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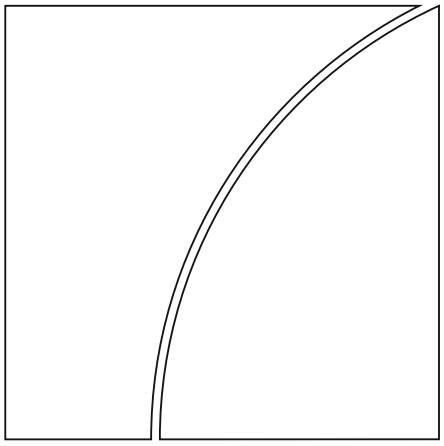

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An early stablecoin? The Bank of Amsterdam and the governance of money

by Jon Frost, Hyun Song Shin and Peter Wierts

Monetary and Economic Department

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Keywords: stablecoins, crypto-assets, central banks, money.

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An early stablecoin? The Bank of Amsterdam and the governance of money

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Abstract

This paper draws lessons on the central bank underpinnings of money from the rise and fall of the Bank of Amsterdam (1609–1820). The Bank started out as a "stablecoin": it issued deposits backed by silver and gold coins, and settled payments by transfers across deposits. Over time, it performed functions of a modern central bank and its deposits took on attributes of fiat money. The economic shocks of the 1780s, large-scale lending and lack of fiscal support led to its failure. Using monthly balance sheet data, we show how confidence in Bank money gave way to a run equilibrium, where the fall of the premium on deposits over coins ("agio") into negative territory was swift and precipitous. This holds lessons for the governance of digital money.

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1. Introduction

Money is a social convention. One party accepts it as payment in the expectation that others will also do so. Anything could serve as money provided that this convention is sustained as an equilibrium.

This bare definition of money does not leave much room for the *institutions* underpinning the monetary system, especially the role of central banks. Over the ages, various forms of private money have come and gone; while some have lasted longer than others, they have invariably given way to central bank money.[2]

We draw lessons on the central bank underpinnings of money by examining a case where a (proto-)central bank actually *failed*, and was liquidated. The idea is that, by seeing what it takes for an issuer of money to fail, we may draw lessons on the central bank underpinnings of the institution of money, with relevance for the digital era.

Our focus is on the rise and fall of the Bank of Amsterdam (1609–1820), perhaps the best known of the public deposit banks in Europe. The Bank was established in the 17th century, and famously discussed at length in Adam Smith's (1776) *Wealth of Nations*. Public deposit banks resembled modern central banks in one key respect – they provided wholesale account-based money through deposit accounts, just as modern central banks do. Just as with modern central banks, a payment was settled by debiting the account of the payer and crediting the account of the receiver. Technological advances have improved the speed and scope of payments, but arguably the basic architecture of account-based money has remained largely unchanged, with the main change being that payments are executed electronically rather than on paper-based ledgers. Indeed, there has recently been a resetting of the consensus that the origin of central banking should be found in the early deposit banks like the Bank of Amsterdam, rather than later institutions that were founded to finance the sovereign (see Schnabel and Shin (2004), Quinn and Roberds (2007, 2014) and Bindseil (2019)).

How then does a central bank fail? Indeed, how *could* a central bank fail when it can always "print" more money? The lessons are revealing. They provide valuable insights for current debates on digital money, and on the limits of monetary financing of government fiscal deficits.

The early incarnation of the Bank of Amsterdam resembled what we now know as a "stablecoin" – where account-based money is backed

[2] For rich historical accounts, see Giannini (2011), Martin (2013) and Desan (2014).

by assets of stable value. The term stablecoin entered the lexicon of monetary economics through several private digital currencies in recent years, including Facebook's Libra in 2019.[3] The early Bank of Amsterdam was a stablecoin in the sense that its account-based money was backed by silver and gold coins ("safe assets").

However, unlike modern central banks, the early Bank of Amsterdam operated as a passive or "rigid" stablecoin in that new deposits could be created only by holders surrendering gold and silver coins. The asset side of the balance sheet was intended to be passively managed, in that the assets were to consist solely of metal coins. The Bank of Amsterdam's charter ruled out lending, and its money was intended to reflect the value of underlying assets only, just as in the case of modern digital stablecoins.

The convenience of Amsterdam bank money for settlement of transactions meant that bank money traded at a premium (or "agio") to the underlying metal coins, with the premium reflecting the value to account holders of the convenience of bank money for settlement. The agio was substantial, typically maintained at around 5% throughout much of its history.

At the same time, as a public institution at the heart of the financial system owned by the City of Amsterdam, the Bank of Amsterdam increasingly found itself performing a public policy role as a liquidity provider and lender of last resort. It maintained settlement liquidity by granting overdrafts to key stakeholders. It began to operate more as an "elastic stablecoin", where the value of its deposits was backed by the general strength of its balance sheet rather than the ability of depositors to redeem deposits into gold and silver coins. In short, Bank money increasingly took on the attributes of modern fiat money (Quinn and Roberds (2007, 2014)), where value is sustained by trust in the unit of account. In this respect, the Bank of Amsterdam began to resemble modern central banks, as a public institution issuing fiat money. Yet the Bank also maintained elements of its earlier stablecoin structure by allowing redemptions by depositors through the "receipts" system, which worked somewhat like a modern repurchase (repo) arrangement, as described below. In preserving the value of money and maintaining an orderly monetary system, the Bank of Amsterdam would be recognisable to modern observers as a proto-central bank.

[3] See Coeuré (2019), G7 Working Group on Stablecoins (2019), FSB (2020) and Arner et al (2020). Stablecoins are private cryptocurrencies that seek to maintain a stable value against assets or fiat currencies.

However, the Bank of Amsterdam was not a fully fledged central bank in one key respect – it did not have the full fiscal backing of the sovereign. The Bank was owned and governed by the City of Amsterdam, but the city authorities did not extend fiscal backing to the Bank to return the Bank to full solvency through fiscal transfers. In response to economic setbacks – in particular the Fourth Anglo-Dutch War of 1780–84 – the Bank began to grant massive loans to the Dutch East India Company (on which more later) as well as lending to the City of Amsterdam itself.

For a while, the value of Amsterdam bank money managed to withstand the shocks that undermined its backing. However, as the economic downturn worsened and confidence ebbed, the Bank of Amsterdam suffered a series of runs, depleting its stock of silver and gold coins. After more than 170 years of successful operation, a proto-central bank failed. As it lost metal coins to the series of depositor runs, the agio of Amsterdam bank money broke its long history of a 5% premium, dropping precipitously and into negative territory. The Bank was eventually closed in 1820, and the modern central bank – De Nederlandsche Bank – took its place.

The charter of the Bank of Amsterdam ruled out lending operations; it was intended to operate purely as a rigid stablecoin. However, the Bank's international standing thrust it increasingly into a lending role. At first the Bank's activities had little credit risk, but amid governance weaknesses and a faltering economy ravaged by war, these increasingly faced a higher risk of default. The main conclusion of our study is that the Bank of Amsterdam found itself in the awkward halfway house between a rigid stablecoin and a fully fledged central bank, without full fiscal backing of the state. The City of Amsterdam was not able to play the role of a modern fiscal authority – it lacked the fiscal powers of general taxation that are in the hands of governments today. The halfway house proved untenable.

The core of our paper is an empirical analysis of the erosion of confidence in the money issued by the Bank of Amsterdam. We employ the time series of the full monthly balance sheet data which has now become available through the work of Quinn and Roberds (2019).[4] We show that the agio of the Amsterdam Bank money was eroded over time as the share of loans in the assets of the Bank increased, even

[4] We thank Stephen Quinn and Will Roberds for sharing the data with us. As described below, we have augmented the data with publicly available data from other sources.

though short-term fluctuations in the lending share had little noticeable impact on the agio. The relationship between the agio and the lending share asserts itself in the medium run, with an adjustment horizon of around six months. Relative to earlier research on the Bank of Amsterdam, we provide new insights on the process by which trust in Bank money was lost, and we show that these have a bearing on much broader issues of central bank solvency and the governance of money in the digital era.

The Bank of Amsterdam and its rise and fall provide many useful lessons, but two resonate particularly loudly for current debates on the nature of the money and the role of the central bank.

First, rigid stablecoins are poorly suited as the foundation for a modern monetary system. Settlement liquidity and the supporting wholesale payment systems that oil the wheels of the modern financial system entail active use of the central bank balance sheet. The trust in the central bank's money as the unit of account is the bedrock for such a system. In the case of the Bank of Amsterdam, it began life as a rigid stablecoin, but its public policy function at the heart of the financial system pushed it increasingly to taking on the role of lending (an elastic structure). Without the ability to lend, it could not have performed its central role in supporting the financial system and international trade as long as it did.

Our second key lesson is that for a central bank to play its role, the fiscal backing of the sovereign and its fiscal sustainability are essential. Being able to issue fiat money gives the central bank considerable latitude to leverage up its balance sheet without loss of confidence in the value of money. However, the ultimate backing for the value of money is the solvency of the public sector – ie central bank solvency subject to the flow constraints in its interaction with the government (Sims (1994), Cúrdia and Woodford (2011), Reis (2015)). The Bank of Amsterdam's failure is a vivid lesson in how a central bank that loses public trust can push its luck too far, beyond the threshold for failure. Fiat currencies need backing, much as a rigid stablecoin does, but modern central banks need the fiscal backing of the government. When a run against a modern central bank with its own fiat currency occurs, it is likely to manifest itself through the collapse of the exchange rate, as we have seen in the case of many emerging market economies.

The technology underlying money has advanced in the digital era, but we will argue that the economics underlying money have not. Sound money still needs sound governance. While private stablecoins may have a role in specific innovative use cases, they are unlikely to

serve as a useful medium for the full range of functions of fiat money. For this, central bank digital currencies (CBDCs) may show greater promise – even as important issues in their design remain open.

The rest of this paper is organised as follows. Section 2 steps back into monetary history and explains the innovations of the Bank of Amsterdam, focusing on its transformation from a rigid to an elastic stablecoin structure and a proto-central bank. In section 3, we show empirically that a long-term relation can be estimated between the value of the Bank guilder and the degree of lending, while the short-run adjustment dynamics deteriorated structurally after policy insolvency. Section 4 draws lessons on rigid versus elastic stablecoins, underscoring the importance of credit in modern payment systems. It applies these insights to modern stablecoin initiatives, and to current debates on monetary financing and the fiscal backstop of central banks. Finally, section 5 concludes.

2. The Bank of Amsterdam and its downfall

The Bank of Amsterdam (*Wisselbank*, or "Exchange Bank") was founded as a public giro or payments bank by the municipality of Amsterdam in 1609. Its creation came during the middle of the 80 Years' War between the United Provinces of Holland and Spain, and at the beginning of a long period of relative prosperity in Holland often referred to as the Golden Age. The Bank was modelled after public deposit banks in Italy, notably the Banco di Rialto of Venice and similar banks in Rome, Genoa and Naples (Bindseil, 2019). It was fully owned by the city of Amsterdam, but had a governance structure made up of three (later four) commissioners – usually merchants or current or former members of the city council – who were appointed for one year at a time (often renewed; see van 't Hart, 2009).

The Bank was founded in the context of a large number of circulating metal coins the early 17th century, and the debasement of those coins by the deliberate mixing of base metals into gold and silver coins (Kindleberger and Aliber, 2005; Schnabel and Shin, 2018). In the Bank's founding decree, it was given a mandate to "*check all agio (of the current money) and confusion of coin, and to be of use to all persons who are in need of any kind of coin in business*".[5] Customers could

[5] The "agio" referred at the time to the premium on different types of currency, ie the difference between the rate of exchange in the market and the nominal value.

physically deposit metal coins with the Bank and receive assurance of their quality. Account balances were recorded in a central ledger, and could be transferred to other account holders without cost, or withdrawn for a small fee. In this context, accounts at the Bank helped to provide a common means of wholesale payment for domestic and international trade.

The Bank's strong performance over more than 170 years, including through times of turbulence, helped to solidify trust in the Bank as an institution. In the *Wealth of Nations*, Smith (1776) devotes several pages to the Bank as an example of the operation of a giro bank of the time:

> *At Amsterdam, however, no point of faith is better established than that for every guilder, circulated as bank money, there is a correspondent guilder in gold or silver to be found in the treasure of the bank. The city is guarantee that it should be so. The bank is under the direction of the four reigning burgomasters who are changed every year. Each new set of burgomasters visits the treasure, compares it with the books, receives it upon oath, and delivers it over, with the same awful solemnity, to the set which succeeds; and in that sober and religious country oaths are not yet disregarded.*

The operation of Bank guilders had strong parallels with modern proposals for stablecoins. The structure of the Bank's balance sheet was generally straightforward. On the liability side, it had current deposit accounts, generally by merchants (initially with about 700 accounts, up to nearly 3,000 in 1720). On the asset side, according to its statutes, the Bank was only intended to keep precious metals such as silver and gold coins (the era's safe assets). It relied on an ecosystem of cashiers (*kassiers*) to provide retail clients with services, such as redemption and credit, through the practice of discounting. Bank guilders were used for wholesale payments (large value payments between merchant bankers) while metal coins and the services of cashiers were used for everyday transactions – "retail payments" in today's parlance. The cashiers offer a parallel with today's retail banks and electronic wallet providers.

The Bank had its offices in the Amsterdam town hall. Printers in the same building provided standardised (if not "smart") contracts and

As will be shown later, the agio or premium on Bank guilders relative to current guilders came to be an important indicator of confidence in the stability of the Bank of Amsterdam.

other ancillary services (Gelderblom, 2013). The Bank's professional management helped it to manage operational risks, such as a fire in the town hall in 1652, in which some coins went missing. Record-keeping took place through a central ledger, copies of which were made twice per year, in January and July (van Dillen, 1925).

2.1 The move to proto-central bank

Throughout its history, the Bank departed from the strict application of full backing – without initially undermining its credibility (Uittenbogaard, 2009). It engaged in liquidity operations familiar to modern central banks, as well as outright lending. For instance, as early as 1615, the Bank lent to the Dutch East India Company (*Vereenigde Oostindische Compagnie*, VOC). Over time, such lending in the form of overdrafts (*anticipatie-penningen*) became a recurring activity. These overdrafts bridged the difference in timing between outgoing and incoming payments, often related to incoming and outgoing ship voyages, thereby providing working capital to the VOC in its trading activities. The provision of overdrafts in this setting played a similar role to the settlement smoothing function played by modern central banks in the wholesale payment systems. Moreover, interest on the loans provided an important source of income for the Bank that was generally distributed to the town authorities.[6]

A key date in the history of the Bank of Amsterdam was 1683, when it ended the policy of redeemability of deposits into coin (Quinn and Roberds, 2014). In some ways, the switch merely formalised prevailing practice that departed from the strict letter of the charter of the Bank, but the date is significant in that it marked the decisive break when deposits were no longer backed by segregated assets in the form of coin but instead were backed by the general creditworthiness of the institution as a whole. In this sense, 1683 was the decisive year when the Bank of Amsterdam changed from being a mere stablecoin issuer to an issuer of fiat money. This change was crucial for the role the Bank would play at the heart of the international payment system.

However, the shift from stablecoin to fiat money was not a complete shift. At the same time as removing the redeemability of deposits into coin, the Bank introduced a separate "receipt" system that allowed coin holders to sell their coins to the Bank with the option to repurchase the

[6] The Bank did not earn seigniorage income. Over 1700–83, interest was 46% of the bank's total profits (Uittenbogaard, 2009, p 123) alongside fees and a negligible amount of profit from bullion trading.

same coins after a fixed period – typically six months – for a small fee (¼ percent for silver coins and ½ percent for gold coins). During this period, the coin sellers would have a deposit claim at the Bank, and the coins under receipt would be earmarked ("encumbered") for potential withdrawal. By providing Bank guilders against coins as collateral, receipts resembled modern repurchase (repo) arrangements (Quinn and Roberds, 2014). With this policy change, the bank moved from a "rigid" to an "elastic" stablecoin, which combined redeemability with fiat money. The ability to purchase underlying coin by crediting the account of the seller meant that the Bank could increase the stock of Bank money through the outright purchase of coins, just as a modern central bank could increase base money through an asset purchase programme and quantitative easing (QE).

The change to fiat money was made possible through confidence in Amsterdam Bank money, cultivated over time. An initial test of the Bank's stability came in 1672, the "year of disaster" (*rampjaar*) in which the Dutch Republic was attacked simultaneously by England, France and two German armies. While the war ended quickly, with the assumption to power of the Orangists and peace treaties with the invading powers in the ensuing years, the conflict led to a rapid outflow of deposits from the Bank of Amsterdam. Swift action by the commissioners – in particular, the opening of the vaults to demonstrate that the coins had in fact been there for decades, even during the fire in the town hall 20 years before – helped to restore confidence. Voltaire (1751) describes this event in colourful detail:

> *Those private persons who were possessed of bank-notes ran in crowds to the Bank of Amsterdam, apprehending that the public stock had been broken in upon: every one was for being paid with the little money supposed to be left. The magistrates immediately ordered the vaults to be opened where this treasure is kept, when it was found entire, as it had been deposited there, for upwards of sixty years. The money was still black and discoloured, with the fire which had burnt down the town-house several years before [in 1652]…"*

The metal stock did fall from 8 million guilders in 1671 to 2 million in 1673, and the balance sheet shrank accordingly. This underscores the nature of the early Bank of Amsterdam as a rigid stablecoin where the size of the balance sheet is passively determined by the actions of depositors. The Bank remained open through this economic crisis, but

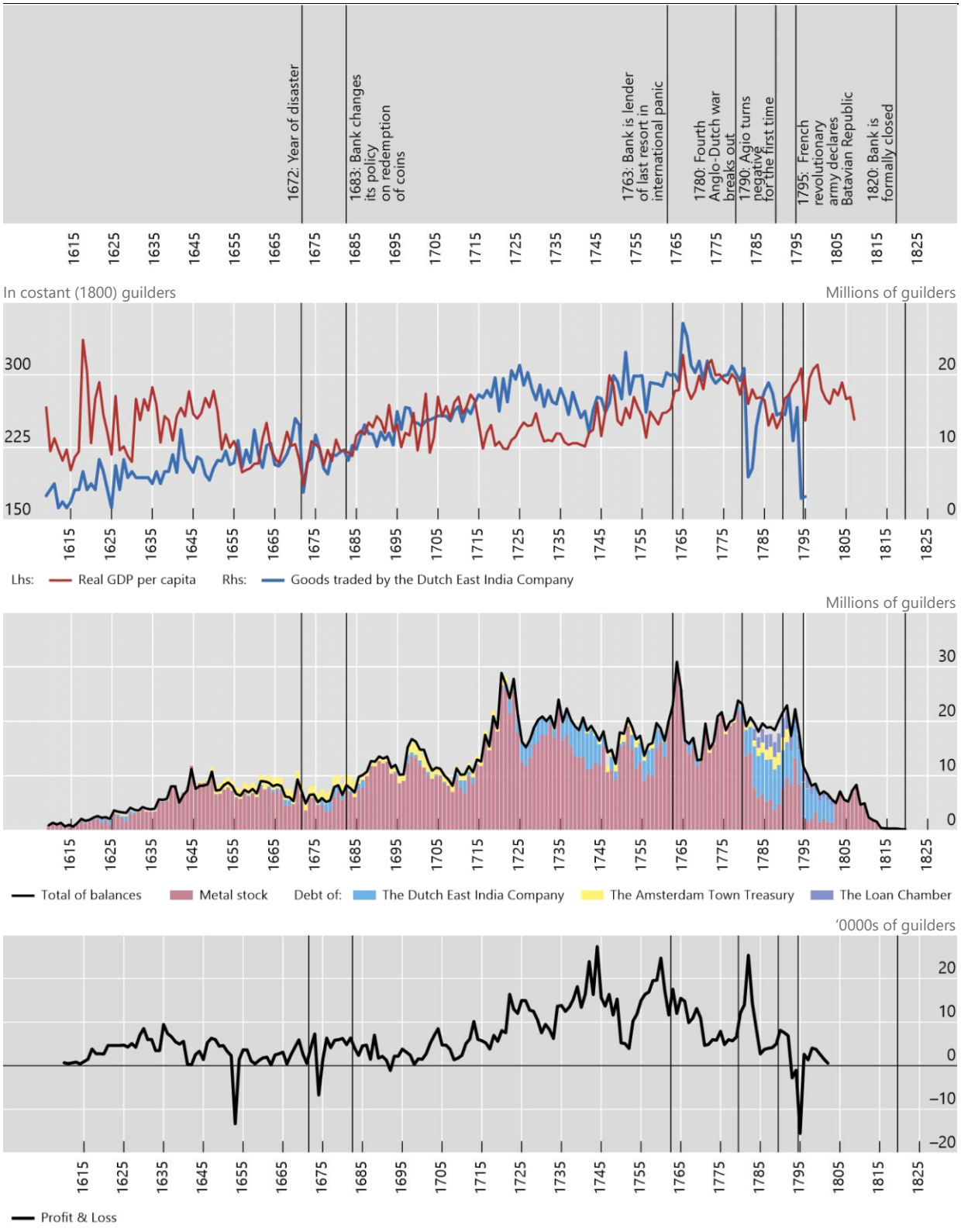
such a sharp contraction of the money stock had repercussions for the wholesale payment system. While interest rates, consumer prices and the agio remained relatively stable, production in the economy fell sharply, and house prices dropped by over half (Eichholtz, 1997). Retail business continued more smoothly, as cashiers continued to do business with the Bank and clients (Willemsen, 2009).

Thus, when the Bank formally ended redemption in 1683, the use of receipts and the secondary market with cashiers were already established practices (Quinn and Roberds, 2019). In subsequent decades, thanks in large part to its new structure, the Bank's business saw rapid growth, with account balances rising from 4.9 million guilders in 1673 to 28.9 million in 1721 (Graph 1, third panel). Profits were generally quite stable (Graph 1, bottom panel), and municipal loans that were forgiven provided additional revenue to the municipal coffers. This distribution of profits, however, prevented the bank from building up an equity buffer.[7]

The Bank's reputation was further bolstered by the demonstrated resilience of the Bank in the face of the panic of 1763, described in more detail in Schnabel and Shin (2004). At the end of the Seven Years' War between England and France, a panic gripped the market for bills of exchange and acceptance loans, which had been used to channel capital from Amsterdam to capital-hungry emerging regions like Prussia. The overstretched merchant house *Gebroeders de Neufville* folded, sending shock waves through the system. The Bank of Amsterdam took on a lender of last resort (LOLR) function, providing emergency liquidity by accepting a broader range of collateral, and with open-market operations (Quinn and Roberds, 2015). This helped to contain the crisis in Amsterdam – although there was still widespread contagion to other financial centres of the time, notably Hamburg and Venice.

[7] In this light, the Bank of Amsterdam resembled its younger sister across the English Channel – the Bank of England. The Bank of England received its royal charter in 1694 from King William III (the Dutch-born William of Orange), and was modelled on the Bank of Amsterdam. Over its history, it lent frequently to the British East India Company (EIC). In 1773, as the EIC teetered on the verge of bankruptcy, it received emergency loans from the Bank of England. At the same time, an act of parliament – the 1773 Tea Act – allowed the EIC to export tea directly to the American colonies, thus competing with smuggled Dutch tea purchased from the VOC, while maintaining the existing taxes on tea (Lawson, 1993). The Tea Act proved unpopular in the American colonies, and led to the December 1773 Boston Tea Party – an important milestone leading to the American Revolution.

Bank of Amsterdam assets, profit and loss, agio and economic indicators Graph 1



Sources: van Dillen (1934); Quinn and Roberds (2016); authors' calculations.

While the Bank's balance sheet expanded in this period – up to a peak account balance of 30.9 million guilders in 1764 – assets remained primarily in metal stock, as shown in Graph 1 (third panel). This episode again helped to bolster confidence in the Bank, and its further move toward an elastic stablecoin structure. While lending to the Dutch East India Company and the Town Treasury was often non-negligible, metal coin made up an average of 87% in the period through 1776.

2.2 Rigid and elastic stablecoins

The Bank of Amsterdam illustrates some of the principles behind the role of central banks to provide settlement liquidity for the smooth functioning of the payment system. Yet it also shows the dangers posed to the system if such discretion is taken too far, and is misused. Therefore, we provide further context to the downfall of the Bank of Amsterdam by giving some background on why rigid stablecoins have limited usefulness in wholesale payments, and why the liquidity operations of the Bank of Amsterdam were a natural extension of its role in the payment system. We divide our discussion into three parts, corresponding to three aspects of the Bank's liquidity operations: (i) maintaining the agio through monetary operations; (ii) maintaining settlement liquidity through sufficient money balances and smoothing seasonal shortages in liquidity through lending and (iii) due this this role, gradually developing a role as a lender of last resort.

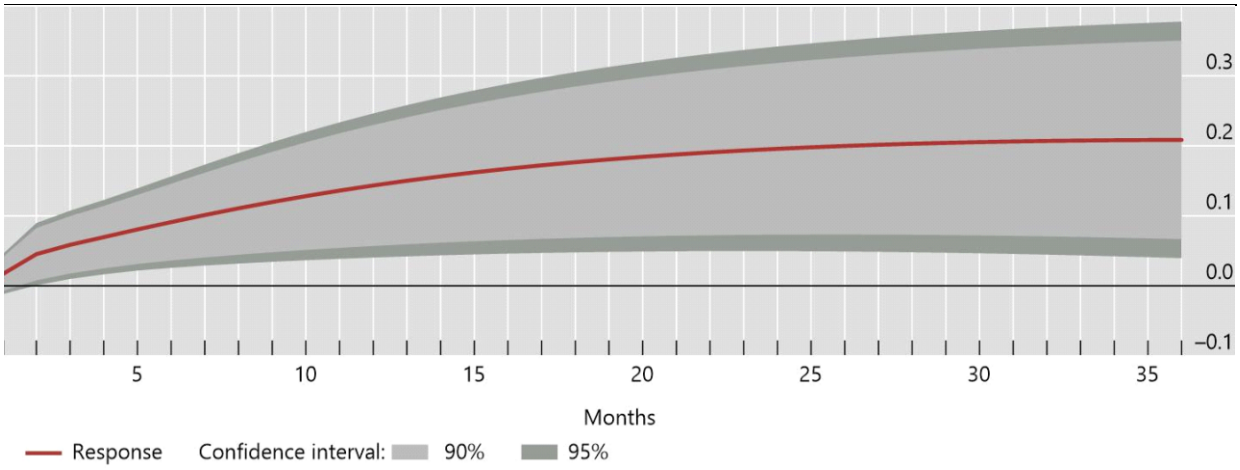
A stable agio through monetary operations

As part of its monetary operations, the Bank of Amsterdam engaged in monetary operations to stabilise the value of the agio. In some ways, these operations resemble those of a currency board. A modern currency board – such as that in Hong Kong or Bulgaria – is geared around maintaining a stable exchange rate to an anchor currency by maintaining backing assets that are larger than the amount of base money (Mundell, 1997). The Bank of Amsterdam sought to keep the agio of Bank guilders to current guilders (metal coins) in a target range between 4 and 5 percent, and thus to ensure Bank guilders could serve as a stable unit of account. For many years, this policy target was implicit and was not publicly communicated; it was only in 1782 that the Amsterdam executive council instructed the Bank's commissioners to maintain this target range (van Dillen, 1925, pp 433–4; Quinn and Roberds, 2019, p 751).

Quinn and Roberds (2019) give evidence from a vector auto-regression (VAR) exercise over 1735–92 that the Bank of Amsterdam adjusted its money stock to stabilise the agio. The Bank expanded the money stock through the purchase of coins when the agio rose, and contracted the money stock through sale of coins when the agio fell. Graph 2 replicates the key impulse response function of unencumbered metal to a shock to the agio, for the adjusted period of 1736–75.[8] It is clear that the Bank purchased unencumbered coins following a shock to the agio, and conversely that they were decreased when the agio fell. As in Quinn and Roberds, the change in the money stock was quite persistent – meaning there were limits to the extent to which the Bank could steer the agio in this manner. Nonetheless, by keeping the agio stable, the Bank helped to maintain trust in the value of Bank guilders, and ensure stable liquidity in the market for wholesale payments.[9]

The Bank purchased unencumbered metal to stabilise the agio

Response to a one-standard deviation shock in the agio, in millions of guilders — Graph 2



The graph shows the impulse response function (IRF) of unencumbered metal to a one standard deviation shock to the Dutch agio. The VAR model on which the IRF has been estimated includes the Dutch agio, the bill interest rates, money backed by loans (deseasonalised), bank money backed by encumbered coins and bank money backed by unencumbered coins. The standard errors are estimated using a Monte Carlo approach with 1000 draws.

Source: Quinn and Roberds (2019); authors' calculations.

[8] The VAR model is estimated over the period January 1736–January 1775. It adopts the following Cholesky ordering: Dutch agio, unencumbered accounts and encumbered accounts. It includes up to two period lags. For brevity, only the response of unencumbered accounts to the agio is presented.

[9] Ugolini (2017) shows that the Bank of England performed similarly significant open market operations during the classical gold standard, including transactions in American coins and reverse repos.

Settlement liquidity and the money stock

Amsterdam was Europe's pre-eminent financial centre for much of the history of the Bank of Amsterdam. The Bank played a central role in European and global trade, channelling hundreds of tons of silver coins (generally from the Spanish colonies in the New World) to growing economies in Asia through its liquid markets, providing an international unit of account in the process. It sustained growth in credit through bills of exchange that enabled the rapid growth in trade and manufacturing. Bills of exchange were "orders to pay", rather than a "promise to pay", but the practice of endorsement and the sequential passing on of bills to trade counterparties allowed rapid credit growth that fuelled the growth of trade. It also gave rise to an interconnected web of international credit relationships (see Schnabel and Shin (2004) for details). The Bank of Amsterdam stood at the heart of this web of financial interconnections, as Bank money was the means to settle bills of exchange. It therefore stood at the core of the large value payment systems – wholesale payment systems – that are today overseen by central banks. Maintaining settlement liquidity is a key function of modern central banks.

"Settlement liquidity" refers to the ability to execute payments promptly, thereby allowing others in the system to fulfil their obligations. For modern large-value payment systems that transact in real time – so-called real-time gross settlement (RTGS) systems – imposing a cash-in-advance requirement can impose inefficient delays and possible "gridlocks" in payments. If a system participant holds 100 dollars in cash balances, but needs to send a payment of 200 dollars, either the shortfall needs to be borrowed from somewhere, or the payment is delayed until sufficient incoming funds replenish the cash balance sufficient to send the payment. In large-value payment systems where the value of payments is large relative to cash balances, settlement liquidity emerges as a key source of potential inefficiency. This is where the central bank comes into its own by providing overdrafts to payment system participants, allowing them to overdraw on their accounts at the central bank, and thereby allowing them make payments immediately.

Over longer periods, the amounts of incoming and outgoing payments can be expected to roughly cancel out, provided that there is not a run on an individual bank, or on the banking system as a whole. But over shorter periods, differences in timing can lead to imbalances. Liquidity needs due to differences in the timing of incoming and outgoing payments need to be covered. Banks will therefore hold

reserves for precautionary reasons. But these are subject to opportunity costs, as the return on reserves will be less than the return on loans. Differences in timing therefore also create a demand for liquidity. The size of such intra-day liquidity has been very significant, especially compared to overnight or longer term liquidity (Hervo, 2008). Allsopp et al (2009) find that, in 88 of the 98 cases identified by their survey, the central bank settlement authorities grant intra-day credit by way of loans, repos or account overdrafts. Central banks are active in this market due to their role in promoting the proper functioning of payment systems.[10]

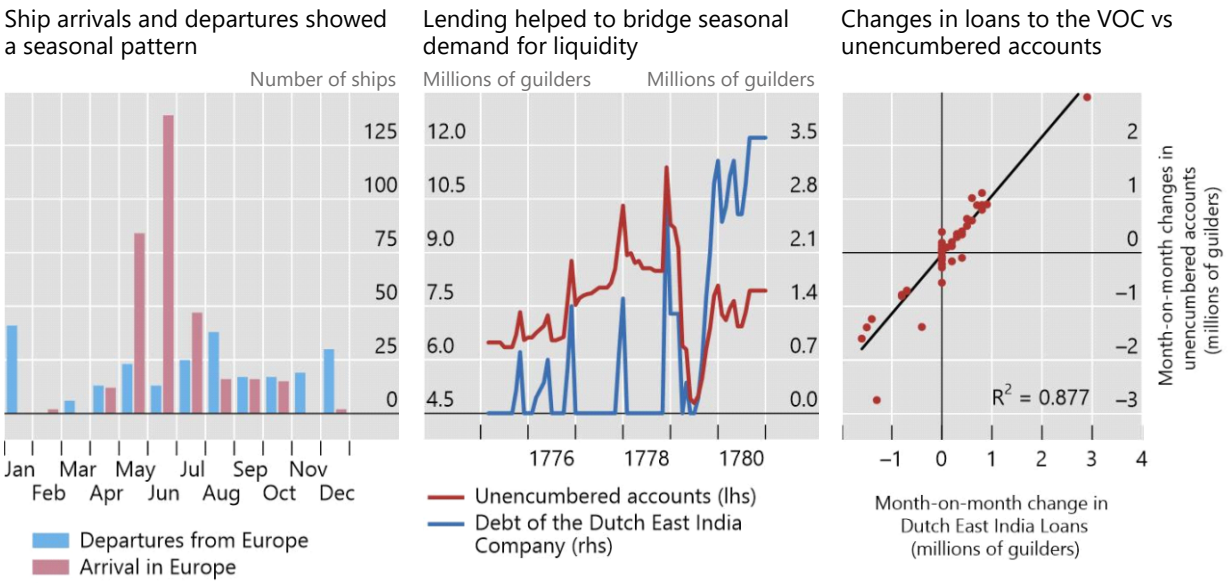
The liquidity provision role of the Bank of Amsterdam is most clearly illustrated by its seasonal lending patterns to the VOC. These data are captured in the (digitised) ship logs from the national archives in The Hague, made available by KNAW Huygens. The ships' logs show that in the years leading up to the war, there was a brisk flow of VOC ships between Dutch ports in Texel, Rammekens and Goeree and colonial outposts in Batavia (today's Jakarta), Galle in Ceylon (today's Sri Lanka) and Bengal, in India.[11] Typically, ships would arrive in Europe between May and July, and then would be kitted out for their outward journey in August to January (Graph 3, left-hand panel).[12] Thus, the VOC faced a seasonal pattern in its financing need for working capital purposes, where its demand for credit peaked in the winter months, after ships had departed but before the arrival of goods to sell from Asia, Oceania and Africa. This resulted in a "saw tooth" pattern of brief borrowing which was quickly repaid (Graph 3, centre panel). Such credit was usually granted through a simple increase in the unencumbered accounts of the VOC at the Bank (Graph 3, right-hand panel).

[10] Separately, modern central banks often use overnight credit for monetary policy implementation. See Borio (1997). A demand-determined, elastic supply of credit is essential for the central bank to set interest rates (Borio, 2019).

[11] Ships sailed a roughly fixed inbound and return route based on trade winds. The inbound route to Asia was perilous because the measurement of longitude was not yet advanced, meaning that ships often missed their target ports in Galle or Batavia. It was only in the 1760s that John Harrison's chronometers (watches) allowed for accurate measurement of longitude – eg on Captain Cook's 1772–5 voyage of the South Seas. For more, see Sobel (1995).

[12] There were exceptions – some ships would depart as early as May-August, or as late as January. Frequently, ships would depart in groups either on the same day or within the same week.

Seasonal shipping and the demand for credit[1] Graph 3



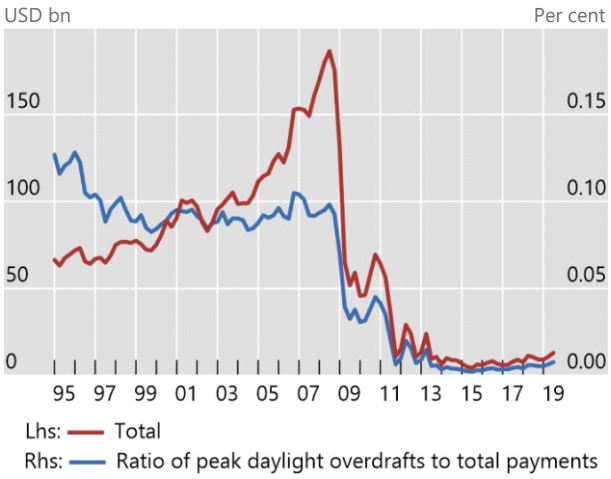
[1] The sample covers the period February 1775–1780

Sources: Quinn and Roberds (2016); http://resources.huygens.knaw.nl/das/DAS/voyages; authors' calculations.

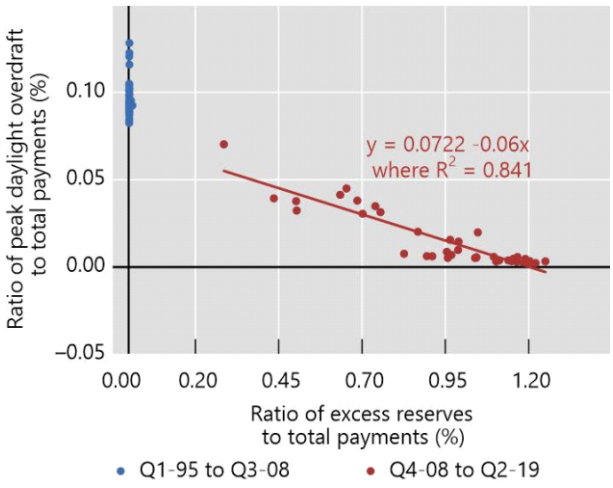
Similar mechanisms for settlement liquidity are visible in wholesale payment systems today. Indeed, Graph 4 illustrates the "daylight overdrafts" provided by the Federal Reserve to the US RTGS system, Fedwire (see also Bech et al, 2012). The red line shows the peak daylight overdraft in dollar terms, while the blue line shows it as a percentage of total daily payment amounts. Daylight overdrafts were used extensively before the expansion of the Fed's balance sheet in 2008, but daylight overdrafts have declined, as the excess reserve balances of commercial banks at the Fed have grown since 2008. The contrast between the pre- and post-crisis periods in Graph 4 (left-hand panel) highlights how important daylight overdrafts were before the crisis of 2008. The right-hand panel shows the relationship between daylight overdrafts and excess reserves. We see the downward-sloping relationship between the two post-crisis, implying that excess reserves have substituted for this type of credit.

Daylight overdrafts were a key feature in Fedwire before the 2008 crisis Graph 4

Daily overdrafts in Fedwire



Daylight overdrafts and excess reserves



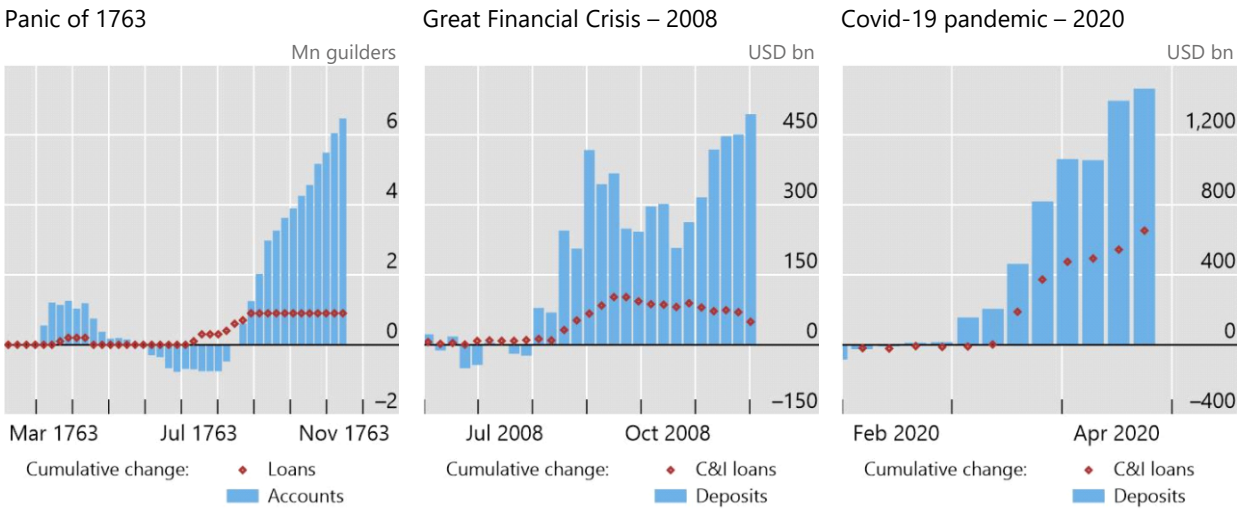
Source: Board of Governors of the Federal Reserve System.

Lender of last resort

The outright lending to the VOC was in contravention to the charter of the Bank of Amsterdam, and such lending was not disclosed. During normal times, the lending was small in proportion to the overall balance sheet of the Bank of Amsterdam, and did not impact the financial strength of the Bank and the confidence in its money.

Yet during periods of crisis, lending could increase – through the Bank's normal repo activities, through unsecured loans and through open market operations. During the crisis of 1763, the Bank of Amsterdam expanded its balance sheet by 8 million guilders, or 35% of its assets, injecting liquidity into the financial system. It did so by broadening the range of collateral accepted under receipts, including silver bullion, thus helping key players in the local banking market remain afloat (Quinn and Roberds, 2015). It also expanded its open market operations by purchasing metal coins and bullion in the market, crediting the accounts of the sellers of coins. Unsecured lending was limited in the panic of 1763. By preventing a seizing up of market liquidity, the Bank served as a flexible node in the system. Deposits at the Bank (receipts) rose (Graph 5, left-hand panel) and were used to unwind long credit intermediation chains. This was to some extent comparable to the rise in deposits and loans of US commercial banks (with the Fed's backing) as they absorbed the shocks of the 2008 Great Financial Crisis and, more recently, the dislocations in market finance in the Covid-19 pandemic (Graph 5, centre and right-panel panels).

Flexible nodes in the system can help stem a drying-up of market liquidity Graph 5



C&I loans = Commercial and industrial loans

Sources: Quinn and Roberds (2015); Board of Governors of the Federal Reserve System; Bloomberg; authors' calculations.

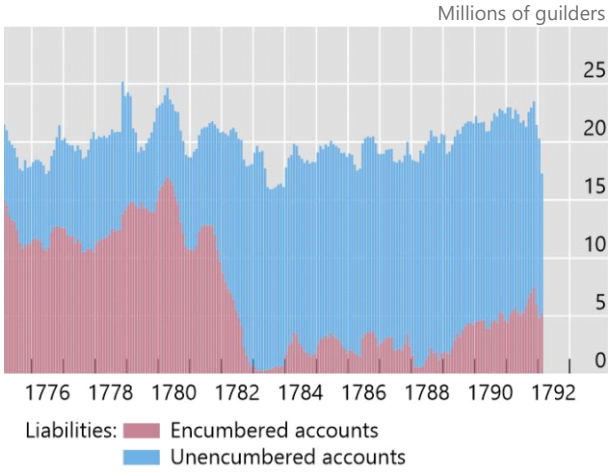
In the Anglo-Dutch war, the Bank relied in particular on unsecured lending and on open market operations. During 1775–92, the Bank of Amsterdam maintained stable money balances through the provision of loans and purchase and sale of coins. Monthly data from 1775–92 show that the Bank often held its balance sheet size roughly stable (Graph 6, left-hand panel). When account holders massively withdrew coins from their encumbered accounts, the overall balance sheet remained roughly stable mostly due to the provision of loans and purchases of unencumbered coins (Graph 6, right-hand panel).

However, when credit quality deteriorated due to the strains posed by war, this led to a more far-reaching failure of the governance of the Bank of Amsterdam. The volume of loans increased drastically and the Bank *de facto* became lender of last resort to the VOC.[13]

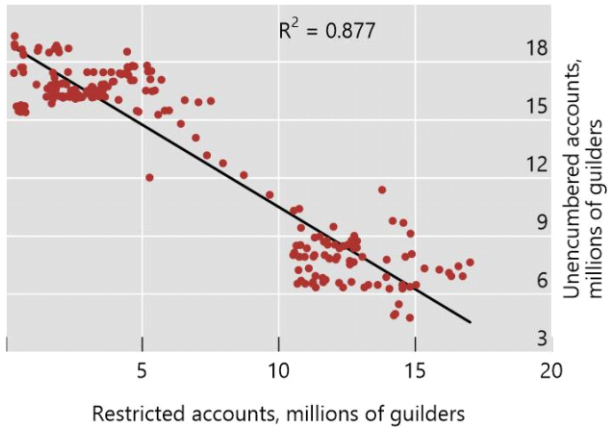
[13] For the classic reference on the role of a lender of last resort, see Bagehot (1873).

Encumbered and unencumbered accounts at the Bank of Amsterdam Graph 6

The Bank created and purchased coin to make up for falling receipts



The two types of accounts substituted for one another



Encumbered accounts refer to those where account holders held a receipt entitling them to redeem their coin after a fixed period (typically six months). Unencumbered accounts were those without a redeemability option. The Bank typically created balances in unencumbered accounts through purchases of coins in open market operations, and by granting loans.

Source: Quinn and Roberds (2016); authors' calculations.

2.3 The downfall of the Bank of Amsterdam

The resilience of the Bank of Amsterdam and its success may also have been its ultimate undoing. In the late 1770s, under the economic pressures generated by a new war with the English, the Bank embarked on a period of more serious divergence from its charter by lending on a more substantial scale, in a sustained and non-transparent way.

With the benefit of hindsight and the intervening history, the Bank of Amsterdam lacked the safeguards and governance structure needed to support a durable fiat currency. Janssen (2015) relates how the excessively cosy relationship between the Amsterdam municipal authorities and the commissioners of the Bank made the latter susceptible to pressure to act in disregard of its charter.[14] The lack of institutional safeguards on the independence of the Bank became increasingly apparent. Moreover, while the Bank's public sector ownership by the city of Amsterdam gave it some degree of limited fiscal backing by the city tax authorities (and also the ability to mutualise losses across segments of Amsterdam society), this may not

[14] She notes, drawing on van 't Hart (2009), that the age of commissioners fell from an average of 46 years in the early part of its history to 33 in the latter half of the 18th century. She noted that "*for young men at the beginning of their career it was even harder than for their experienced predecessors to defend themselves against the powerful mayors*".

have been sufficient for the large scale of activities of the Bank given the large volume of international trade through Amsterdam. In any case, the actions of municipal authorities to receive profit distributions of the Bank without a symmetric recapitalisation flow in times of losses cast doubt on the value of the municipal backing for the sustainability of solvency.

The pivotal event was the shock of the Fourth Anglo-Dutch war (1780–84) which led to extensive naval confrontations between the Dutch Republic and England in several theatres of conflict – in European, West Indian and Asian waters. This conflict was an economic shock that strained the VOC, which was the main borrower of the Bank of Amsterdam. Shipping volumes by the VOC fell dramatically; sales of trade goods in the Netherlands dropped from 20.9 million guilders in 1780 to only 5.9 million in 1781 (Graph 7, bottom panel).

Amid dire and deteriorating economic conditions, the Bank commissioners made the fateful decision to start granting large-scale overdrafts to the VOC. As a result, the credit exposure of the Bank rose initially to 4.8 million guilders before the Bank stopped new lending in 1781, but the stock of loans to the VOC remained high. The slump in the VOC trade continued (Jonker and Sluyterman, 2000).

The scale of this exogenous economic shock is perhaps best illustrated by the fate of VOC ships. In May 1781, VOC ships such as the *Amsterdam, Batavia* and *Indiaan*, on their way back to port, were sent to Mauritius to assist the French; all were either damaged or went missing. In July 1781, the ships *Honkoop, Hoogkarspel, Middelburg, Parel* and *Dankbaarheid* were seized or burnt down by the English in Saldanha Bay (modern South Africa). The loss of this many ships imposed catastrophic financial and operational losses for the VOC. On top of everything else, the logs also record that crews of several ships came down with scurvy in September 1781, leading to a high death rate among the crew. Loans already extended could no longer be repaid.

In May 1782, the commissioners made the fateful decision to swap the suspended loans to the VOC into longer-term bonds (van Dillen, 1934). Throughout 1782, the Bank steadily ramped up its lending to the VOC; outstanding loans rose from 0 in June 1779 to a peak of 7.8 million guilders in February 1783. Together with loans to the Town Treasury and the City Loan Chamber (*stadsbeleningskamer*), which in turn provided credit to local merchants, a full 71% of the Bank's assets were now in credit. As loans increased, the metal stock fell, from 17.6 million guilders in 1776 to 7.8 million in 1783 (Graph 7, second

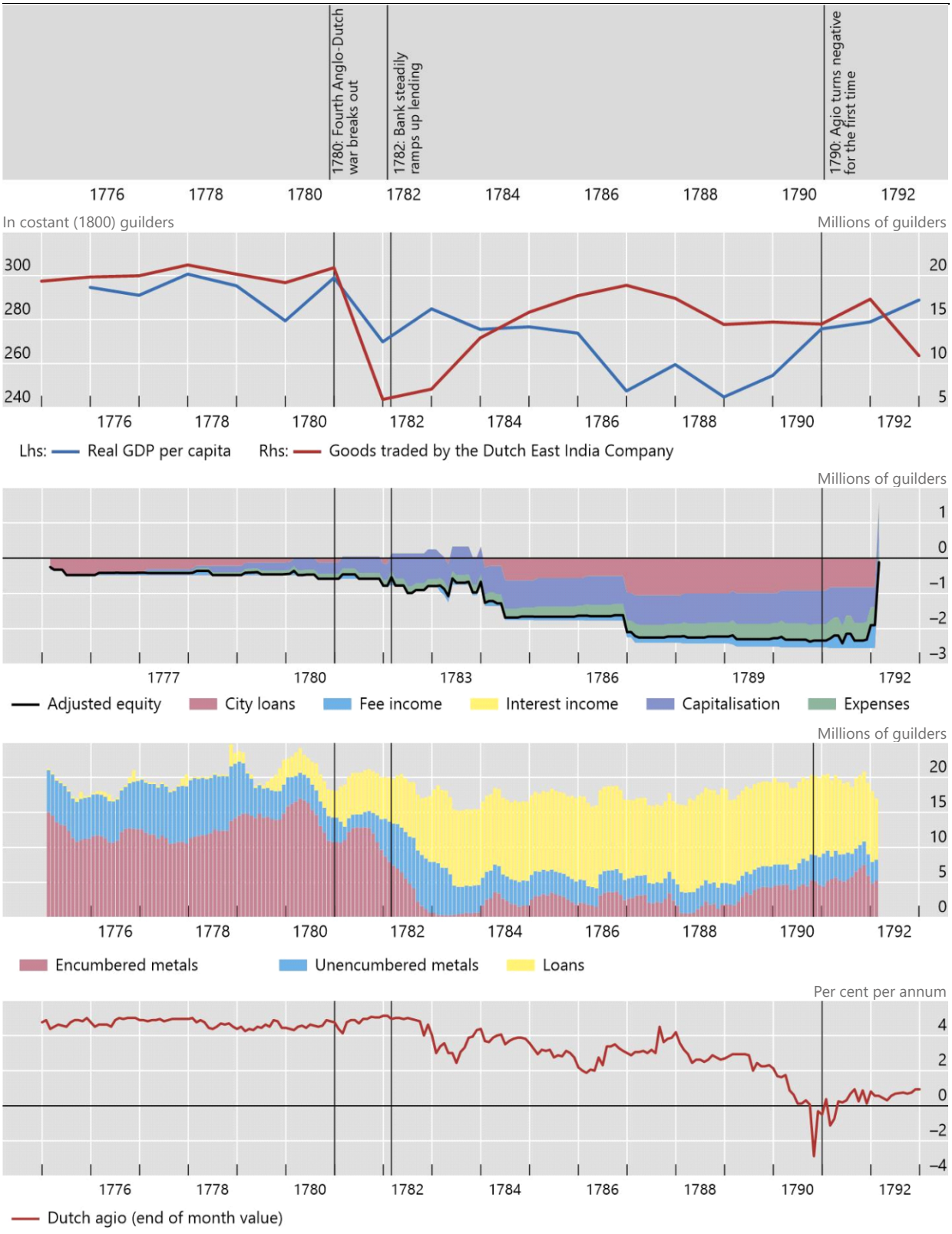
panel). This was because account holders with receipts redeemed coins by allowing their receipts to expire.

To finance the additional lending in the absence of coin inflows, the Bank bought coins on the open market through money creation – by crediting the accounts of coin sellers (Quinn and Roberds, 2016). Bank guilders were now only backed by metal coins for 40% of their value, and by 1784, this had declined even further to 33%. With the conclusion of the war in May 1784, the Bank had accumulated a large credit exposure which soon become non-performing. The temporary shock had become one of chronic insolvency (Uittenbogaard, 2009, p 131).

The Bank's insolvency, and the refusal of the city authorities to recapitalise it, are important elements in its downfall. The Bank's income sources comprised mainly fees from the receipt system and interest margins on loans. However, while the loans to the VOC became non-performing, the bank had not been rebuilding capital to cover these losses, as profits were regularly distributed to the city. Moreover, it did not have seigniorage income of modern central banks, nor an adequate fiscal backstop. The city of Amsterdam did make limited attempts to recapitalise the Bank, but the funds were quickly diverted back to city coffers (Quinn and Roberds, 2016). From the perspective of modern central banking theory, the City of Amsterdam's fiscal capacity was insufficient to provide the sovereign backing of an institution that had become a proto-central bank.

The extent of lending exposures remained opaque for a further decade, but market developments as indicated by the agio suggests that market participants were exercising scepticism on the full solvency of the Bank of Amsterdam. In July 1789, as the Bastille was stormed in Paris and uncertainty spread across Europe, there was a brief drop to 2%. The agio on the Bank guilder trended downward thereafter, and eventually turned negative in October 1790–February 1791, before recovering briefly following a bond issue of 6 million guilders for recapitalisation (van Dillen, 1964).

Bank of Amsterdam assets, adjusted equity, agio and economic indicators Graph 7



Sources: van Dillen (1934); Quinn and Roberds (2016); authors' calculations.

2.4 The aftermath

It was only in 1795, after the invasion of the Netherlands by French revolutionary armies, that the true extent of the Bank's insolvency came to light. The new authorities decreed that the Bank's accounts would be made public, revealing the low metal stock. The agio on Bank guilders dropped to nearly -30% on the revelation. From 1795 to 1820, the Bank lived on as a severely weakened institution. After William, Prince of Orange-Nassau, proclaimed himself King William I in 1813, he founded the De Nederlandsche Bank, today's central bank of the Netherlands (Vanthoor, 2006; Uittenbogaard, 2015). The Bank of Amsterdam was finally closed in 1820.

The economic fallout from the war, compounded by the downfall of the VOC and the failure of the Bank of Amsterdam were severe. Income per capita fell by 17% between 1794 and 1807 (Graph 7, second panel), and prices of housing fell by 29%. The Bank guilder lost its role in international finance, and the centre of gravity in European finance shifted definitively to London (Carlos and Neal, 2011).

3. Asset backing and confidence in money

We now turn to the core empirical findings of our paper, where we examine the ebbing confidence in the money issued by the Bank of Amsterdam. This is reflected in fluctuations in the agio of Bank guilders over current guilders. The analysis draws on the monthly reconstruction of the balance sheet of the Bank of Amsterdam by Quinn and Roberds (2016). We augment the balance sheet time series with the economic dataset of the period from the digitised archive data of KNAW Huygens and economic indicators from van Zanden and van Leeuwen (2012). The dataset contains monthly data for the period February 1775 to December 1792.

Our working hypothesis is that the increased lending activity of the Bank served to erode the confidence in Bank money, especially when the loan quality deteriorated. In time, such an erosion of confidence would eventually be reflected in a lower agio of Bank of Amsterdam money – that is, the value of Bank guilders relative to the physical coins. However, the opaqueness of the lending activity would also suggest that the erosion of confidence would have been a long and drawn-out affair, where the deteriorating loan quality was reflected in the agio over a long period of time.

Motivated by these considerations, we approach the exercise by posing two related questions. First, what was the long-run impact on the agio of the lending activities by the Bank of Amsterdam? Second, in the run-up to the Bank's downfall, how did the short-run adjustment dynamics play out?

Graph 7 (bottom panel) shows the agio for the shorter time period of our empirical analysis encompassing 1775 to 1792. As discussed above, the policy objective of the Bank of Amsterdam was to maintain a stable agio of around 5% in the value of the Bank guilder relative to the value of current guilders in circulation. For this reason, the 5% agio serves as our benchmark. We see that the agio starts off close to the 5% benchmark, but experiences a sustained decrease, punctuated by sharp drops. The period around 1789 is especially noteworthy, when the agio dips briefly into negative territory. The trajectory of the agio during this period suggests that the series is not stationary, and this is confirmed by augmented Dickey-Fuller tests. The first differences of the series, however, pass the test for stationarity. For this reason, we work with the monthly changes in the agio in our regressions below.

Graph 7 (fourth panel) shows the loan share and coins under receipt, which are measured here as a percentage of total assets.[15] The loan share starts to increase sharply at the start of the crisis. A large drop in the coins under receipt occurs later, after the loan share has increased to around 30% (which corresponds to a decrease in the reserve ratio to around 70%). The decline in the agio occurred somewhat later, from 1783 onward. In this respect, the run on the Bank of Amsterdam was a delayed response to an earlier weakening of the liquidity position.

One factor in the delayed response of depositors may have been the remedial response of the Bank to shore up its metal stock through money creation. As reported earlier, the Bank used open market operations to support the agio by selling silver and gold coins, thus reducing the volume of unencumbered accounts. Even as late as 1783, the Bank of Amsterdam sold 3.5 million worth of coins in guilders and managed to shore up the agio.

However, from 1784 onwards, the Bank's finances were sufficiently weakened that it became increasingly difficult to sustain the agio with monetary operations (Quinn and Roberds, 2016). The stock of unencumbered coins was dangerously low, and credit losses weighed

[15] As an alternative to the loan share, we could have looked at the reserve ratio, which has a correlation of -1 with the loan share by definition.

on the Bank's solvency. For this reason, Quinn and Roberds argue that the Bank of Amsterdam became "policy insolvent", meaning that its adjusted equity became so deeply negative (Graph 7, third panel) that the Bank lost its ability to maintain its implicit policy objective to maintaining an agio of 5%.

3.1 Cointegration analysis

We shed further light on the erosion of confidence by searching for a long-run equilibrium relationship between the Bank's reserve ratio and the agio through an error-correction relationship. This is given by:

$$Agio_t = \alpha Loan\_share_t + constant + \varepsilon_t \quad [1]$$

$$\Delta Agio_t = \beta \Delta Agio_{t-1} + \gamma \Delta Loan\_share_{t-1} + \theta \varepsilon_{t-1} + \mu_t \quad [2]$$

where $Agio_t$is the agio between Bank and current guilders in per cent in month t, $Loan\_share_t$ is the share of loans in the Bank's total assets in per cent in month 1, Δ refers to month-on-month changes, and α, β, γ and θ are estimated coefficients. ε_{t-1} and μ_t are error terms.[16]

The error correction model rests on two principles. The first principle (expressed in equation [1]) is that, over the long run, there is a cointegrating relationship between the size of the agio and the value of the assets backing Bank guilders. This long-run relationship reflects the underlying credit risk arising from extensive lending. The second principle (expressed in equation [2]) is that in the short run the agio will veer toward its underlying long-run value. With an error correction model, we allow the possibility that the adjustment can take some time given the opaqueness of the Bank of Amsterdam's lending operations, and the fact that it was drawing on the credibility of Bank money built up over an extended period.

Table 1 shows the ordinary least squares (OLS) regression results for equation [1]. If the variables are cointegrated, estimation by OLS produces a consistent estimator of the cointegrating relationship (Verbeek, 2017). Column 1 shows the results of the regression for the agio where the credit risk term is included simply as the loan share (the

[16] Finding the exact specification and lag structure usually requires further inference. In our case, the constant, the contemporaneous value of the difference in the loan share and lags beyond the first lag are not statistically significant and have therefore been dropped from the regression. The Durbin-Watson statistic for our regression results below is above the critical value, meaning the test shows not statistical evidence that the error terms are positively autocorrelated.

proportion of loans to total assets of the Bank). The coefficient is highly statistically significant and negative, while the constant is significant and positive. A loan share of zero, implying full compliance with the mandate of no lending, corresponds to an agio of 0.048, or 4.8%, very close to the upper bound of the policy band of 5%. However, the augmented Dickey-Fuller test of the residuals does not reject the null hypothesis of a unit root in the residuals, using Engle-Granger critical values.[17] The Johansen test for cointegration leads to a similar conclusion. Our hypothesis of a long-term equilibrium relationship between the agio and loan share is therefore not confirmed.[18]

Visual inspection of the residuals, however, suggests a stationary process for most of the period, except after 1789, when the agio drops sharply, as shown in Graph 7 (bottom panel). Quinn and Roberds (2016, p 93) also note this large decline in the agio. They point to the political instability after the French revolution that occurred at that time. A contemporary observer attributed the weakness of the Bank guilder to sovereign loans made by Amsterdam merchant banks to Russia, Sweden, and Austria (cited in van Dillen, 1964, p 420). We therefore run the Gregory-Hansen test, which tests for an endogenous breakpoint in a cointegration relationship (Gregory and Hansen, 1996). Results indeed indicate a structural break in the constant in July 1789 – the month of the storming of the Bastille. We therefore introduce a dummy for the period after July 1789 and allow for a different intercept from that time onwards. Results are shown in column 2. The R-squared jumps up from 0.37 to 0.80. Moreover, the breakpoint is highly statistically significant and points to a level drop at an agio of 2.8%. The other variables are still highly significant as well, at the 1% level, and confirm the expected negative long-term relationship between the loan share and the agio. Importantly, the null hypothesis of a unit root in the residuals is now strongly rejected, at the 1% level. Similarly, the Johansen procedure also points to one cointegration relationship.

It is of course possible that lending or credit risk were influenced by the agio, itself. To isolate the effect of credit risk on the agio, we instrument the credit risk with an estimate of the lagged monthly value

[17] Since we are using an estimated value, we do not use the Dickey-Fuller critical values, but the larger adjusted Engle-Granger cointegration critical values. See https://www.real-statistics.com/statistics-tables/engle-granger-table.

[18] The Dickey-Fuller tests for the agio and loan share do not reject the null hypothesis of a unit root in levels, but do reject a unit root in first differences. Testing for cointegration in equation [1] is therefore appropriate.

of goods traded by the VOC – an exogenous factor that was strongly correlated with the VOC's financing needs.[19] We run a simple two-stage regression where loan share is first regressed on lagged trade values, and the predicted value is used as our instrument of credit risk. Our hypothesis is that the increase in the loan share reflects that the Bank of Amsterdam reacted to a worsening external environment. The causality may therefore run from the negative external shocks of the effect of the war on trade to the Bank's lending behaviour, and subsequently to the decline in the agio.

Regression results for long-term effects of loan share on agio Table 1

Dependent variable	Agio		
	(1)	(2)	(3)
Loan share	–0.034***	–0.025***	
	(–11.0)	(–13.8)	
Loan share, lagged and instrumented[1]			–0.035**
			(–2.0)
Constant	0.048***	0.049***	0.052***
	(32.0)	(56.8)	(7.7)
Dummy=1 for period from July 1789 onward		–0.029***	–0.026***
		(–20.5)	(-6.9)
Estimation method	LSE	LSE	2SLS
Observations	205	205	107
R-squared	0.37	0.80	0.78
Test results for null hypothesis of unit root in the residuals	Not rejected; test statistic of – 1.2 versus –2.6 at 10% critical value	Rejected at 1%; test statistic of -4.0 versus –3.5 at 1% critical value	Rejected at 1%; test statistic of – 3.7 versus –3.5 at 1% critical value

T-values in parenthesis (and Z-values for the instrumented regression). ***/**/* denotes results significant at the 1/5/10% level. The sample period is Feb 1775–Dec 1792.

[1] The instrument variable for the loan share is the lagged value of monthly traded goods.

Column 3 shows the regression results of our instrumental variable regression. The findings indicate that the lagged effect of the loan share on the agio is again statistically significant, even if the number of observations is smaller. Moreover, the null hypothesis of a unit root in the residuals is again rejected at the 1% level. We take this evidence as suggestive of a lagged causal effect, running from the deterioration in

[19] The monthly series is constructed from annual trade values and digitised ship logs from KNAW Huygens, under the assumption that the value of goods traded in each year can be attributed to each month during the sample period in proportion to the weight (tonnage) of goods that arrived in Europe on VOC ships during that month.

the external environment to the policy response by the bank of Amsterdam, to the decline in the agio. This reflects the decline of the Bank guilder as a stablecoin that originally promised an agio of 5%, a reserve ratio of 100% and a loan ratio of 0%.

3.2 Short-run adjustment analysis

Given that a long-term equilibrium relationship exists between our two variables, there also exists a valid error-correction representation of the data. We can therefore estimate an error correction model that describes how the agio behaved in the short run, consistent with the estimated long-run relationship between the agio and loan share. To do so, we add the lagged error term ε_{t-1} from equation [2] to our short-term adjustment equation in first differences. Since all variables are stationary, as confirmed by Dickey-Fuller tests, this can be estimated by OLS.

Table 2 presents the results. Column 1 shows a naïve regression in first differences, without the error correction term. The coefficient of the lagged agio is statistically significant and negative, pointing to some offsetting (mean reversion). The lagged loan share is barely statistically significant (at 10%), which provides weak evidence of a delayed response.

Column 2 adds the lagged error correction term ε_{t-1}, ie the residual from column 2 in Table 1. The error correction term enters with the expected negative sign, pointing to adjustment towards a long-term ratio, and it is highly statistically significant. Its value of -0.17 suggests that the adjustment to long-term equilibrium of the relationship between the agio and the loan share took about 1/0.17, ie almost six months. This happens to coincide with the period that coins were encumbered under the receipt system. This delayed response of the agio to the loan share would have given the Bank of Amsterdam some room for manoeuvre to adjust its loans, without experiencing an immediate response in the agio, or managing it through its open market operations through the sale or purchase of (unencumbered) coin. Notably, the first difference in the agio does not bear a near-term (one month lag) relationship to changes in the loan share, as seen in the statistically insignificant coefficient of loan share in column 2.

The final step in our estimations is therefore to assess the effect of policy insolvency of the Bank of Amsterdam on its room for manoeuvre. We are interested in testing whether the response of the agio to the loan share became faster after policy insolvency around 1784 (Quinn

and Roberds, 2016).[20] We therefore split the sample in each year to see if the coefficient estimates change. Test results confirm a statistically structural break in the coefficient. This is reflected in column 3. This shows a highly statistically significant response of the agio to the lagged loan share, starting in January 1784. Its value of -0.011 is almost half of the long-term response of -0.025 as estimated in Table 2. Taken together, these results suggest that the agio departed structurally from its policy objective due to lending by the Bank, and that this response became more immediate after the Bank became policy insolvent.

Regression results for short-run adjustment dynamics — Table 2

Dependent variable	Agio first differences		
	(1)	(2)	(3)
Error correction term		–0.17***	–0.17***
		(–3.1)	(–3.0)
Agio, first difference,	–0.36***	–0.28***	–0.29***
Lagged	(–5.6)	(–4.6)	(–4.8)
Loan share, first	–0.19*	–0.014	–0.012
difference, lagged	(–1.7)	(–1.3)	(–1.2)
Loan share * dummy for 1784 onward, first difference, lagged			–0.011***
			(–4.3)
Estimation method	LSE, robust SE	LSE, robust SE	LSE, robust SE
Observations	204	204	204
R-squared	0.14	0.21	0.22

T-values in parenthesis (and Z-values for the instrumented regression). ***/**/* denotes results significant at the 1/5/10% level. The sample period is Feb 1775–Dec 1792.

[1] The instrument variable for the loan share is the lagged value of monthly traded goods.

4. Stablecoins and the payment system

The Bank of Amsterdam started off as a "rigid stablecoin" which was managed in a passive way, in reaction to the actions of depositors. However, the imperative of maintaining a well-functioning payment system increasingly drove the Bank to take on the roles that resemble the operation of central banks, such as maintaining a stable currency value (as in modern currency boards), supporting settlement liquidity

[20] We also ran the Stata test *sbsingle* for finding an endogenous breakpoint. This calculation finds weak evidence of a structural break in March 1785, ie rather similar to the results as reported in the main text.

by smoothing seasonal spikes in liquidity needs and functioning as a lender of last resort. It thus became an "elastic stablecoin" – but one without adequate fiscal backing. This discretion allowed the Bank guilder to become an international unit of account and to support global trade and investment flows. Yet when the discretion to lend was stretched too far, confidence in the Bank was ultimately eroded. The runs on the Bank resembled the collapse of currency boards in emerging markets, in which private actors convert their balances into safe assets, until these are depleted and the value peg is abandoned.

In the digital era, echoes from the Bank's rise and fall can once again be heard. While technology has changed, trust remains the bedrock of a sound monetary system (Carstens, 2019). In light of the lessons from the Bank of Amsterdam, we review a number of recent private stablecoin initiatives. The details differ along several dimensions, including their assets, redeemability, structure, payment function, scope and payment infrastructure. As such, a comparison may be instructive. Table 3 gives an overview of these design choices, and compares them to the (early) Bank of Amsterdam.

The largest operational digital stablecoin is Tether, which was launched in 2014 as "*a digital token backed by fiat currency [that] provides individuals and organizations with a robust and decentralized method of exchanging value while using a familiar accounting unit*" (Tether, 2016). Tether is meant for both retail and wholesale use, and is accepted on a number of crypto-asset trading platforms, where it helps to facilitate investments into and out of crypto-assets like Bitcoin. It operates through a "*transactional ledger embedded in the Bitcoin blockchain*" (Tether, 2016) – ie a permissionless distributed ledger technology (DLT). Tether holds assets in the form of both "traditional currency and cash equivalents" and lending to third parties; in practice, there are some open questions as to its classification as rigid or elastic.

Another stablecoin, with a very different use case, is JP Morgan (JPM) coin. This initiative was introduced in 2019 as "*a digital coin designed to make instantaneous payments using blockchain technology*" (JP Morgan, 2019). The coin is initially a prototype, restricted to "*a small number of J.P. Morgan's institutional clients… (e.g., Banks, Broker Dealers, Corporates)*" for international settlement purposes. Volumes to date have not been disclosed. The coin is tied to the US dollar, and is "*1:1 redeemable in fiat currency held by JP Morgan*" (JP Morgan, 2019). It operates with the Quorum Blockchain, a permissioned DLT. Assets are held entirely in central bank reserves – but on the balance sheet of

a commercial bank with full access to central bank liquidity facilities and bank liquidity creation. It can thus be judged as an elastic stablecoin.

Design choices in stablecoin arrangements

A comparison of the Bank of Amsterdam guilder to modern stablecoin proposals Table 3

Liability	Bank of Amsterdam guilder (1609-1820)	Tether (2012-present)	JPM Coin (2019-present)	Libra[1] (proposed)
Assets	Initially: 100% gold and silver coins. Later limited short-term credit, and then large-scale credit to VOC, city, debt chamber	"*traditional currency and cash equivalents and, from time to time, ... other assets and receivables from loans made by Tether to third parties*"	100% central bank money in USD held by JP Morgan	100% basket of low-risk securities and bank deposits in USD, EUR, GBP, SGD
Redeemability	Initially at par, with guarantee from city of Amsterdam; later on open market through cashiers	In the market at market value	At par, fiat money	Wholesale: at value of basket, through authorised resellers Retail: at market price, secondary market
Structured as	Bank deposit Bank owned by city	Crypto wallet	Claim on underlying USD	Fund investment Association of companies
Main payment function	(Inter)national trade settlement	Payments on crypto exchanges	International settlement	(Inter)national retail payments, remittances, settlement
Scope	Wholesale	Retail and wholesale	Wholesale	Retail and wholesale
Payment infrastructure	Central ledger	Permission-less DLT	Permissioned DLT	Permissioned DLT
Rigid or elastic?	Initially rigid, then elastic	--	Elastic	Rigid

[1] Table entries refer to retail Libra coin, rather than Libra Investment Token.

Sources: van Nieuwkerk (2009); Tether (2016); Fnality (2019); J.P. Morgan (2019); Libra (2020); authors' judgment.

Implementation experiences are obviously lacking for stablecoins that have been proposed but are not yet operational. Hence, we can only compare key design features at this stage. One such example is Facebook's Libra proposal.

The Libra proposal initially aimed to introduce "*Libra… a simple global currency and financial infrastructure that empowers billions of people*" (Libra Association, 2019). The Libra stablecoin would reference a basket of currencies (initially US dollars, euro, British pounds, Japanese yen and Singapore dollars). It would be governed by the Libra Association, made up of various private companies who would operate "nodes" in the network, and assets would be held in the Libra Reserve. Services would be provided by an ecosystem of authorised resellers, wallet providers (like the new Facebook subsidiary Calibra, now renamed Novi) and other intermediaries. It would use permissioned

DLT, with initial plans to open the network to a permission-less approach within five years. In its more recent incarnation ("Libra 2.0"), Libra is meant to have local currency versions of its coin (tied to USD, EUR, GBP and SGD) and it has abandoned ambitions to move to a permission-less approach. The new whitepaper emphasises its role as "*a simple global payment system*" rather than a currency (Libra Association, 2020). It would use a rigid approach whereby volumes are determined fully by user demand.

Due to the global reach of Facebook, with 2.7 billion users, there is potential for Libra to be adopted very rapidly when it is launched. Much like Coca Cola uses its own vast distribution network to sell its core and related products, Facebook could use its network to sell new financial services to its very large customer base. This in turn raises questions on cross-border supervision (Zetzsche et al, 2019). Given its global scale, Libra could facilitate payment and capital flows that are relevant at a macroeconomic level. Given the ambition for an ecosystem of wallet providers and other institutions to provide financial services on top of Libra, users could use Libra to build up investment portfolios and even leveraged financial positions.

In the past years, a number of further stablecoins have emerged, including crypto exchange Circle's USDCoin, Gemini's Gemini Dollar, the Paxos Standard, TrueUSD and MakerDAO, each of which reference the US dollar or other individual fiat currencies. The Saga proposal would use a basket of currencies similar to Libra (Saga, 2019).

The creation of a coin with a stable value is intended to facilitate a role of the stablecoin as a means of payment within the network that it creates. Stablecoins solve the problem of price volatility that befalls private cryptocurrencies like Bitcoin, which are denominated in their own unit of account (see Schilling and Uhlig, 2020; Gandal et al, 2020). Settlement of stablecoins can take place in the stablecoins, themselves, possibly separating between peer-to-peer retail settlement and wholesale settlement through the books of the stablecoin provider. Such a central role within the payment system could imply incentives to lend, as indicated.[21] These incentives may become stronger due to

[21] An illustration is provided by the recent experience of Tether. In mid-2018, it came to light that Tether had secretly lent about $850 million to Bitfinex, an affiliated crypto-asset trading platform with whom it shares a CEO. In April 2019, in a court affidavit, Tether's legal representatives disclosed that 74% of accounts are backed by USD securities; in October 2019, this was claimed to be 84%. One study argues that Tether influenced Bitcoin and other prices during the 2017

the private nature of the governance mechanism: the stablecoin issuer can increase its profits by lending or otherwise increasing the amount of higher yielding assets. A possible conflict of interest therefore arises between the owners of the coins, and the entity that manages the assets. Maintaining the value of the stablecoin through 100% backing would be in the interests of the holders of the stablecoin. But the manager may face incentives to decrease the backing ratio by responding to demand for credit, since this will increase profits.[22] If governance mechanisms are strong enough to withstand such pressures, this may hinder the stablecoin in fulfilling its role in the payment system.[23] As with collective investment and money market funds, such requirements could be enforced with regulation (Zetzsche, 2019; Morley, 2019).[24] Yet if governance and regulation are not strong enough, lending may lead to an erosion of confidence, and put pressure on the value of the stablecoin. In either case, stablecoins do not seem well-placed to take up the kind of roles that central banks have with respect to the smooth functioning of payment systems.

There are a number of policy concerns with stablecoin initiatives that go beyond the bounds of this analysis. These include anti-money

boom, with purchases following market downturns resulting in price appreciation (Griffin and Shams, 2018). If so, this course of action would harm the interests of the holders of Tether, insofar they believed the promise of full backing. One contemporary observer has argued that Tether "*is sort of the central bank of crypto trading … [yet] they don't conduct themselves like you'd expect a responsible, sensible financial institution to do*" (as quoted in Vigna and Russolillo, 2018). In some ways, this role resembles the central role of the Bank of Amsterdam in its own day – including with regard to (undisclosed) lending.

22 Even without lending by the issuer, itself, there is a strong likelihood that wallet providers or others will engage in fractional reserve banking with the coin as collateral. See Wall (2019).

23 It may therefore be constructive to look at investment fund regulation, given that investment funds face a similar conflict of interest. Investment funds have a unique organisational structure, due to the separation between the legal entity that manages the assets and those that have a claim on those assets, ie the collective investors. This creates a principal-agent problem and asymmetric information. This explains why investment funds are subject to a special form of financial regulation that contains governance and transparency requirements (Morley, 2019; Zetzsche, 2019).

24 Incidentally, the origins of collective investment funds can be found in almost the same period as the Bank of Amsterdam's downfall. The fund *Eendragt Maakt Magt* ("*Unity Creates Strength*"), founded in Amsterdam in 1772 by Abraham van Ketwich, is often seen as the world's first collective investment fund (Rouwenhorst, 2005; Zetzsche, 2015). The fund suffered large losses on government bonds in the Napoleonic wars, and was ultimately closed in 1824.

laundering, taxation, data privacy, competition and consumer and investor protection (G7 Working Group on Stablecoins, 2019; FSB, 2020). These issues are the subject of ongoing regulatory dialogue. There are also specific problems with multi-currency stablecoins, ie those proposals that use a new global unit of account. In particular, the notion of new global currencies in their own unit of account may clash with the understanding of optimal currency areas and differences in the optimal monetary policy stance across economies (Mundell, 1961). By introducing value fluctuations – however small in normal times – against sovereign fiat currency, such coins may introduce frictions and policy issues well-known to those who have studied dollarisation in emerging market economies. It is for these reasons that some policymakers have demanded that stablecoins must be redeemable at par in fiat currency (Bailey, 2020).

By contrast, central bank digital currencies (CBDCs) may not pose these same challenges. In recent years, central banks around the world have embarked on research and development around CBDCs for retail and wholesale use (Auer et al, 2020; BIS, 2020). Wholesale CBDCs would represent a different means of making digital money to financial institutions, to complement the existing money of central bank reserves. Retail CBDCs would go a step further and make such money available to the general public, similar to banknotes and coins. Both would build on the existing governance of central banks.

There remain important policy issues around CBDCs and financial stability, such as the potential for "digital runs" to CBDC in periods of stress, and monetary policy transmission – where CBDCs could even enhance policy effectiveness (CPMI-MC, 2018). There are important societal questions around the footprint of the central bank in the financial system, and the potential for central banks to crowd out private intermediaries (Fernández-Villaverde et al, 2020). Central banks are actively researching CBDC designs and aim to build them in such a way that, first, they will "do no harm" and co-exist with other public and private forms of money (Group of Central Banks, 2020). In the context of this paper's analysis, CBDCs would at least have – by their very nature – access to central bank balance sheets and central banks' sovereign backing. The sound institutional underpinnings of modern central banks could thus be transferred into the digital era.

5. Concluding remarks

Money is a social convention. Yet it is also the key yardstick for the value of disparate goods, services, claims and assets. Sound money allows individuals, firms (including financial firms) and governments to transact, and to record their obligations to one another in a way that binds the economy together. The governance of money is about ensuring a flexible system that meets the needs of the economy and yet is robust enough to ensure confidence. Experience with monetary institutions through the ages has shown that central banks are best placed to be the bulwark for the monetary system. This is not to say that central banks always get it right; the Bank of Amsterdam is the poster child of what can go wrong when governance goes awry. Yet the solution has been to bolster the mandate and solvency of central banks – not to replace them with untested private sector solutions with managers accountable to shareholders rather than the general public.

This paper has shown that the economic concepts of stablecoins and of central bank solvency are not new. Indeed, the Bank of Amsterdam provides a rich source of experience on the working of money backed by assets, and the corrosive effect of excessive discretionary credit amid weak governance on the stability of this system. The Bank and its Bank guilder worked well and maintained an impeccable reputation over a long period of time. The Bank's public underpinning and initially responsible use of its discretion helped it to establish trust in monetary exchange and support payments and settlement for trade across Europe and globally. At times, it allowed limited overdrafts to creditworthy borrowers and thereby enhanced settlement liquidity. Yet its governance was ultimately not sufficiently robust to resist pressure to misuse its balance sheet for other purposes. Its decision to lend extensively in the 1780s undermined its credibility, and ultimately led to the Bank's downfall.

This case study and our empirical evidence provide two broad lessons. The first concerns the shortcomings of rigid stablecoins as the underpinning of a widely used payment system. Specifically, if stablecoin managers stick to their governance rules (eg full backing), they provide limited settlement liquidity. If stablecoin managers do not stick to their governance rules, they may be enticed to expand such practices over time. Either way, rigid stablecoins may be a poor substitute for central banks in wholesale payment systems.

The second lesson concerns the fiscal backing and solvency of the central bank. While institutions with a strong reputation can use their

room for manoeuvre to inject essential flexibility, there may be a breaking point beyond which they should not go. In particular, when the scale of losses is large and fiscal backing is limited, it was possible for at least this proto-central bank to fail. The Bank ultimately gave way to a modern central bank with more explicit fiscal backing and an explicit sovereign fiat currency.

The story of the Bank holds important lessons for today's debates on money in the digital era. In particular, as a range of new private stablecoins are proposed for wholesale and retail use, there is the potential that the same limitations of rigid stablecoins, and conflicts of interest around elastic stablecoins, may arise. Ultimately, while such digital stablecoins could play a constructive role in certain specific use cases, it seems unlikely that they can fulfil the full range of functions of money. For this, discretionary credit and appropriate fiscal backing will be needed. Central bank digital currencies (CBDCs), which build on the existing governance of central bank money, are better placed to fill this gap.

Of course, there are a number of limitations to the comparison between the Bank of Amsterdam and modern digital money. The Bank was a public institution, operated in an environment without modern financial regulation. It used technology that of course differs starkly from recent token-based stablecoin proposals. Nonetheless, the history of the Bank illustrates the arguments around discretionary credit and governance in a particularly useful manner. There are also strong differences between the Bank and modern central banks, as previously discussed. Nonetheless, the downfall of the Bank may shed light on questions around central bank solvency in an age of large-scale central bank interventions in markets during the Covid-19 pandemic.

Overall, this analysis demonstrates the value in reviewing historical precedents for recent digital innovations. In particular, there have likely been further examples of structures that resemble today's stablecoins and today's central banks. Finding and analysing the incentives and governance underlying these structures may be a fruitful avenue for further research.

References

Allsopp, P, B Summers and J Veale (2009), "The Evolution of Real-Time Gross Settlement", The World Bank, Financial Infrastructure Series.

Arner, D, R Auer and J Frost (2020), "Stablecoins: risks, potential and regulation", Bank of Spain Financial Stability Review, November.

Auer, R, G Cornelli and J Frost (2020), "Rise of the central bank digital currencies: drivers, approaches and technologies", BIS Working Papers, no 880.

Bagehot, W (1873), *Lombard Street*, London: Henry S. King and Co.

Bailey, A (2020), "Reinventing the wheel (with more automation)", speech, 3 September.

Bank for International Settlements (2020), "Annual Economic Report", Chapter III, "Central banks and payments in the digital era", Basel.

Bank of Canada, Bank of England and Monetary Authority of Singapore (2018), "Cross-Border-Interbank-Payments-and-Settlements: Emerging opportunities for digital transformation", November.

Bank of England (1999), "Risk, Cost and Liquidity in Alternative Payment Systems, Quarterly Bulletin, February.

Bech, ML, A Martin and J McAndrews (2012), "Settlement Liquidity and Monetary Policy Implementation – Lessons from the Financial Crisis", *FRBNY Economic Policy Review*, vol 18, no 1, pp 1–25, March.

Bindseil, U (2019), *Central banking before 1800 – a rehabilitation*, Oxford: Oxford University Press.

Borio, C (1997), "The Implementation of Monetary Policy in Industrialised Countries: a Survey", Annex IV: Payment and Settlement Systems, BIS, Basel.

——— (2019), "On money, debt, trust and central banking", BIS Working Paper no 763.

Carlos, AM and L Neal (2011), "Amsterdam and London as financial centers in the eighteenth century", *Financial History Review*, vol 18, no 1, pp 21-46.

Carstens, A (2019), "The future of money and the payment system: what role for central banks?", Lecture at Princeton University, 5 December 2019.

Cœuré, B (2019), "Update from the Chair of the G7 working group on stablecoins", July.

Committee on Payments and Market Infrastructures (CPMI) and Markets Committee (MC) (2018), "Central bank digital currencies", March.

Desan, C (2014), *Making Money: Coin, Currency, and the Coming of Capitalism*, Oxford: Oxford University Press.

Dillen, J van (1925), *Bronnen tot de Geschiedenis der Wisselbanken* ("*Sources for the History of the Exchange Banks*"), The Hague: Rijksgeschiedkundige Publicatieën.

——— (1934), "The Bank of Amsterdam", in J G van Dillen (ed.) *History of the Principal Public Banks*, The Hague: Martinus Nijhoff: pp 79–124.

Eichholtz, P (1997), "A Long Run House Price Index: The Herengracht Index, 1628-1973", *Real Estate Economics*, vol 25, no 2, pp 175–92.

Engle and Granger (1987), "Cointegration and Error Correction: Representation, Estimation and Testing", *Econometrica*, no 55, pp 251–76.

Fernández-Villaverde, J, D Sanches, L Schilling and H Uhlig (2020), "Central Bank Digital Currency: Central Banking For All?", NBER working paper no 26753.

Financial Stability Board (2020), "Regulation, supervision and oversight of "global stablecoin" arrangements", 13 October.

G7 Working Group on Stablecoins (2019), "Investigating the impact of global stablecoins", October.

Gandal, N, J Hamrick, T Moore and T Oberman (2018), "Price manipulation in the Bitcoin ecosystem," *Journal of Monetary Economics*, 95, 86–96.

Gelderblom, O (2015), "Waarvoor hebben we de financiele sector nodig?" ("What do we need the financial sector for?"), Utrecht.

Giannini, C (2011), *The Age of Central Banks*, Cheltenham: Edward Elgar Publishing.

Goodhart, C (1998), "The two concepts of money: implications for the analysis of optimal currency areas", *European Journal of Political Economy*, no 14, pp 407–32.

Gregory, W and E Hansen (1996), "Residual-based Test for Cointegration in Models with Regime Shifts", *Journal of Econometrics*, vol 70, no 1, pp 99-126.

Griffin, J and A Shams (2018), "Is Bitcoin Really Un-Tethered?", *Journal of Finance*, vol 75, no 4, pp 1913–64.

Group of Central Banks (2020), "Central bank digital currencies: foundational principles and core features", Report No 1 in a series of collaborations from a group of central banks, October.

Hervo, F (2008), "Recent Developments in Intraday Liquidity in Payment and Settlement Systems", Banque de France Financial Stability Review, Special Issue on Liquidity.

Janssen, M (2015), "Het old boys network van de Wisselbank" ("The old boys network of the Bank of Amsterdam"), *Historisch Nieuwsblad* 1/2015.

Jonker, J and K Sluyterman (2000), *Thuis op de wereldmarkt: Nederlandse handelshuizen door de eeuwen heen* ("*At home on the world markets: Dutch international trading companies from the 16th century until the present*"), The Hague: Sdu.

J.P. Morgan (2019), "J.P. Morgan Creates Digital Coin for Payments", February.

Kindleberger, C and R Aliber (2005), *Manias, Panics and Crashes: A History of Financial Crises*, London: Palgrave Macmillan.

Lawson, P (1993), *The East India Company: A History*, London and New York: Routledge, Taylor & Francis.

Libra Association (2019), "An Introduction to Libra", June.

——— (2020), "Libra White Paper: v2.0", April.

Martin, F (2013), *Money: The Unauthorised Biography*, London: The Bodley Head.

Morley, J (2019), "Why do Investment Funds have Special Securities Regulation?", in WA Birdthistle and J Morley (eds), *Research Handbook on the Regulation of Mutual Funds*, Cheltenham: Edward Elgar Publishing.

Mundell, R (1961), "A Theory of Optimum Currency Areas", *American Economic Review*, vol 51, no 4, 657–65.

——— (1997), "Currency Areas, Common Currencies, and EMU", *The American Economic Review*, vol 87, no 2, Papers and Proceedings of the Hundred and Fourth Annual Meeting of the American Economic Association: 214–21.

Nieuwkerk, M van (ed.) (2009), *De Wisselbank: van stadsbank tot bank van de wereld* ("The Bank of Amsterdam: from city bank to bank of the world"), Amsterdam: Sonsbeek.

Quinn, S and W Roberds (2014), "The Bank of Amsterdam through the Lens of Monetary Competition", in: P Bernholz and R Vaubel (eds), *Explaining Monetary and Financial Innovation*, Heidelberg: Springer Financial and Monetary Policy Studies, vol 39.

——— (2015), "Responding to a Shadow Banking Crisis: The Lessons of 1763", *Journal of Money, Credit and Banking*, vol 47, no. 6, 1149–76.

——— (2016), "Death of a Reserve Currency", *International Journal of Central Banking* 12: 63–103.

——— (2019), "A Policy Framework for the Bank of Amsterdam, 1736–1791", *The Journal of Economic History*, vol 79, no 3, 736–72.

Reis, R (2015), "Different types of central bank insolvency and the central role of seigniorage", NBER Working Paper 21226.

Rouwenhorst, K (2005), "The Origins of Mutual Funds", in WN Goetzemann and K Rouwenhorst (eds), *The Origins of Value: The Financial Innovation That Created Modern Capital Markets*, Oxford: Oxford University Press.

Saga (2019), "Saga's White Paper", December.

Schilling, L and H Uhlig (2020), "Some Simple Bitcoin Economics," *Journal of Monetary Economics*, no 106, 1–94.

Schnabel I and HS Shin (2004), "Liquidity and contagion: the crisis of 1763", *Journal of the European Economic Association*, vol 2, no 6, 929–68.

——— (2018), "Money and trust: lessons from the 1620s for money in the digital age", BIS Working Paper No. 698.

Sims, C (1994), "A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy", *Economic Theory*, no 4, 381–99.

Smith, A (1776), *An Inquiry into the Nature and Causes of the Wealth of Nations*, Hamilton: McMaster University Archive for the History of Economic Thought.

Sobel, D (1995), *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*, London and New York: Walker & Company and Fourth Estate.

Tether (2016), "Tether: fiat currencies on the Bitcoin blockchain", tether.to.

Ugolini, S (2017), *The Evolution of Central Banking: Theory and History*, London: Palgrave Macmillan.

Uittenbogaard, R (2009), "De kredietverlening door de Wisselbank (1609-1802)" ("Lending by the Bank of Amsterdam (1609-1802)"), in M van Nieuwkerk (ed).

——— (2015), *Evolution of Central banking? De Nederlandsche Bank 1814 - 1852*, Heidelberg: Springer.

Van 't Hart, M (2009), "Corporate governance", in M van Nieuwkerk (ed).

Vanthoor, W (2006), *The king's eldest daughter: the history of The Nederlandsche Bank 1814-1998*, Amsterdam: Boom uitgevers.

Verbeek, M, (2017), "A Guide to Modern Econometrics", 5th edition, Hoboken: Wiley & Sons, Ltd.

Vigna, P and S Russolillo (2018), "The Mystery Behind Tether, the Crypto World's Digital Dollar", *Wall Street Journal*, 12 August.

Voltaire, F (1751), *Siècle de Louis XIV*, ch 10, as translated in T Francklin and T Smolett (1779), *The Works of M. de* Voltaire, London: S Crowder and Co.

Wall, L (2019), "Fractional Reserve Cryptocurrency Banks", Notes from the Vault, April.

Willemsen, R (2009), "Het bedrijf van de Amsterdamse Wisselbank" ("The business of the Bank of Amsterdam"), in M van Nieuwkerk (ed).

Zanden, J van and B van Leeuwen (2012), "Persistent but not Consistent: The Growth of National Income in Holland 1347-1807", *Explorations in economic history*, vol 49, no 2, 119–30.

Zetzsche, D (2015), *Prinzipien der kollektiven Vermögensanlage* ("Principles of collective investment funds"), Tübingen: Mohr Siebeck.

——— (2019), "The Anatomy of European Investment Fund Law", in WA Birdthistle and J Morley (eds), *Research Handbook on the Regulation of Mutual Funds*, Cheltenham: Edward Elgar Publishing.

Zetzsche, D, R Buckley, and D Arner (2019), "Regulating Libra: The Transformative Potential of Facebook's Cryptocurrency and Possible Regulatory Responses", European Banking Institute Working Paper Series 2019/44; University of New South Wales Law Research Series UNSWLRS 19-47; University of Hong Kong Faculty of Law Research Paper No. 2019/042.

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