This version: January 12, 2011

How Amsterdam got Fiat Money[1]

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Abstract: We investigate a fiat money system introduced by the Bank of Amsterdam after 1683. Using data from the Amsterdam Municipal Archives, we reconstruct changes in the bank's balance sheet from 1666 through 1702. Our calculations show that the Bank of Amsterdam, founded in 1609, was engaged in two archetypal central bank activities—lending and open market operations—both before and after its adoption of a fiat standard. After 1683, the bank was able to conduct more regular and aggressive policy interventions while reducing its capital base. The bank's successful experimentation with a fiat standard foreshadows later developments in the history of central banking.

[1] The authors would like to thank John McCusker for sharing agio data, Lodwijk Petram for sharing the Deutz folios, and Albert Scheffers for help with the balance books. Also, for comments on earlier drafts we are grateful to Christiaan van Bochove, Toni Braun, Pit Dehing, Marc Flandreau, Oscar Gelderblom, Joost Jonker, and Charles Sawyer, as well as participants in seminars at the University of Alabama, the Bank of Canada, the Federal Reserve Banks of Atlanta, Chicago and New York, and Rutgers University. We are indebted to Michelle Sloan for many hours of skilled data encoding. Generous research and travel support was provided by the FRB Atlanta and TCU.

1. Introduction

Financial innovation consists of doing more trading with less collateral. A key innovation, present in all modern economies, is the use of *fiat money*—a kind of virtual collateral whose value derives only from the force of law and custom. Conventional wisdom says that fiat money can enhance liquidity through "credit policy"—the directed relaxation of collateral constraints through a central bank's lending operations, and through "monetary policy"—the beneficial manipulation of economic aggregates through variation of the money stock.[2]

Fiat money, and its implications for policy, are usually seen as twentieth-century developments. This paper analyzes an earlier and less well known experiment with fiat money, undertaken by the Bank of Amsterdam (*Amsterdamsche Wisselbank*, henceforth AWB or simply "bank"). The Amsterdam experience with fiat money is noteworthy for its originality, its prominence in European financial history, and its compatibility with price stability over a long period (roughly a century: 1680 through 1780). The AWB opened in 1609 as a municipal exchange bank, an institution for facilitating settlement that was common in Early Modern Europe. Our focus is on the period around 1683 when the bank limited its depositors' ability to withdraw coin, and so effectively became a fiat money provider. The fiat money regime remained in place until the bank's collapse in 1795.[3]

The bank's transition from exchange bank to fiat bank has been described by economic historians (e.g., Mees 1838, van Dillen 1934, Neal 2000, Gillard 2004, van Nieuwkerk 2009), but these contributions do not fully explain the motivation for the transition. If fiat money did indeed lower and smooth the costs of collateral in Amsterdam markets, how were these changes mani-

[2] In its pure form credit policy does not change the stock of money; see e.g., King and Goodfriend (1988).
[3] The bank was not fully dissolved until 1819.

fested, and who benefited? To lapse into modern terminology, how did an early central bank alter monetary and credit policies after limiting the right of withdrawal?

To shed some light, we examine historical data on the bank. Using ledgers available from the Amsterdam Municipal Archives, we have compiled partial balance sheets, at a daily frequency, for the AWB from 1666 through 1702, a period centered on the fiat money transition. When combined with information from other sources, these data present a revealing picture of the bank's activities.

First, the data clearly show that the fiat money regime freed the City of Amsterdam to collect retained earnings from the bank. Also, the bank changed how it lent to its preferred customer, the Dutch East India Company (*Vereenigde Ostindische Compagnie* or VOC or simply "company": a government-sponsored enterprise employing approximately 50,000 people during our period of interest). The bank lent to the company both before and after 1683; but afterward this lending became more seasonal and regular in nature. Seasonality means that this lending often does not show up in the annual bank balance sheets assembled by van Dillen (1925) nor in the annual balance sheets of the company assembled by de Korte (1984). Dividends and lending became cheaper and less risky for the bank because liquid claims on the bank were limited and chances of a run were ameliorated.

Secondly, our analysis indicates that both before and after 1683, the bank regularly engaged in open market operations. Again, however, the character of this intervention evolves under the fiat regime, as the bank more often chose to "drain funds" by selling off its metal stock. Indirect evidence suggests that an objective of these operations was to smooth short-term fluctuations in the stock of base money.

In short, the data show that by 1683, the bank's managers had ample experience with both lending and open market operations. The move to fiat money allowed for more vigorous pursuit of these same activities.[4]

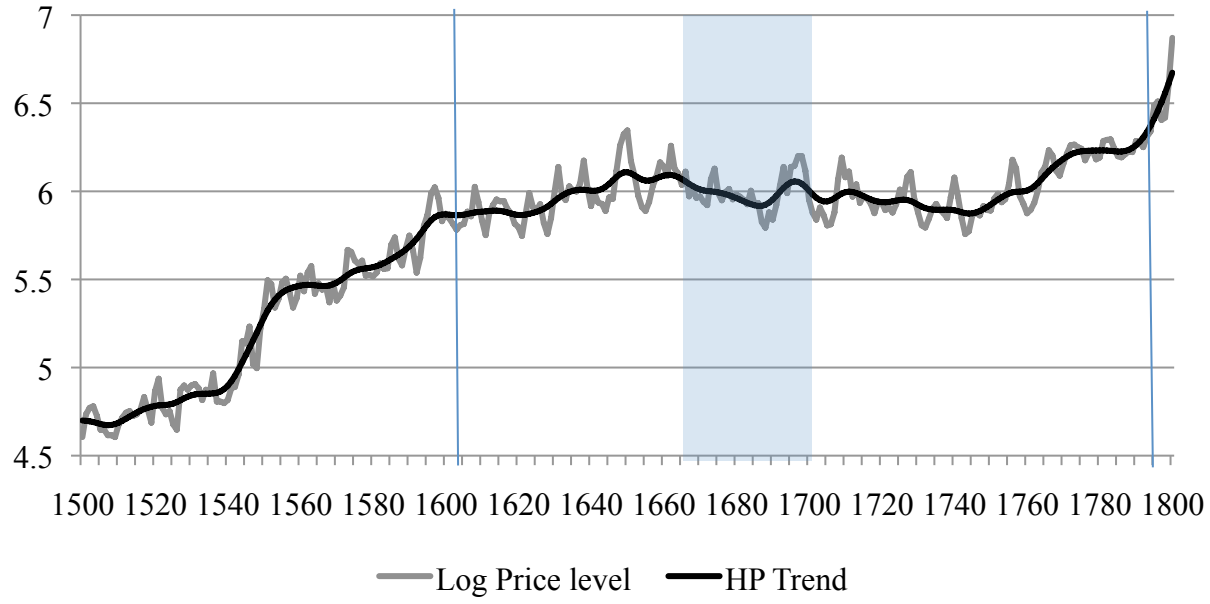
The rest of the paper is organized as follows. Section 2 sets the historical stage for the 1683 policy change. Section 3 describes and presents the data. Section 4 offers some interpretations of the data. Section 5 discusses related literature, and Section 6 concludes.

2. Historical prologue

For Amsterdam, the original purpose of its bank was to protect commercial creditors from the unreliable commodity money in circulation. Modest debasement and resultant inflation was ubiquitous in the Early Modern Netherlands. Figure 1 shows the log of an annual price index for the northern Netherlands from 1500 to 1800, and marks the founding of the AWB in 1609. The bank was to be an island of debt settlement backed by high-quality coins (Quinn and Roberds 2009b). The Dutch chose to follow the model of Venice's *Banco di Rialto* and make the AWB an exchange bank that provided only payment and settlement services (Dehing and 't Hart 1997, 45-6). The bank did not issue notes and was not to lend. The bank did contribute to long-run price stability until the bank's end in 1795 (also marked in figure 1). This paper's sample period (the shaded area in figure 1) has a slightly deflationary trend except for a bout of inflation caused by the Nine Years War (1688 to 1697).

[4] It is well known that a fiat money system is not a necessary condition for activist monetary and credit policies; see, e.g., Goodfriend (1988) for a discussion of the Bank of England's interventions under the Classical Gold Standard.

Figure 1. Dutch Price Level, 1500 to 1800



Source: van Zanden (2004).

The bank used asymmetric rules to discourage metal outflows while promoting metal inflows and internal settlement. The bank had no fees on deposits, and one could present the bank with precious metal in any form. If a coin had a price assigned by statute, then the bank honored that price. Metal in other forms was valued by content. And once created, a balance could settle a debt through transfer to the creditor's account at no fee.[5] Creditors gained finality and a trusted general collateral claim. Similar to modern large-value payment systems (e.g., Fedwire), the AWB created finality through gross settlement, meaning that the bank payments could credibly be viewed as final because the bank avoided extending credit and never (explicitly) adopted netting of payments.[6]

[5] The bank was permitted to charge transfer fees but chose not to until 1683 when it began charging both sides of all transfers 0.00025 percent payable at the end of the fiscal year (van Dillen 1934, 85).

[6] Some qualifications are necessary. The bank cleared payments once every day (Mees 1838, 124-5) so there was in principle scope for multilateral netting at a daily frequency, i.e., the practical seventeenth-century definition of "real-time" gross settlement was probably once per day. Also, despite rules to the contrary, some accounts were occasionally in an overdraft position, particularly before the 1683 transition (Willemsen 2009).

At withdrawal, Amsterdam obliged the bank to supply high-quality Dutch coins at official prices, but the bank was allowed to charge a fee of up to 2 percent for silver coins and 2.5 percent for gold coins: though under normal conditions, fees averaged 1.5 percent or less (Van Dillen 1964a, 348; see also Table 2 below). The fees compensated the bank for minting costs and helped cover operating expenses. Some uncertainty also existed, for the bank had discretion regarding which of those Dutch coins it offered at withdrawal. If a customer desired a different coin, then the bank could charge an additional premium based on its role as a moneychanger. Moneychanger fees of some level were necessary to prevent coin-to-coin arbitrage.[7] Most important to our story, however, is that the fees discouraged withdrawals.

This paper focuses on the consequences of withdrawal structure, so we stress that the effects of the high withdrawal fees varied by customer. Unlike a modern central bank, anyone with sufficient funds could open an account. Among merchants who routinely operated within the bank's internal payment system, fees were a negligible concern, for they did not expect to withdraw balances. Of greater moment to them was that the city of Amsterdam *required* all large bills of exchange to be settled at the AWB. The requirement intended to create a demand for deposits, and it did, for bills of exchange were the primary means of commercial credit. The bank's total balances reached 925,562 guilders after one year (van Dillen 1934, 117), and grew to 8.3 million guilders by 1683, amounting to about 5 percent of the coin stock of the Dutch Republic (De Vries and van der Woude 1997, 90).[8]

In contrast, customers who needed specie learned to skip the primary withdrawal process, and avoid bank fees, by paying for coins outside the bank with free transfer inside the bank. Fee

[7] Arbitrage is discussed in more detail in Section 4.
[8] The guilder, also known as the florin, was the unit of account in the Dutch Republic. At the time of the AWB's founding, the guilder did not correspond to an actual coin in circulation. A guilder (*gulden*) coin was introduced in 1680, but it was never assigned an ordinance value in bank guilders.

avoidance also meant that potential deposit customers did not bring metal to the bank. By 1650, the outside market in bank balances had deepened as private bankers, called cashiers, emerged as dealers who specialized in holding AWB balances and various coins (Van Dillen 1964a, 366-7).

The secondary market lived on margins within the bid-ask spread of the bank's deposit-withdrawal facility, and the expected costs of the primary market were particularly high for short-term deposits. For example, someone who deposited metal and withdrew it one month later at a 1 percent fee had, in effect, borrowed funds at a simple annualized rate of 12 percent. The bank was thus an expensive place to "park" specie. Relative costs fell with time, and long-term participants in the Amsterdam payment system, like cashier-bankers, could recoup these "borrowing" costs through their secondary market operations. As a result, the short-term metal market stayed outside the bank. Little metal routinely flowed in or out of the bank, for deposits waited for periods of cheap metal and withdrawals for expensive metal.

2.1 Lending

Lending was the first major deviation from the bank's original plan. The young AWB soon began lending to the city, the province of Holland, the Republic, government sponsored entities like the East India Company, and select individuals such as mint masters and officers of the Admiralty (Van Dillen 1934, 94-100).[9] After a turbulent half century, however, the bank limited new lending to Amsterdam and the company. Table 1 gives the bank's balance sheet at the end of January 1669. The bank's metal-to-deposit ratio is 74 percent. While not a reckless position, the bank needed to be mindful of the threat of a run.

[9] The bank's lending activities were widely rumored, but the bank did not publicly acknowledge these until much later. See, e.g., Steuart (1805, 403).

Table 1. AWB balance sheet

On January 31, 1669, in millions of bank guilders

Assets	**Liabilities**
4.5 Metal	6.1 Deposits
2.1 Loans to Amsterdam	1.8 Capital
0.2 Loans to Holland	
1.1 Loans to VOC	
Total 7.9	Total 7.9

Source: Amsterdam Municipal Archives, 5077/1314.

Indeed, the French invasion of the Dutch Republic triggered a run in June 1672, during which (our calculations find) the bank lost 34 percent of its balances in two weeks.[10] Both the Province of Holland and the East India Company suspended debt payments, [11] but the bank successfully passed this test, partly because withdrawal fees had kept the large yet volatile short-term specie flows out of the bank. The absence of "hot money" directly reduced the scale of the run and spared the bank the adverse signals produced by the sudden flight of short-term capital.

Evidence also suggests that the bank adjusted fees to affect withdrawal rates, for the bank raised fees in 1672 and kept them high for years afterward. We use the ratio of the bank's non-interest revenues as a percentage of withdrawals to proxy for average fee rates; these ratios are reported in table 2 for 1666 to 1683.[12] We are missing complete withdrawal information for some years, and other years with low withdrawal activity, like 1669 and 1676, are particularly sensitive to our withdrawal sorting algorithm (explained in Section 3).[13]

[10] On June 14, 1672, the bank's total balances were 7.6 million guilders. Balances had fallen to 5.0 million by June 30 with a metal stock at an estimated 4.5 million.
[11] For sovereign debt, see Gelderblom and Jonker (2010). For the VOC, see de Korte (1984, 66).
[12] After 1683, the bank reported only profit: revenue less expenses.
[13] For example, half of the 106,000 guilders withdrawn in 1676 are accounted for by one withdrawal for 50,650 guilders.

Table 2. Non-Interest Revenues as a Percent of Withdrawals

1666	1667	1668	1669	1670	1671	1672	1673	1674
1.16%	1.36%	1.25%	2.26%	1.48%	1.50%	2.50%	NA	2.06%
1675	1676	1677	1678	1679	1680	1681	1682	1683
3.57%	0.61%	NA	1.67%	NA	2.59%	3.76%	NA	0.80%

Source: Authors' calculation: see Appendix A.

2.2 The bank guilder

The other major deviation from the AWB's original scheme requires some background, for it defies conventional expectations, then and now (Quinn and Roberds 2009a). In 1638, the Dutch Republic raised the official price of a coin called the *patagon*, a coin minted in the neighboring Spanish Netherlands. The invading *patagon* intentionally contained 4 percent less silver than the domestic *rijksdaalder* delivered by the bank. The new price put the bank in an unsustainable position, for the 1638 rule said that the bank had to accept *patagons* at 2.5 guilders each, but an older rule made the bank to offer out *rijksdaalders* at the same price. After a period of arbitrage losses, the bank switched to giving out *patagons* at withdrawal — a 4 percent "haircut" for depositors. To then make depositors whole in terms of silver, but still avoid rekindling arbitrage, the bank decided in 1645 to reduce the price of *patagons* at the bank by 4 percent, from 2.5 to 2.4 guilders each. So, in the end, a customer received 4 percent more coins per guilder, but each coin held 4 percent less silver.

This ad hoc solution had the unintended effect of creating a separate unit of account for bank funds, the *bank guilder*, distinct from the *current* (non-bank) *guilder* (Quinn and Roberds 2007). How so? The Patagon was worth 2.4 bank guilders inside and 2.5 current guilders out-

side.[14] In turn, a secondary market developed between the two units of account. Before 1638, each type of coin had a direct secondary market relationship with the bank that swapped media of exchange: coins for accounts. After 1645, the secondary market focused on exchanging units of account: bank guilders for current guilders. A separate price then traded current guilder accounts at cashier-bankers into coins. The exchange market between bank guilders and current guilders deepened to become the principal measure of the value of the bank guilder. The exchange rate was called the agio, and the market measured the agio as the premium commanded by bank guilders. To the extent that the metal content of current money changed only slowly after 1659, the agio can be thought of as a price of bank money in terms of a reference collateral good, i.e. silver.

2.3 The restructuring

The changes of the 1680s—the focus of this paper—hinge around the AWB introducing a new primary withdrawal structure that greatly reduced the asymmetry between deposits and withdrawals.[15] In 1683, the bank started to give customers a receipt for the *specific* coins they deposited.[16] At withdrawal, the receipt obliged the bank to return the same coins at the deposit price. Also, the receipt's redemption fee was only ½ percent for gold and ¼ percent for silver. Customers found the receipt's specific claim and low fee far more attractive than the traditional general claim at a high fee. Customers rushed to use the new facility.

[14] When the Dutch Republic replaced the *patagon* with domestic coins in its 1659 minting ordinance, the state retained the dual price structure and assigned each of two new silver coins, the *dukaat* and the *rijder*, a distinct bank guilder value and current guilder value.

[15] The new structure had been suggested by an Amsterdam businessman, Johannes Phoonsen, in a 1676 essay (van Dillen 1921), partly as a way to guard against bookkeeper fraud.

[16] The receipt allowed its holder to claim the coin anytime within a six-month period, i.e., the receipt resembled an American call option on a specific type of coin, or put option on bank funds.

The bank also made receipts negotiable, and resale mattered because the pre-existing stock bank guilders did not get receipts.[17] About 8 million bank guilders had only the right to expensive traditional withdrawal. For new deposits, the 1683 reform unbundled the traditional deposit contract (in which a depositor receives a transferable claim on the bank, plus an option to withdraw) into two separate contracts: the bank guilder account and the receipt. The receipt's option to withdraw lasted six months, but one could renew it for another six months by paying the withdrawal fee. Receipts were especially popular with foreign merchants as a way to park precious metals in Amsterdam and take advantage of profitable trading opportunities if these presented themselves. If needed, coin could be withdrawn at low cost.

Receipts smoothed the introduction of fiat money, for customers learned to trade for the new withdrawal claim instead of exercise the old claim attached to the account. Demand for traditional withdrawal withered, so the bank could quietly limit the right to traditional withdrawal sometime in the 1680s.[18] From this point onward, someone holding a bank balance could withdraw coin only if they had a receipt. The stock of bank guilders split into commodity-backed receipts and what Mees (1838) terms an "irredeemable coin of account"—fiat money.

Customer acquiescence to fiat money seems to follow from people no longer expecting to use traditional withdrawal except during a run on the AWB. Attentive customers could perceive themselves gaining more than they lost. After the introduction of receipts, the option to withdraw the old way was "in the money" only during a run, yet a run was the mass execution of traditional withdrawal rights. Eliminating the individually superior yet collectively dangerous strat-

[17] Legally, new deposits became repurchase agreements between the depositor and AWB (van Dillen 1964b, 395). Also, receipts were often traded separately from their associated deposits; see Adam Smith, *Wealth of Nations*, Book IV, Chapter 3.

[18] Exactly when redeemability was abolished is unknown. To quote van Dillen (1934, 101): "to that great change no ordinance nor any precise date can be assigned." Indirect evidence, described in Section 4, indicates that redeemability had been de facto abolished by 1685.

egy (traditional withdrawal) left a feasible limit on the extent of a run (the stock of receipts), so giving up the option made individuals better off, as long as others also relinquished their option. In the tight-knit world of Dutch political economy, such collective understandings were not uncommon. For example, provincial governments repeatedly but informally suspended sovereign debt payments during crises with little creditor outcry (Gelderblom and Jonker 2010).

Receipts limited withdrawal fees, fiat money limited the pool of potential withdrawals, and customers bought the combination. Of course, fiat money could also change the behavior of the bank, so now we turn to our measurements of bank activity.

3. Data

Researchers interested in the activities of modern central banks have access to copious amounts of data. The Federal Reserve System, for example, publishes its balance sheet on a weekly basis (the H.4.1 release) and publishes daily data on the market price of its liabilities (the effective fed funds rate). Some studies have even examined records of individual transactions over central banks' payment systems (for Fedwire, see e.g., Bartolini et al. 2008; Furfine 1999, 2001, 2003, 2006; McAndrews and Potter 2002; McAndrews and Rajan 2000) to analyze money market activity. Almost incredibly, much of this same information is preserved for the Bank of Amsterdam. This section introduces the data used in our investigations.[19]

Turning first to balance sheet data, complete balance sheets for the AWB (totaling both assets and liabilities) are only available at a yearly frequency.[20] However, the ledgers of the bank, available at the Amsterdam Municipal Archives, record *every* transaction in bank funds over a given period, so we use the ledgers to reconstruct daily time series of movements in bank liabili-

[19] The data are described in detail in Appendix A.
[20] These were calculated at the end of every January when the bank was closed to reconcile accounts. See Van Dillen (1925).

ties, i.e., changes in aggregate stock of bank guilders. Money creation (e.g., deposits) and destruction (withdrawals) is recorded on ledgers of a bank master account.[21] Similarly detailed records of the bank's metallic assets and some determinants of capital (fee revenues, expenses, and open market profits) have not survived for our period of interest, but distributional assumptions allow us to construct monthly capital-to-asset ratios in line with known annual figures.

Loan assets can be reconstructed at the daily level. Lending to the East India Company in particular is easily detected using a "Furfine algorithm": VOC loans appear as large debit entries to the bank's master account (credits to the company), for large sums in round numbers, and (principal) repayments as similar credit entries.[22] Potential open market operations are more problematic. A given debit entry to the bank's master account, for example, may represent an open market purchase, or simply a deposit. Still, we can identify some likely episodes of open market interventions with the help of a second Furfine algorithm, described below.

With the loss of most early ledgers, a continuous series of extant ledgers only begins in 1666, so our data set starts then. We end in 1702 to capture 35 years of activity surrounding 1683. We focus only on transactions that change the stock of bank guilders. Even so, we have encoded 20,000 individual master account debit transactions (those that created bank guilders through the deposit of metal, purchase of metal, or new lending). Credit transactions (withdrawals, sales, or loan repayments) produced 17,000 individual transactions. To gain visual clarity and compatibility with the agio data, data have been aggregated into monthly observations: lev-

[21] The *Specie Kamer* or "coin room."
[22] A nearly identical method, pioneered by Furfine (1999), has been used by researchers to filter interbank loan transactions from modern large-value payment system data (e.g., fed funds transactions from Fedwire data).

els being the start of a month and flows being month finish less month start. 420 monthly observations are available over the sample period of 444 months. [23]

Available price data are less complete, but nonetheless extensive. The time series we use is a set of monthly (presumably, average) observations on the market price of bank money (i.e., the agio), spliced together from two sources. The first is an augmented and unpublished version of the agio series in McCusker (1978), generously provided to us by John McCusker. The second is from the records of Joseph Deutz, a prominent Amsterdam merchant, available at the Amsterdam Municipal Archives.[24] The McCusker data cover our whole period, while the Deutz data run from 1662 to 1688. Combining the two data sources yields 290 monthly observations. For some of our econometric exercises (e.g., VARs), the agio series was interpolated to a full sample using a related series, the London price of Amsterdam bills reported in McCusker (1978).[25]

Agios are quoted in sixteenths of a guilder, attesting to the liquidity of the market for bank funds. A sixteenth of a guilder also represented the typical profit margin for a cashier on a bank money trade (Steuart 1805, 405).

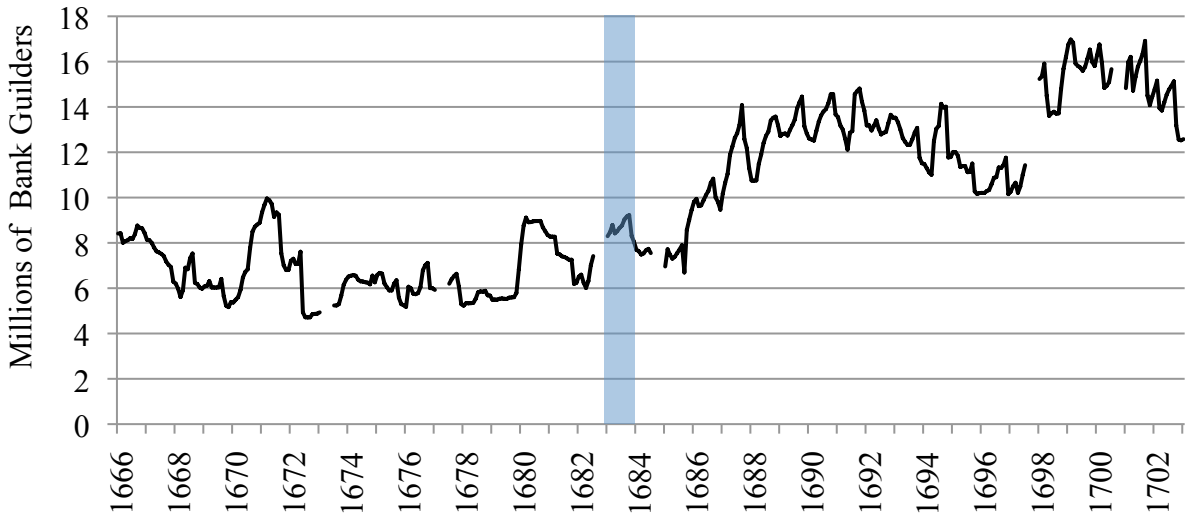
3.1. Balances and the Agio

The basic data on quantity (balances) and price (agio) are presented in figures 2 and 3. Also, to focus on the routine, figure 3 truncates the negative agio values observed during the 1672 French invasion and very high agio observations in 1693.[26] Interpolated values of the agio are shown as grey lines in figure 3. Vertical lines in the charts mark the initiation of the receipt

[23] Six half-years are missing out of the 70 half-years covered here. Missing periods are February-July 1673, February-July 1677, September 1682-January 1683, August 1684-January 1685, August 1697-January 1698, and August 1700-Janurary 1701.
[24] Amsterdam Municipal Archives inventory numbers 234 / 290-295.
[25] See Appendix A for the details of the interpolation.
[26] The early 1693 spike in the agio resulted from a widely anticipated, legally mandated devaluation of two coins, the *schelling* and the 28-stuiver *florijn*, that had become severely debased (Mees 1838, 113-114). The coins circulated as current money but were not eligible for deposit at the AWB. The devaluations were for 7 and 8 percent respectively, causing the agio to temporarily run as high as 13 percent (the usual 5 percent premium of bank money above current money plus the amount of the anticipated devaluation).

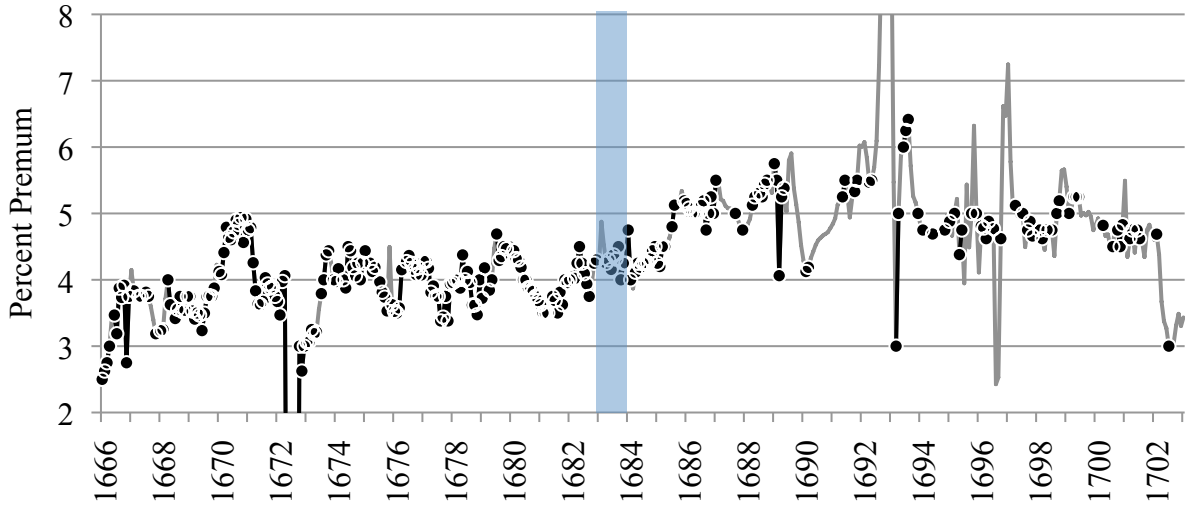
system in 1683. We use the advent of receipts to cut our sample because we lack a date between 1683 and 1685 for the transition to fiat money.

Figure 2. Monthly AWB balances, 1666:2-1703:2



Source: Authors' calculation: see Appendix A.

Figure 3. Monthly agio, 1666:2-1703:2

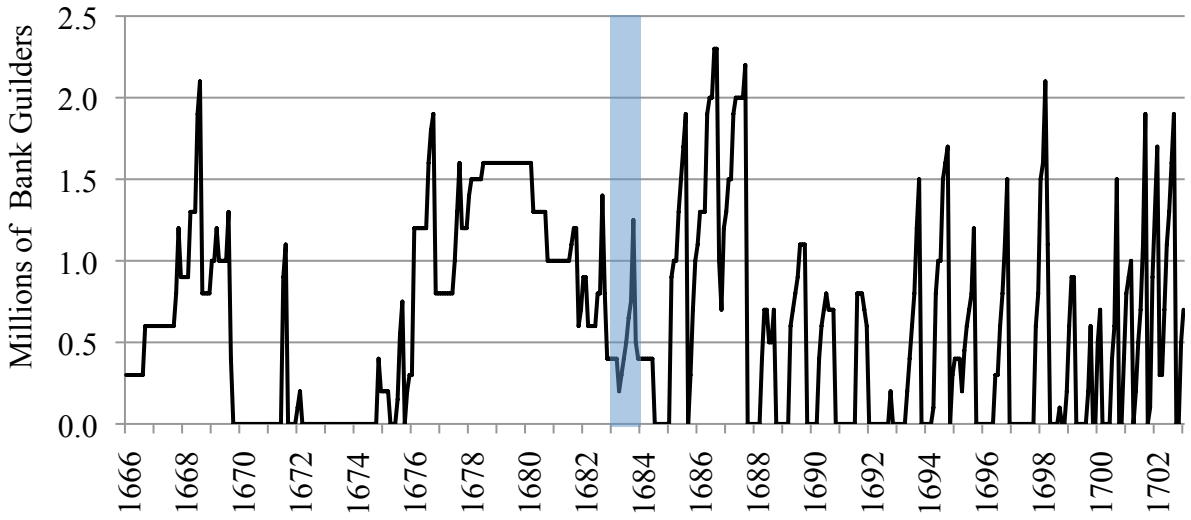


Sources: McCusker (1978); Amsterdam Municipal Archives 234/290-295; Authors' interpolation in grey.

3.2 The AWB's uses of funds

The first step in analyzing the asset side of the bank's balance sheet was to separate VOC loan balances using the procedure mentioned earlier.[27] These are shown in Figure 4.

Figure 4. Monthly VOC loan balances (principal), 1666:2-1703:2



Source: Authors' calculation: see Appendix A.

Lending to the company was an important activity of the bank, both before and after 1683 (Uittenbogaard, 2009). The Amsterdam city council authorized a credit line of 1.7 million in 1682 (Mees 1838, 196), but figure 4 shows that this limit had already been breached in practice. The peak level of VOC indebtedness does not increase after 1683, but the data clearly show that multi-year bank credit to the company fell away while short-term trough-to-peaks grew.

The data challenges are more severe for non-loan uses of funds. Bank records say nothing about what collateral changed hands when bank guilders were created or destroyed, but the bank did use different accounting channels for different types of transactions. We have identified one channel for coin deposits and another channel for bullion purchases. Essentially, coin deposits

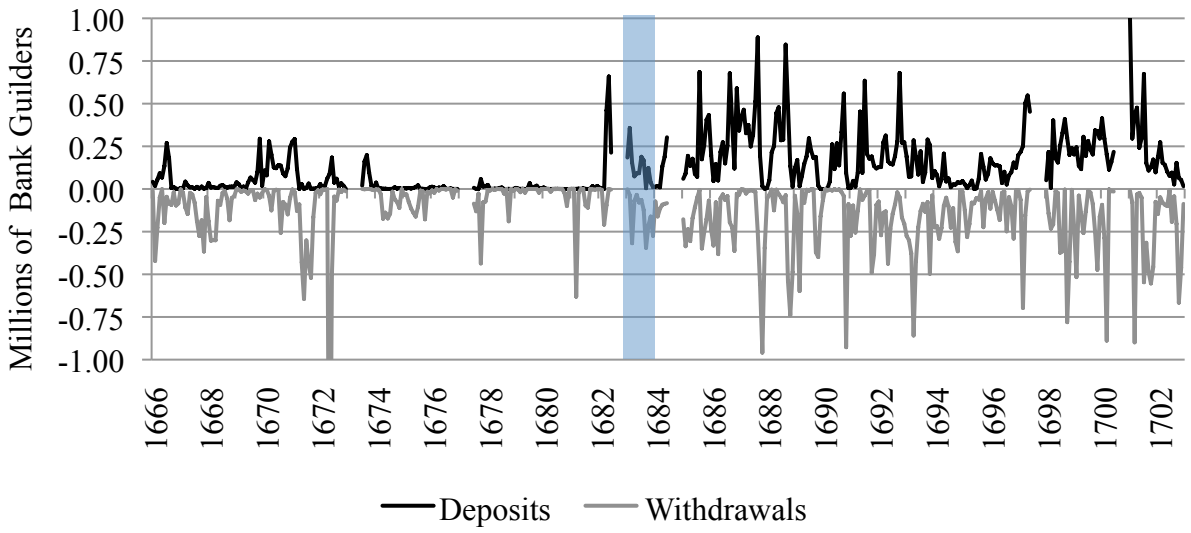
[27] We also segregate Amsterdam's loans and analyze that data in Section 4.1.

are routed through the accounts of the bank's clerical staff, while purchases (i.e., sales of balances) appear directly as debit entries to the bank's master account.

Metal sales by the bank (purchases of balances) do not have a distinct accounting channel, so these sales are (somewhat more tentatively) proxied using another Furfine algorithm: whole guilder transactions are assigned as "coin withdrawals" and transactions with fractional amounts to "bullion sales." We describe coins as being deposited and withdrawn because the bank was obliged to accept and return official coins at ordinance prices. Recall that the withdrawal contract was defined in terms of official coin prices and that altering such prices undermined the collateral structure of all balances. In contrast, the bank had latitude regarding bullion (including non-official coins, metal wire, etc.), and the bank routinely violated what restrictions had been placed on the buying and selling of bullion (van Dillen 1934, 92-3).

Based on this sorting of transactions, much of the increase in balances after 1683 came through more coin deposits. And, as would follow from lower withdrawal fees, there were also more coin withdrawals. Figure 5 presents the amount of coin deposits and withdrawals by month from February 1666 to January 1703. Inflow and outflow deepened considerably after the regime change and were in no obvious way discouraged by the move to fiat money. Note that post-1683 inflows roughly mirror outflows, providing some confirmation for the algorithm used to identify coin withdrawals.

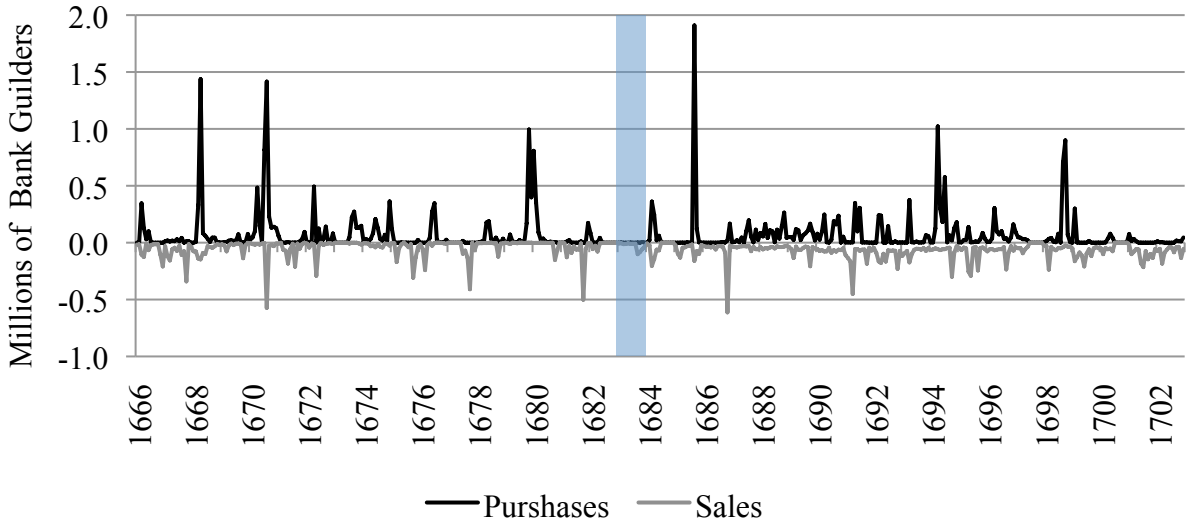
Figure 5. Monthly coin deposits and withdrawals, 1666:2 to 1703:2



Source: Authors' calculation: see Appendix A. Note that June 1672 Coin Withdrawals is truncated: the observation's value is minus 2,478,372 bank guilders.

The transactions we identify as bullion operations show a different pattern. Figure 6 presents our calculation of bullion purchases and sales by month over our sample period. Total purchases before 1683 (14.6 million) roughly equal purchases after (15.4 million), while total sales doubled from 8.6 million (1666-1682) to 16.7 million (1683-1703). A dramatic aspect of the bullion series is the infrequent spikes that we identify as large open market operations. There is noticeable asymmetry between sales and purchases: there are 9 months where the bank purchased more than 700,000 guilders worth of metal, but no months during which the bank sells so much metal.

Figure 6. Monthly bullion purchases and sales, 1666:2 to 1703:2

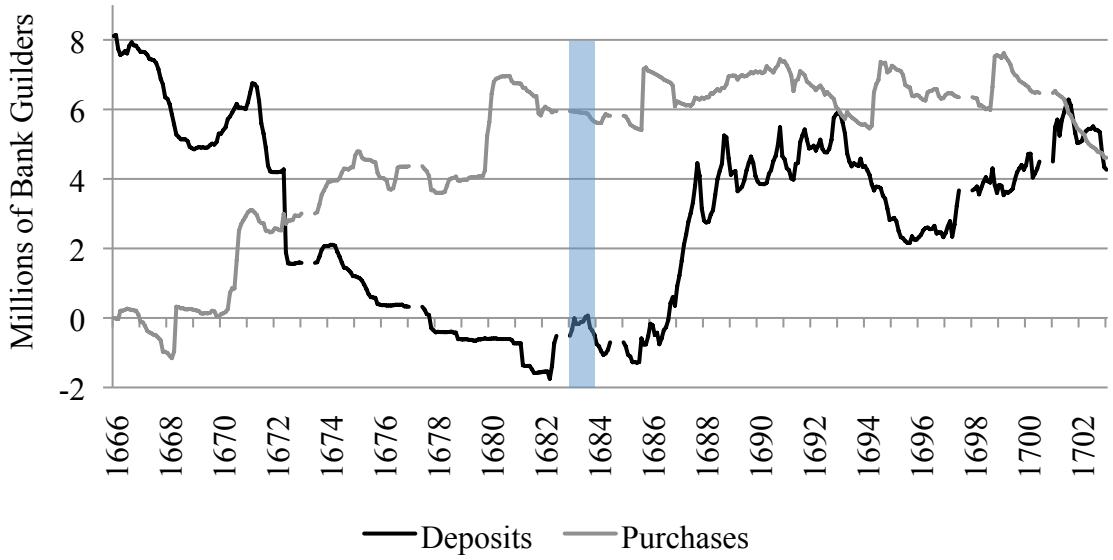


Source Authors' calculation: see Appendix A.

To finish our partial reconstruction of asset side of the AWB's balance sheet, the series shown in figures 5 and 6 must be integrated over time to obtain series on cumulated deposits and cumulated purchases. Since there are no initial values for these two component series, some normalizing assumption is required. [28] We conservatively set the bank's February 1666 purchases to zero, and set the initial value for cumulated deposits to be the entire stock of bank balances, excluding outstanding loans. The two series are graphed together in figure 7. The pre-1683 era shows that the stagnation of bank balances involved a long decline in deposits and an offsetting rise in the purchases. [29] After 1683, deposits were the driving force behind the expansion of bank balances.[30] The receipt system was a way to arrest the long term decline in deposits.[31]

[28] The cumulative series exclude adjustments for missing ledgers and discrepancies: adjustments included in balances to reconcile our monthly series with the annual numbers reported by van Dillen (1925).
[29] The decline of deposits likely began in the 1650s when the long-term growth in AWB balances ended. Quinn and Roberds (2009a) argues that the stabilization of the monetary system in the 1650s obviated the AWB's original role of protecting creditors from poor coinage, so demand for deposits slackened.
[30] Post-1683, cumulated purchases would approximate "outright purchases" of assets on a modern central bank's balance sheet, while cumulated deposits would (again quite roughly) correspond to "repurchase agreements."
[31] Demand for deposits also revived from instability in coin quality lasting from 1680 to 1693. See Section 4.2.

Figure 7. Cumulated net deposits and net purchases, 1666:2 to 1703:2



Source: Authors' calculation: see Appendix A.

3.3 Summary statistics

Table 3 reports statistics on the data series before and after the regime change. The table indicates that after 1683 the agio fluctuated around its approximate statutory level of 5 percent; it also becomes more variable. The distribution of first differences in the agio does not change significantly across samples, i.e., there is no change in "smoothness" of the agio after 1683. Balances increase due to accumulated metal purchases and an influx of deposits. Outstanding loans to the East India Company average about the same before and after 1683, but these become less smooth after the reform. Purchases become notably less variable.

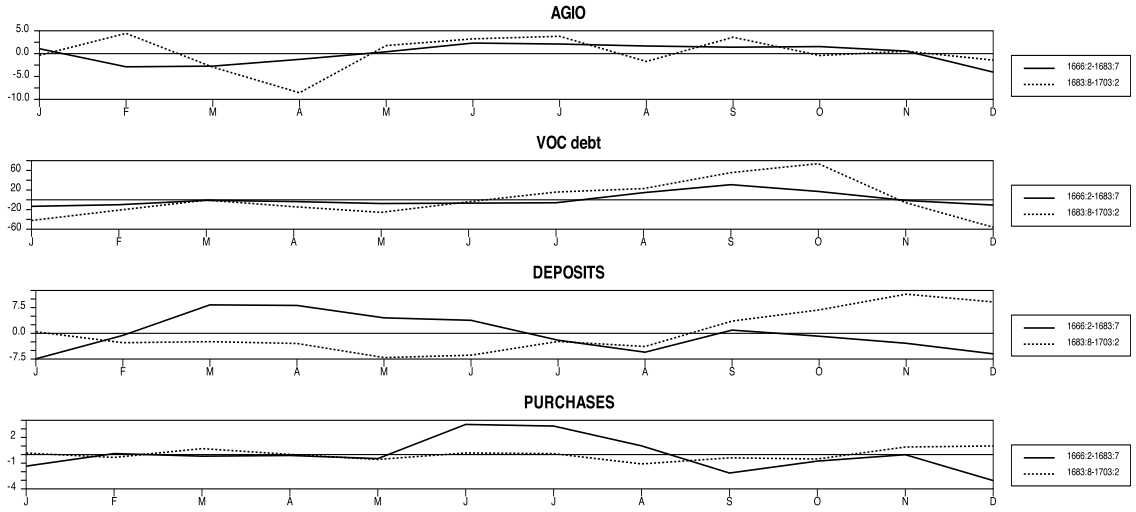
Table 3. Statistics on the agio and AWB balances

Series	Sample	$\mu(x)$	$\sigma(x)$	$\mu(\Delta x)$	$\sigma(\Delta x)$	$K(x)$	$K(\Delta x)$
Agio (percent)	1666:2-1683:7	3.89	0.458	0.007	0.256	5.69**	1.04
	1683:8-1703:2	*4.83*	*0.530*	*0.067*	*0.407*		
Total balances (million guilder)	1666:2-1683:7	6.81	1.28	-0.006	0.407	8.84**	1.84**
	1683:8-1703:2	*12.45*	*2.39*	*0.007*	*0.570*		
VOC Loan Principal	1666:2-1683:7	.685	.492	0.000	.234	1.57*	2.52**
	1683:8-1703:2	*.545*	*.621*	*0.001*	*.467*		
Deposits	1666:2-1683:7	2.44	3.11	-0.043	0.226	4.30**	3.42**
	1683:8-1703:2	*3.24*	*1.99*	*0.020*	*0.276*		
Purchases	1666:2-1683:7	3.14	2.31	0.031	0.196	7.95**	3.35**
	1683:8-1703:2	*6.41*	*0.653*	-0.006	*0.190*		

Source: Authors' calculation. Statistics for the agio omit two episodes of outliers: June-October 1672 and January-February 1693. *K* is the nonparametric Kolmogorov-Smirnov test statistic for the null hypothesis of equality of distributions across subsamples: two-sided 5% and 1% critical values for *K* are 1.36 and 1.63, respectively.

The empirical literature on the founding of the Federal Reserve (see Section 5) emphasizes changes in seasonal patterns for certain macro series around the time the Fed began operations in 1914. With these results in mind, we conducted two exercises to see whether the reforms resulted in similar changes. The first exercise was to simply calculate monthly means for the agio and the three monetary component series; these are shown in figure 8.

Figure 8. Monthly means (percent deviation from annual means)



Source: Authors' calculation. Outlier periods are omitted for the agio series.

There is little visual evidence of seasonality in the series for the agio and purchases, either before or after 1683. VOC debt becomes highly seasonal after the regime change with a marked October peak, and there is a shift in the seasonal peak of deposits from spring to fall. These patterns were confirmed in a second, more formal exercise, which consisted of performing standard F-tests for the significance of seasonal dummies in each equation of a VAR model (described in more detail in section 4) for the four series. Deterministic aseasonality is rejected at conventional significance levels for VOC purchases (more strongly in the second subsample), but accepted for the agio and purchase series, before and after 1683. For deposits, aseasonality is accepted before 1683 but rejected afterwards.

Initial exploration of the data thus suggests that the duo of receipts and fiat money saw higher flows and levels of deposits, less variable purchases, a higher average agio, and more seasonality in deposits and in borrowings on the part of the East India Company. The next section investigates to what extent these observed changes can be attributed to changes in policy.

4. The impact of policy changes

To market participants at the time, receipts were the only obvious discontinuity in the function of the bank after 1683. As before, the bank continued to serve as a trusted settlement service provider and as a (surreptitious) financial intermediary to the Dutch East India Company. Convertibility of deposits was limited, but money could easily be traded for coin on the open market, much as before. Receipts brought lower fees, but were there gains associated with the adoption of a fiat standard?

Our answer, in essence, is that placing restrictions on withdrawals allowed Amsterdam to partly escape the opportunity costs of a system of exchange based on commodity money (e.g., Sargent and Wallace 1983), as compared to a system with either greater availability of credit, or fiat money. To be certain, some amount of commodity money was essential for the functioning of a seventeenth-century open economy. A great entrepôt of its day, Amsterdam was where Europe purchased goods from Asia and other points east with silver unearthed in the Americas (de Vries and van der Woude 1997). Over time, Amsterdam also became the center of the European bullion trade.

However, the data shown in figure 5 indicate that before 1683, the bulk of the metal backing for deposits rarely entered or left at the monthly frequency, so the principal purpose of this metal was to confer value to the bank guilder. Over the longer term (figure 7), withdrawals outpaced deposits, but the bank chose to offset this trend with purchases, so overall balances remained stable (figure 3). The prospect of maintaining a stock of seven million guilders' worth of metal must have tempted even the most ardent hard-money advocates. Fiat money nudged the AWB's functionality somewhat closer to that of a modern central bank.

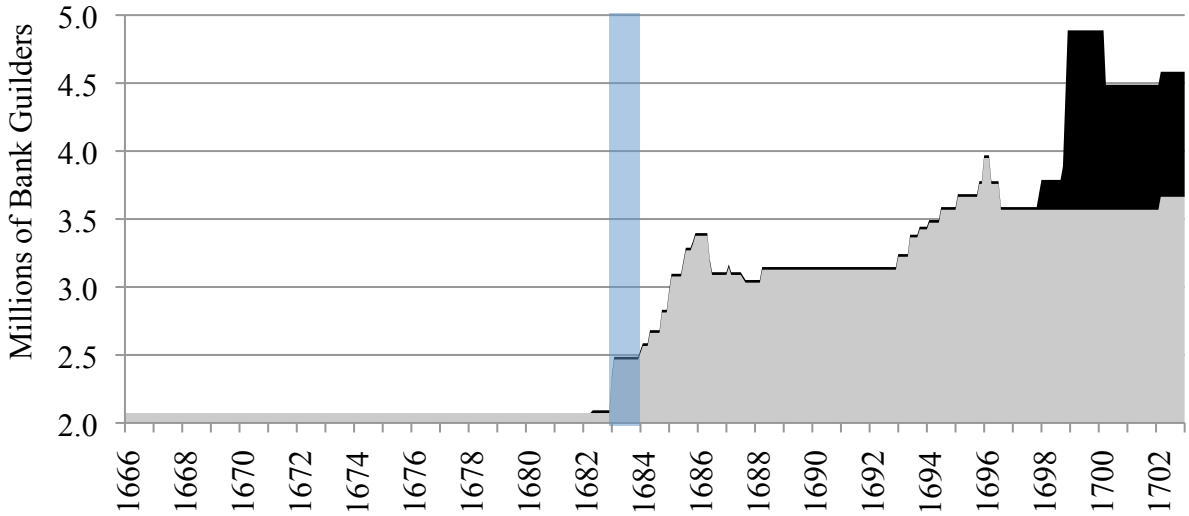
4.1 Credit policy

The AWB's early lending activities represented a partial shift to an asset-backed currency. As long as all deposits were convertible, however, the bank learned to be reluctant about extending credit much in excess of its capital position, for the bank exposed itself to the risk of a run by lowering its metal-to-deposit ratio. Alternatively, the bank could slacken its liquidity constraints by imposing higher withdrawal fees as it did in 1672, but this discouraged deposits and imposed costs on market participants. We will now elucidate how, with fiat money, the bank lent more frequently with less capital cushion.[32]

The bank labeled Amsterdam a major borrower, but the city was really the bank's owner.[33] In the early 1650s, the city had borrowed 2 million guilders in metal from its bank, and soon afterwards the city stopped paying interest on the loan and never again paid interest on its debt. Figure 9 shows our calculation of the city's cumulative debt over the sample period. In 1683, the city began taking out metal, in grey, and occasionally returning some. Starting in 1698, the city had the bank create balances instead (in black).[34] To further obfuscate the situation, the bank occasionally wrote off the loans by reducing the bank's capital to near zero, so both the capital and loan series became in increasingly misleading over time (Willemsen 2009, 85).[35] To correct for this, figure 9 ignores the write downs.

[32] See Appendix B for a formal model of the changeover in the bank's credit operations.
[33] The Province of Holland's debt also appears on the AWB's books, but Holland never borrows more during our sample period.
[34] A lone 20,000 guilder balance was created in June 1682.
[35] In our era, the write-offs were 2.3 million guilders in 1685 and 170,000 guilders in 1691.

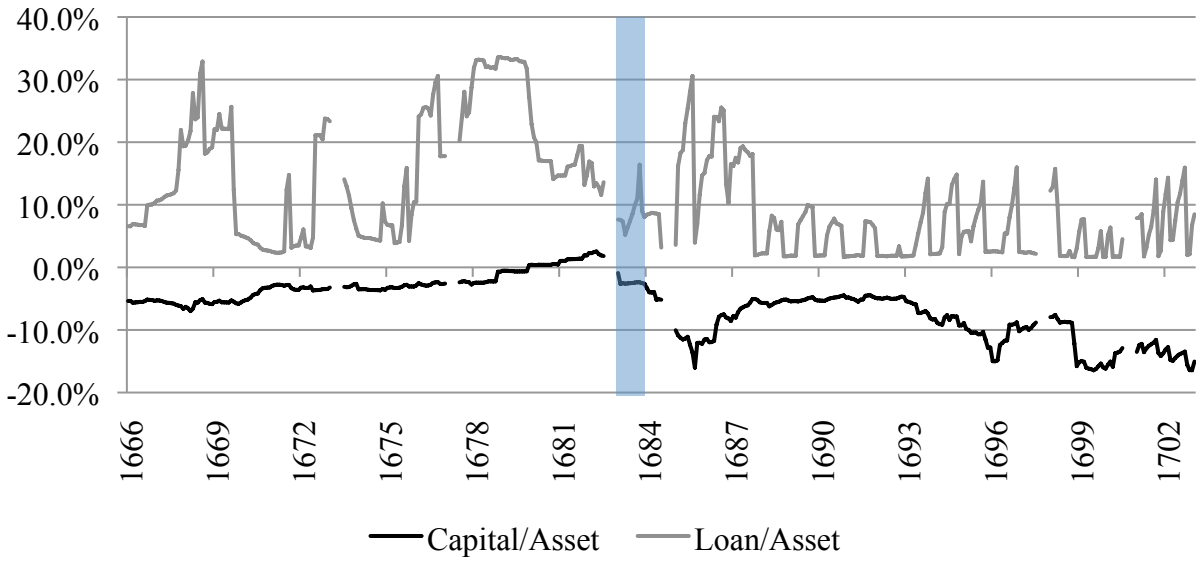
Figure 9. Amsterdam debt, 1666:2 to 1702:2



Source: Authors' calculation using Amsterdam Municipal Archives 5077/1311-1323.

To see the bank's true capital position, figure 10 gives a capital-to-asset ratio that treats municipal "loans" as capital deductions. To calculate monthly capital, we distributed annual profit within a year by each month's share of withdrawal volume. The adjustment shows that the 2 million guilders the bank gave to city in the early 1650s (to build a new city hall) put the bank into a negative position, and it shows that this era ended when capital (retained earnings) grew faster than assets after the Crisis of 1672. Negative capital, however, returned after 1683 through the process depicted in figure 9 above. Thereafter, the city took capital during periods of need and then let deposits (figure 7) raise the capital ratio. From 1683 to 1703, the city took 2.5 million guilders from the bank (our calculation). Limiting the right of withdrawal allowed the city to take metal and the bank to admit (at least to itself) to having no capital.

Figure 10. Adjusted monthly asset ratios, 1666:2 to 1703 :2



Source: Authors' calculations using van Dillen (1925, 701-97, 971-84) and our data set (see Appendix A).

Figure 10 also plots a loan-to-asset ratio which, after removing municipal activities, leaves mostly variations in East India Company borrowing. In the first half of our period, the combination of long-term lending to the company and a weak deposit base meant that the ratio averaged 16 percent. With the regime change, peak lending did not change (figure 4), but the loan/asset ratio declined to a 7 percent average because loans did not linger and because the deposit base grew (figure 7).

The frequency of lending followed from the bank becaming a routine supplier of operating credit to the company. The bank was a major lender to the company because it enjoyed certain advantages: its perpetual nature,[36] its political position,[37] and its privileged position in bill settlement. But the company also had direct access to the Dutch bond market and averaged a total

[36] The 1609 charter of the bank contained no "sunset date." This contrasts with say, the First Bank of the United States, which received a 20-year charter.
[37] During the period we analyze, the AWB was governed by a board of commissioners, comprised of three or four prominent individuals such as former mayors ('t Hart, 2009).

year-end debt of 10 million current guilders over our sample period.[38] The strong seasonality suggests that the company increased its use of the bank as an overdraft facility to acquire metal to ship to Asia.[39]

Some confirmation of this can be detected from surviving records. De Korte (1984) collected annual East India Company balance sheets that give levels at the start of a fiscal year (usually May 31) for assets such as cash, credits, and the inventory of unsold goods; and for liabilities (primarily corporate debt). Better still, three flow variables are also known for the fiscal year: expenditures paid, dividends paid and revenues collected.[40] An OLS estimation reported in Table 4 calculates how these variables correlate with our dependent variable of interest, the amount the company borrowed that year from the bank.[41] Expenditures during a year strongly and positively correlate with borrowing, and suggest a derived demand for bank loans of 25 percent of expenditures. In contrast, information about that year's sales revenue (known after ships returned to the Netherlands) lacks explanatory power.

[38] See Appendix A.
[39] The regime change, however, does not explain the rise and fall of multi-year lending to the VOC. That change coincides with structural changes in the VOC's corporate debt following from the crisis of 1672 (de Korte 1984, 66). At the start of our sample, 1666, the VOC's long-term debt was in the form of bonds callable at par by either debtor or creditors (de Korte 1984, 66).. The VOC had a program of retiring long-term debt in 1670 until the crisis in 1672, and the lack of borrowing in figure 4 for those years is evident. During the 1672 crisis, the VOC suspended the call option, and in the years that followed restructured its debt to avoid this problem. First, the VOC began offering short-term anticipations that gave a senior claim on auction proceeds from the next fleet to arrive. Then the company issued long-term debt without creditor call options. The bubble of multi-year borrowing (figure 4) from 1676 to 1682 coincides with the VOC's debt restructuring.
[40] All are measured in current guilders, and all are for operation in the Netherlands. Ships at sea and operations in Asia are excluded.
[41] VOC borrowing totals follow the VOC's fiscal year rather than the AWB fiscal year reported in van Dillen (1934, 979-984).

Table 4. VOC Correlates to AWB lending, 1666 to 1702

Dependent Variable: AWB LENDING in Bank Guilders

Independent Variables in Current Guilders.

	Coefficient	*t*-Statistic	*p*-value
Flow Variables			
1. EXPENDITURES	0.243575	2.854951	0.0079
2. DIVIDENDS	0.086721	0.588119	0.5610
3. SALES	0.001038	0.013216	0.9895
Levels at Year-Start			
4. INVENTORY	-0.057136	-1.495904	0.1455
5. CASH	-0.158387	-0.823348	0.4170
6. CREDIT DUE	-0.402999	-1.614495	0.1172
7. TOTAL DEBT	-0.006557	-0.141776	0.8882
N= 36		Adjusted R-squared	0.365084
		Durbin-Watson	1.778873

Source: See text and Appendix A.

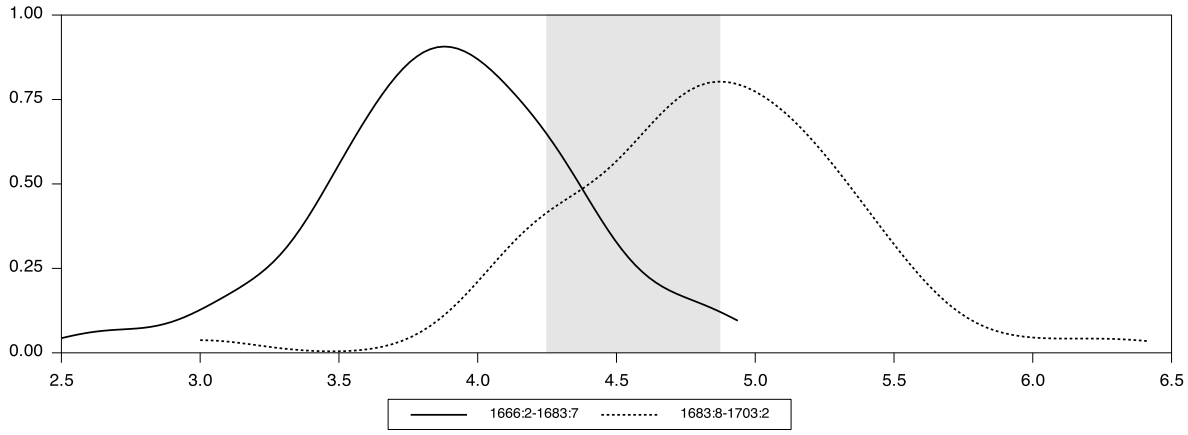
Unfortunately we do not know exactly where bank loans fit into the company's capital structure, e.g., the seniority of bank loans relative to other kinds of debt. But the VOC's frequent borrowing suggests that the ready availability of bank credit contributed to the company's ability to increase average expenditures after 1683, especially given that half of equipment costs were coins taken away from Holland as exports (Korte 1998, 16).

4.2 Monetary policy: arbitrage

The original and overriding policy goal of the Bank of Amsterdam was to maintain a stable value of bank balances—the settlement medium for financial transactions within the city. The pre-1683 monetary regime partially fulfilled this goal by helping to eliminate the inflationary trend that prevailed in the early decades of the seventeenth century (see figure 1). However, a defect of this regime was a persistent "undervaluation" of bank money: high withdrawal fees meant that the market value of the agio could fall 1.5 percent below its statutory value before

triggering a corrective market response (see figures 3 and 5). Figure 11 plots the empirical density of the agio in our two sub-periods. Before 1683, the market value of bank money rarely approached its statutory level of about 5 percent. In contrast, the distribution shifted after 1683 to have numerous observations above 5 percent.

Figure 11. Estimated densities for the agio



Source: Authors' calculations. Estimated densities are histograms, smoothed with Gaussian weights. Outlier values are excluded. Shaded area is the post-1683 target zone suggested by van Dillen (1934).

It is not clear how much of this shift in valuation can be attributed to deliberate policy actions by the bank. Van Dillen's (1934, 102) description of the bank's policy is reminiscent of the operations of a modern currency board: "… for many years [after 1683], they bought in bank money when the agio fell to 4 1/4 percent and sold whenever it rose to 4 7/8 percent." As can be seen from figure 11, however, the data are not consistent with a simple "currency board" characterization: most of the time the market agio lies outside its putative target band (shaded). Instead, there is evidence suggesting that much of the post-1683 change in the agio was the result of how the new regime changed arbitrage incentives.

To illustrate coin-to-bank arbitrage, we consider the coin that anchored the Dutch system of trade coins in our sample period: the silver *rijder*.[42] The *rijder* dominated circulation because mint ordinances favored its production. For example, ordinances assigned the *rijder* the same official mint price as the *dukaat* (a smaller silver coin), but the *rijder* had a seigniorage rate of 1 percent while the *dukaat's* rate was 0.2 percent, so mints preferred the *rijder*.[43] Profits mattered: until the advent of receipts in 1683, *rijder* production at Dutch provincial mints outpaced *dukaat* production by 2 to 1.[44] The *dukaat* was also favored for export, so many left circulation while *rijders* remained.

The *rijder's* mint specifications, table 5, provide the basic arbitrage information for our sample period. The mint ordinance assigned two values to the *rijder*. The ratio of the current guilder value over the bank guilder value (less 1) gives the implied statutory agio α. If the bank charges $w > 0$ at withdrawal, then the (steady-state) market agio a should lie in the interval[45]

$$\left(\underline{a}, \bar{a}\right) \equiv \left(\frac{1+\alpha}{1+w} - 1, \alpha\right), \tag{1}$$

if the coin is to reside in the bank. Table 5 reports the upper and lower steady-state boundaries assuming w = 1.5%. A market agio above 5 would encourage the deposits, an agio below 3.45 would encourage the withdrawals, and an agio in between would create no arbitrage incentives. Recall also that the AWB could assess an additional fee on popular coins at withdrawal, so an additional premium could reduce the *rijder's* lower bound to match less popular coins like the

[42] We emphasize that many other types of coin were deposited in the bank, especially after the introduction of receipts.
[43] As of the 1668 mint ordinance, both coins had a mint price of 24.873 guilders per mark (Polak 1998, 174-5). The mint equivalents were 24.933 for the *dukaat* and 25.131 for the *rijder*.
[44] Our calculation is in terms of marks of pure silver minted, and it derives from Polak (1998, 103-164). See Appendix A.
[45] After 1683, the cost of a withdrawal would include the market value of a receipt. Hence in practice the agio could fall slightly below the lower endpoint in (1) without violating no-arbitrage.

dukaat. Thus, for the pre-1683 period, the steady-state interval would have been approximately $\left(\underline{\alpha} = 2.5\%; \overline{\alpha} = 5.0\%\right)$. Figure 11 shows that the agio rarely moved beyond these bounds.

Table 5. Implied Agios for the Silver *Rijder*

Statutory Values	
3.15 current guilders	
3.00 bank guilders	
Implied deposit (statutory) agio (α)	5.00%
Implied withdrawal agio $\left(\frac{1+\alpha}{1+w}-1\right)$	
with $w = 1.5\%$	3.45%
with $w = 1.5\%$, and a *rijder*-specific fee of 1%	2.44%
with $w = 0.25\%$	4.74%

Source: Polak (1998, 73-4).

The 1683 fee reduction explains the shift in the agio distribution to a mean of 4.83 percent. A fee of 0.25 percent (the new standard for silver coins) caused the *rijder's* arbitrage bounds to tighten, so the lower bound moved up to 4.74 percent. The old (average) agio of 3.9 percent now favored the use of receipts to withdraw *rijders*, and the consequent rise in the agio from the diminishing stock of bank guilders relative to current guilders. We cannot say if the AWB intended for the lower fees to push the agio to a new center, but the bank did accept the new reality. For example, in January 1687, the AWB switched the agio it used for internal record keeping from 4.25 to 5.[46] Similarly, for the three-*gulden*, a coin very similar to the *rijder*, the AWB chose an agio of 5.26 percent.[47]

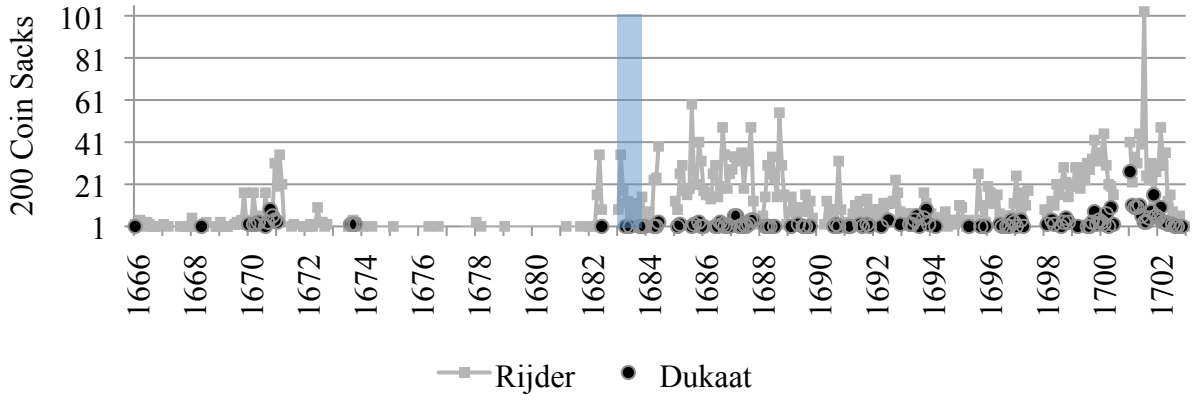
At the new mean, however, the variance did not contract despite the reduction in fees, so the post-1683 distribution has more observations above and below bounds than simple arbitrage

[46] Amsterdam Municipal Archives inventory number 5077/1322, f. 9.
[47] The AWB recorded 3-*gulden* coins at 2.85 bank guilders (AMA 5077/1322, f. 43).

would predict. We attribute the prevalence of observations below the lower bound (agios below 4.75 percent) as a by-product of the receipt negotiability. The new regime began with no *rijder* receipts, so the agio adjustment process had to wait for deposits—at agios that discouraged deposits. Yet people did deposit *rijders*.

To show this, figure 12 plots a measure of the types of coins deposited through use of yet another filtering algorithm: one built around sacks of coins. The 200 coin sack was the standard bulk unit, so a sack of *rijder* coins was worth 600 bank guilders. A sack of *dukaat* coins was 480 bank guilders. We filtered the population of deposit transactions for amounts of exactly 480, 600, or their multiples up to times ten. Each observation is then converted into sacks, so, for example, 960 bank guilders converts into two sacks of *dukaten*. The sacks are then aggregated by month, and the joint-multiples of 2,400 and 4,800 are excluded. The result, figure 12, shows that *rijder* deposits surged under the new regime and that the *dukaat* was a minor contributor.[48]

Figure 12. Filtered sample of monthly deposits



Source: Authors' calculation: see Appendix A.

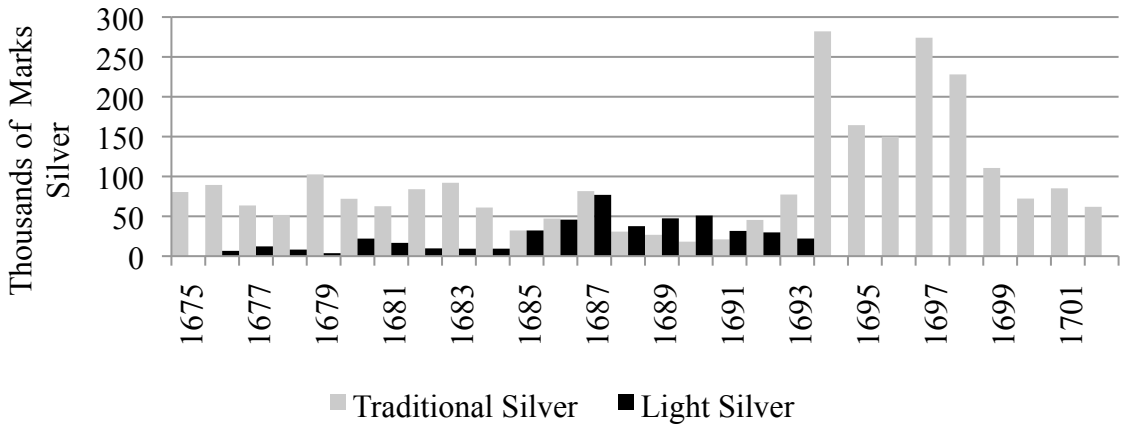
The deposits may stem from a "liquidity" demand for bank guilders that responded to the new regime despite the slightly unfavorable agio. Also, the ability to sell receipts mitigated the

[48] Moreover, deposits did respond to arbitrage opportunities. When the agio flirted with 5 percent in 1670 and 1671, *dukaten* were attracted, but the much larger effect was the in-rush of *rijders*.

expense of deposits relative to purchasing balances on the secondary market. In effect, the demand for withdrawals subsidized deposits, and the adjustment process was slowed, so even more agio observations occurred below the arbitrage bound.

In contrast, we think that the abundance of agio observations above the 5 percent upper-bound (1687 to 1693) was caused by a shock external to the bank. From 1676 to 1693, some mints, especially Zeeland's provincial mint, began producing coins with higher mint prices than the traditional *rijder*. These "light" coins were an effort to gain revenue. To get a sense of this, figure 13 plots the production of silver at the provincial mints in the form of traditional coins (*dukaat*, *rijder*, and *gulden*) and as the new, rival coins (*daalder* and *florijn*). The lighter (high mint equivalent) coins were displacing traditional coins.

Figure 13. Annualized Coin Production at Provincial Mints



Source: Derived from Polak (1998, 103-164).

The new coins undermined the silver content of circulating current money, so the agio rose to historic highs.[50] The AWB returned to its original role of sheltering creditors as agio-arbitrage and low fees encouraged deposits of *rijders* until Holland refused to recognize the legal status of

[50] The agio peaked at 12.5 percent in January 1693 and hovered around 6.25 during the third quarter of 1693. *Dukaat* production at the provincial mints, other than Zeeland, surged in 1693 and 1694, but *rijder* production did not. The *dukaat's* advantage relative to the *rijder* was an attractive agio when deposited at the AWB, so the high agio promoted coin production for the purpose of deposit at the bank.

the light coins in 1690 (figure 12). After the entire United Provinces banned light coin production in 1694,[51] observed agios mostly stabilize between 5.25 and 4.38 for the rest of our sample period.[52] The high agios in our post-1683 sample reflect instability in the quality of current coins that gets sorted out in 1694. Otherwise, the agio distribution stays centered on the arbitrage boundaries set by the *rijder* coin, so fee policy was monetary policy in terms of setting a new anchor for rates.

4.3 Monetary Policy: Open market operations

The presence of arbitrage effects does not exclude the possibility that the bank sought to influence the agio through open market operations. Historical accounts (van Dillen, Mees, and others) agree that such operations occurred but are mute regarding their manner and extent. Our reconstruction of master account transactions points to the AWB buying and selling bullion rather than coin. Open market operations meant that the bank would sell (buy) bullion below (above) the market price and decrease (increase) the quantity of bank guilders.

To what end? The bank could attempt to counteract the impact of fluctuations in bank money by offsetting deposit inflows with bullion sales and withdrawals with bullion purchases, i.e., the bank could "sterilize" these flows in modern parlance (see, e.g., Hamilton 1997). The bank could similarly sterilize changes in VOC credit. This section presents evidence that the bank used bullion operations to pursue these goals, and that the fiat money standard facilitated these operations by allowing more aggressive bullion sales.

[51] Figure 13 also suggests that sorting out the monetary uncertainty stimulated demand for new coins.
[52] But our sample does grow thin. Also, our estimated agios in figure 3 are erratic around 1696 because the pound-bank guilder exchange reflected great monetary difficulties in England. England was experiencing a liquidity crisis as the Great Recoinage, begun in 1695, temporarily reduced the stock of circulating coins. For example, the Bank of England suspended convertibility in 1696 (Clapham 1944, 36).

4.3.1 Operations in bullion

Why trade bullion rather than coin?[53] Trading coin would have violated the bank's fundamental assignment of respecting and maintaining the mint ordinance values of coins. In contrast, bullion could be traded without necessarily upsetting the circulation of coins at all. To see this, suppose that a coin from the preceding section contains b ounces of silver. Also, note that when mints offer to convert silver to coin, they collect a fraction σ of the silver as seigniorage. If we take the market agio as a and we normalize the coin's face value to unity, then the steady-state price of silver γ (expressed as bank guilders per ounce) lies in the interval[54]

$$\left(\underline{\gamma}, \bar{\gamma}\right) \equiv \left(\frac{1-\sigma}{b(1+a)}, \frac{1}{b(1+a)}\right). \tag{2}$$

The bank had to take these limits into account in its open market operations if it did not want to disrupt the circulation of coins.

The 1683 reform eased these constraints. Receipts allowed the AWB to purchase existing options to withdraw coins, so the stock of potentially circulating coins could be reduced without the bank offering an unofficial price. Lower fees also allowed the bank to more easily "tighten" by selling bullion. To see the effect of lower fees on the range of bullion sale prices, insert the lower bound $(\underline{a})$ for the agio in (1) into (2) to get bounds on the steady-state price of silver γ when the agio is at its steady-state minimum:

$$\left(\frac{1-\sigma}{b\left(\frac{1+\alpha}{1+w}\right)}, \frac{1}{b\left(\frac{1+\alpha}{1+w}\right)}\right). \tag{3}$$

[53] Why not trade in government debt? Holland had no secondary market for sovereign debt in this era (Gelderblom and Jonker 2010).

[54] I.e., γ lies in an interval formed by the mint price of the coin and the mint equivalent of the coin, converted to bank guilders at the market agio. See e.g., Redish (1990), Sargent and Smith (1997), or Sargent and Velde (2003) on the derivation of interval (2).

The decrease in *w* decreased the lower bound $\underline{\gamma} = (1-\sigma)(1+w)/[b(1+a)]$ in (3), allowing the bank to more easily sell bullion at a price above the mint's purchase price.

Receipts also eliminated the need for coin-specific premia by ending cross-coin substitution. To see why, assume two coins with (bank) nominal value/metal pairings of (x_1, b_1) and (x_2, b_2). Under traditional withdrawal rules, coin 1 needs a fee $w_1 \geq \max\left(\frac{b_1}{b_2}\frac{x_2}{x_1} - 1, 0\right)$ to avoid coin-to-coin arbitrage. The receipt system avoided the problem by making all withdrawal claims coin specific.

4.3.2 Evidence of open market operations

Returning to the data, the integrated series on purchases and deposits, graphed in figure 7, provide a narrative to the AWB's open market activity. Before 1683, open market activity seems to have had a defensive character. "Reserves" of metal were accumulated by large purchases at favorable times. Purchased metal was cautiously drawn down through sales, the chief exception being the years 1680-83, by which point virtually no coin was being deposited (see figure 5) and cumulated deposits were approximately zero (figure 7). After the move to fiat money, infrequent spikes in purchases continue as before, but these are followed by lengthy periods over which the bank is a net seller of metal (1685-87, 1691-94, 1695-98, 1699 onward). By then the bank apparently felt more comfortable parting with its metal purchases.

A case-by-case examination indicates that these exceptional transactions were almost always purchases during periods of high agios or sales during periods of low agios.[55] Such actions reinforced arbitrage adjustment and were potentially profitable. In addition, the bank's large purchases were sometimes offset by large deposit outflows, and vice-versa for large sales, so the

[55] See Appendix A for a case-by-case analysis.

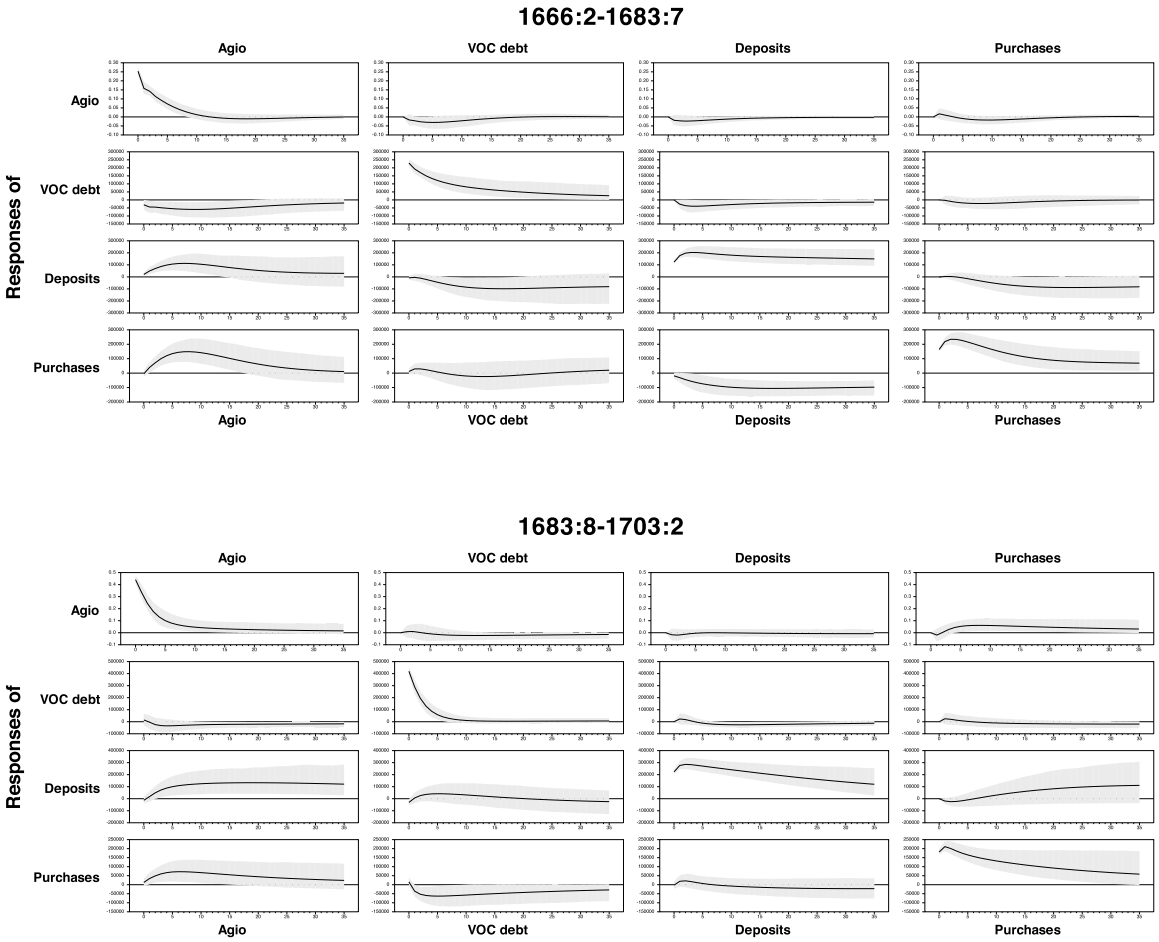
bank was also engaged in sterilization operations. Indeed, the pre-1683 era looks like a long-run policy of opportunistic sterilization of net deposit outflows (see figure 7).

Price (agio) and quantity (sterilization) motivations are confirmed in a more formal exercise in which a standard vector autoregression was fit to the four principal data series (the agio, VOC debt, cumulated deposits, and cumulated purchases). The VAR was fit over a sample that includes all available observations on balances, except the two outlier episodes in 1672 and 1693. The specification includes monthly dummies and 2 lags.[56] Stationarity of the model coefficients across the 1683 break is strongly rejected by a classical likelihood ratio test ($p<.001$).[57] 36-month impulse responses from the two VARs (pre- and post-1683) are graphed in figure 14 below. Responses shown are for a Choleski decomposition of the forecast error variance-covariance matrix with the agio first in the ordering.[58]

Noteworthy in figure 14 are the persistently negative responses of purchases to shocks to deposits (before 1683) and to VOC debt (after 1683), consistent with the idea that the bank's open market operations worked to smooth short-term fluctuations in the money stock. During both periods, shocks to the agio are persistent and generate a persistent increase in purchases, implying that the bank added funds to the market when bank balances became unexpectedly scarce, and drained funds when money was plentiful. Also note there is essentially no feedback from purchases to the agio, again somewhat contrary to a simple "currency board" characterization of the bank's open market operations.

[56] The 2-lag specification is chosen under the Hannan-Quinn criterion for both subsamples. More lags are chosen under the Akaike criterion and under sequential likelihood ratio tests, while the BIC selects only one lag.
[57] Stationarity of coefficients is also rejected under the Akaike and Hannan-Quinn criteria; however stationary is favored under the Schwarz criterion.
[58] The graphs depict posterior mean responses under a diffuse prior, together with ninety percent posterior error bands.

Figure 14. Sample impulse responses



Source: See text.

Summarizing this section, our analysis suggests that the bank conducted open market operations throughout the sample period, with some purchase operations in particular being quite aggressive when the agio was favorable to the bank. There are negative correlations between shocks to deposits (and later, to VOC loans) and shocks to purchases, indicating that the motivation for many of these operations was to smooth fluctuations in the money stock. The regime change both encouraged deposit flows (receipts) and eased arbitrage constraints on the bank (fiat money), allowing the bank greater latitude to sell off purchased metal.

5. Connections to the literature

The above analysis invites comparison to similar analyses of U.S. macro time series before and after the 1913 founding of the Federal Reserve. Numerous studies (e.g., Clark 1986, Miron 1986, Mankiw, Miron, and Weil 1987) have documented that U.S. monetary aggregates become highly seasonal after 1914. This shift is often attributed to Federal Reserve policies, especially a quasi-pegging of short-term interest rates through the opening of the discount window.

Figure 8 indicates that comparable shifts do not occur in the components of the AWB money stock, with the exception of loans to the East India Company. The relative aseasonality of other money stock components is consistent with the more evolutionary nature of the policy change, and the bank's restriction of its seasonal lending to a single counterparty.

The VAR analysis reported in Canova (1991, 700-701) (see also Tallman and Moen 1998) finds that before 1914, external shocks to high-powered money are highly causal for the U.S. domestic money stock, but that this same effect is greatly diluted after 1914. We cannot fully replicate Canova's exercise for the AWB due to data limitations (monthly observations on key macro series such as output and prices are unavailable), but figure 14 displays some similarity to the pre-1914 U.S. case: favorable shocks to the agio (to the extent these originate abroad) have a persistent positive impact on money. In contrast to the post-1914 U.S. experience, however, this pattern attenuates somewhat but does not disappear after 1683.

Some aspects of the bank's operations resemble those of modern currency boards. E.g., the Hong Kong Monetary Authority has standing offers to sell Hong Kong dollars at a unit price of US $0.129 and to repurchase its money at a 1.27% lower price, roughly matching the bank's pre-1683 statutory bid-ask spread. The combination of fiat money and the receipt system evidently allowed the bank to function with a lower "backing ratio" of external assets to central bank

money than do modern currency boards, which often operate with a backing ratio of 100 percent or more.

Currency boards can be effective in stabilizing monetary value, but a commonly cited defect is their inability to ward off banking crises (Chang and Velasco 1999, 2000). Yet no widespread banking crises occurred in Amsterdam during the period we analyze. This is perhaps due to Amsterdam's reliance on a web of informal trade credit and personal guarantees (bills of exchange) for business financing, rather than deposit banks. And, as has been demonstrated, the bank could and did indirectly ease credit conditions by providing financing to the largest enterprise in the economy.

Later on, Amsterdam expanded its credit markets at the cost of increased financial fragility. A system of "acceptance credit" developed in the eighteenth century, under which bills of exchange were guaranteed against default ("accepted") by one of a small number of prominent local merchants. This lowered the chances of a single default but concentrated credit risk in a small number of counterparties. A full-fledged financial panic developed in 1763 after the failure of an acceptance house; the bank could do little in response (Schnabel and Shin 2004).

6. Summary and conclusion

The above analysis has documented the causes and consequences of the Bank of Amsterdam's introduction of a fiat standard. Based on modern experience, one might have expected the bank's adoption of a fiat money to have preceded its pursuit of activist monetary and credit policies. As shown above, however, the historical record favors nearly the opposite hypothesis—that fiat money was introduced as a way to facilitate policies already in place. These policies, in turn, had been made possible by the bank's near-monopoly on domestic large-value payments.

The principal policy goal of the bank—maintenance of a unit of account of stable value—remained the same after the 1683 transition. However, as shown above, adoption of a fiat standard allowed the bank to pursue various secondary activities—provision of credit to the East India Company, payment of dividends to the city, and smoothing of money stock fluctuations—with a vigor that would have been impossible under its original design.

Simplicity was nonetheless the hallmark of the bank's operations. The transparency of the bank's main mission meant that there was little need for policy statements, elaborate targeting schemes, or exit strategies. Paradoxically, secrecy also played a role: while the general intent of the bank's policies was public information, its financial condition was not. Many contemporary observers, Adam Smith included, believed the Bank of Amsterdam to possess a stock of metal far in excess of its actual holdings, and the bank's true condition was revealed only after its final collapse. Until that point, the managers of the world's first big fiat money factory seem to have absorbed a lesson familiar to today's high-tech mavens: for a virtual good, reputation is everything.

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