want to prolong again, this can also be done, provided that you transfer 53.5 florins to the Bank as you did before. And this can happen several times over, for as long as you see some profit in it. In this way some amounts have likely been prolonged seven or eight times, from which one can easily understand that this [business] is profitable to the Bank. We are told that during 1714 and 1715, more than a million Louis d'Or were brought into the Bank; on these coins alone the ½ percent fee would be 53,500 florins, not counting prolongations.

We shall now show what profit or loss accrues to a banker who has brought in the 1000 Louis d'Or as in the example above. We have supposed that no more than 11.4 florins per coin was offered to him, by which he would could receive no more than 11,400 florins for his stock of 1000 coins.

Now the Bank dispenses to him for these
10,700 florins

And, applying an agio I assume to be 5 percent
535 florins

Equals their total value in current money
11235 florins

[40] Authors' translation of L'Espine and Le Long (1763, 197-202). L'Espine and Le Long illustrate the use of receipts with Louis d'Or, a large French gold coin that does not appear in the Bank archives after 1736. This example would therefore have been obsolete when this edition of the manual was published in 1763, suggesting that it was probably retained from an earlier edition.

Since this valuation of the 1000 coins is now 165 florins less than what he was offered, his receipt will cost him 0.162 florins per coin.[41] If he now, within six months (that being as long as his receipt runs without a prolongation), can get 5 or six stivers [.25 or .3 florins] more for every Louis d'Or, then he sells these and delivers the receipt, without conveyance or endorsement, to the buyer, who pays him in current money. And, if the buyer then has an opportunity to profitably sell these, he can take advantage of this opportunity at any time. In this way receipts can frequently go through 7, 8, or more pairs of hands within their specified maturity, without the need for any conveyance or endorsement.

If you want to withdraw the 1000 Louis d'Or from the Bank during the six months' maturity of the receipt—say because you want to send them elsewhere or because you sell them for current money—then you first have to compensate the Bank for the funds it advanced, that being in this case

10,700 florins

To which ½ percent must be added

53.5 florins

Totaling all together

10753.5 florins

For this sum you write a payment order to the Bank, *on your account*, and then bring this order to the Bank, and request the 1000 Louis d'Or in accordance with the receipt. The Bank bookkeeper, having received this, first researches whether there are sufficient funds in your account. Finding that there are, he immediately sends along a Bank servant to inform the Lord Commissioners of the Bank, that they may dispense to the bearer the requested 1000 Louis d'Or. One of the Lord Commissioners then goes to retrieve these, and transfers them to the person bringing the receipt, sealed [in a sack] with their weight inscribed on them, in return for the surrender of the receipt. At this point the matter is concluded.

It should also be mentioned that although you may have purchased a receipt for coins that were brought into the Bank by another, that you must still make out the order to the Bank *on your account* if you want to withdraw the coins. The name of the original depositor of the coin does not matter in the least; it is the holder of the receipt, regardless of who that may be, whose obligation it is for the value of the withdrawal, and therefore whose account must be debited.

There is sometimes heavy trading in receipts, primarily in [Spanish] Pieces of Eight, [Dutch] Ducatons, and [French] Louis D'Or. In the years 1714 and 1715, so many Louis D'Or were brought into the Bank, that receipts did not fetch more that 4 or 5 stivers [.2 to .3 florins] per Coin. In 1716 the price rose to 16 to 17 stivers [.8 to .85 florins] per Coin.

[41] Literally, 3 Dutch stivers plus 4.8 pennies. This may be an arithmetic mistake, 0.165 florins would be 3 stivers plus 6 pennies.

C.2 An example of a "carry trade" funded with receipts

The value of the trading strategy described by L'Espine and Le Long (essentially, funding one's position in the Amsterdam bill market via the receipt window) can be illustrated with a simple example. Suppose there are two hypothetical investors in the Amsterdam bill markets. The initial endowments and the trading strategies of the two investors are as follows:

Investor 1 is endowed with a ryxdaalder coin worth 2.4 bank florins at the receipt window, as described in Table 2 above. He deposits this coin with the Bank and uses the proceeds to purchase a 2-month bill of exchange on London. When the London bill is paid, he uses the proceeds to purchase a 2-month bill on Amsterdam. When the Amsterdam bill is paid, he "cashes out" by either redeeming the receipt at a cost of ¼ percent or selling his bank florins in the spot market, whichever yields more current guilders (for purposes of this example we ignore the "liquidation value" of the receipt, which would still have 2 months to run, if Investor 1 chooses the latter option).

Investor 2 is endowed with a current guilder. He sells this in the spot market for bank money, and uses the proceeds to purchase a 2-month bill on London. When the London bill is paid, he uses the proceeds to purchase 2-month bill on Amsterdam. When the Amsterdam bill is paid, he "cashes out" by selling his bank florins for current money in the spot market.

Recalling the notation in Appendix B, let A_t be the log of the initial Amsterdam price of a bill drawn on London and let L_{t+2} be the log of the London price of a bill on Amsterdam, two months later. Let a_t be the initial market agio expressed in decimal terms and let a_{t+4} be the market agio four months later. Investor 1's return is given as (A_t and L_{t+2} are logged bill prices as defined in Appendix B)

$$R_1 = 2.4\left(\max\left\{ \frac{1}{2.406}, \frac{1+a_{t+4}}{2.5} \right\} \right)\left[\exp(L_{t+2} - A_t) \right],$$

whereas Investor 2's return is

$$R_2 = \left(\frac{1+a_{t+4}}{1+a_t} \right)\left[\exp(L_{t+2} - A_t) \right].$$

It follows that $R_1 > R_2$ whenever

$$\max\left\{\frac{2.4}{2.406}, \frac{2.4(1+a_{t+4})}{2.5}\right\} > \left(\frac{1+a_{t+4}}{1+a_t}\right) .$$

This can occur in either of two cases. In the first case

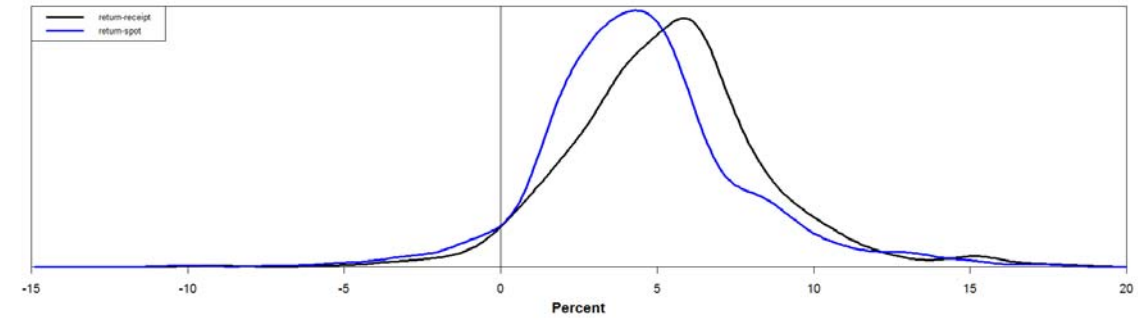
$$\frac{2.5}{2.4} = 1.04167 < 1+a_t ,$$

i.e., the agio is above 4.167 percent. In the second case,

$$\frac{2.4}{2.406} = .9975 > \frac{1+a_{t+4}}{1+a_t} ,$$

i.e., the agio falls by more than .25 percent over the four-month trade. These conditions were often observed in practice. Figure C.1 plots the smoothed histograms of annualized returns (i.e., $300 \times$ logs of) R_1 and R_2 over our sample:

Figure C.1: Empirical densities of R_1 and R_2 (annualized), 1736:1-1791:12



From the figure, we can see that the hypothetical investor funding a "carry trade" by borrowing from the Bank using ryxdaalders averages about a 90 basis points higher return than an investor who funded the same trade through the spot market (even ignoring the liquidation value of the receipt, which would have further increased this differential). In reality, it is doubtful that the Amsterdam markets allowed such a differential to persist, because its existence would have created an incentive to bid up the market price of ryxdaalders. This most likely would have been accomplished via the purchase of

ryxdaalder (and similar trade coin) receipts in the daily spot market as described by L'Espine and Le Long, Adam Smith, and other contemporary observers. Unfortunately, very few records of receipt sales have been preserved, so this conjecture cannot be verified empirically.