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Anna Grodecka-Messi and Xin Zhang

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Central Bank Liquidity Support, Bank Lending, and the End of Currency Competition*

Anna Grodecka-Messi and **Xin Zhang**

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Abstract

Private money creation lies at the heart of currency competition due to seigniorage rents that are an important contributor to banks' franchise values. However, it undermines the role of central bank in money provision and has been historically a contentious issue. As shifting from private to public money may come at a cost of bank disintermediation and affect economic growth, such a swap should be well-planned to minimize its costs. In this paper, we study the transition from private to public money in a historical context. The 1897 banking law in Sweden granted the banknote monopoly to the Swedish central bank. To facilitate the shift, the central bank provided preferential liquidity support to formerly note-issuing private banks. Drawing on newly digitized monthly archival data, we show that this liquidity provision played a critical role in shaping private banks' performances during the transition. Once the support started being withdrawn, affected banks experienced a 23% drop in profitability. No signs of bank disintermediation are found.

Keywords: Money and Banking, Inside Money, Outside Money, Bank Profitability, Bank Lending, Banknote Monopoly.

JEL: E42, E5, G21, G28, N23.

*Author information: Anna Grodecka-Messi: Sveriges Riksbank, Brunkebergstorg 11, 103 37 Stockholm, Sweden, e-mail: anna.grodecka-messi@riksbank.se. Xin Zhang: Sveriges Riksbank, Brunkebergstorg 11, 103 37 Stockholm, Sweden, e-mail: xin.zhang@riksbank.se.

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1 Introduction

The competition between private and public money has been the subject of numerous debates, both historically, when the central bank note monopoly was established, and in modern times, when the increasing role of inside money and cryptocurrencies (re)launched a debate about the importance of sovereign's money. Recent developments induced central banks to consider the introduction of central bank digital currencies (CBDCs) (Gorton and Zhang, 2022). Most historical discussions related to private vs central bank money focused on the issues of (perceived to be dangerous) governmental control over the supply of money and of financial (in)stability linked to private money provision, inspired by the period of free banking in the U.S. (Rolnick and Weber, 1983; Selgin, 1988). Modern finance literature deals predominantly with the problem of bank disintermediation that could lead to lower growth, were part of the inside money be substituted by the central-bank supplied outside money (Brunnermeier and Niepelt, 2019; Andolfatto, 2021; Keister and Sanches, 2022; Chiu et al., 2023a).

The important contribution of Brunnermeier and Niepelt (2019) shows that under certain conditions private and public monetary systems can be equivalent so that the equilibrium allocation and price system remain unchanged. Central bank transfers to the private banking sector are crucial for this outcome. Chen and Filippin (2025) examine the equivalence result in the presence of collateralized liquidity support by the central bank and demonstrate that conditional central bank transfers affect private banks' business models, impacting the composition of their asset portfolios.

Building on the theoretical literature on the private and public monetary systems, we contribute to the debate by providing empirical evidence on the effects of a shift from private to public money in the presence of preferential central bank transfers to the private banking sector. Unlike in Brunnermeier and Niepelt (2019), our analysis does not consider a static equilibrium, but rather the transition between the two monetary systems. During this period, the liquidity support of the central bank is slowly withdrawn. We show that central bank transfers are crucial in shaping private banks' outcomes in the transition period. To our knowledge, it is the first empirical evidence on the role of central bank transfers in facilitating the swap between private and public money. In particular, we study the historical episode of the introduction of the Swedish central bank's banknote monopoly. Sweden holds a unique place in the monetary history as a country with the longest continuously operating central bank and the inventor of banknotes in Europe. At the turn of the 20th century, the Swedish banking sector underwent a substantial institutional transformation following the enactment of legislation that conferred upon Sweden's Central Bank, Sveriges Riksbank, the exclusive right to issue banknotes, after several decades of coexistence of private and public notes. The banknote monopoly of the Riksbank ended the monetary competition between privately issued notes and central bank notes in Sweden.

Sweden offers a unique setup to study the effects of the end of private banknote issuance, as the institutional reform happened in a tranquil period. Moreover, for the period of interest, we have access to monthly balance sheet and interest rates data, as well as yearly return data

for the universe of commercial banks in the country. The unique combination of high-quality and high-frequency historical data on both loan quantities and prices allows us to draw robust conclusions on the effects of the legislation on commercial banks and their credit provision. We gather monthly bank-level data for all Swedish commercial banks in the period 1894M1-1911M12. In 1890s, the Swedish private banking sector comprised two comparable groups of banks, one of which could issue notes alongside Sveriges Riksbank. These note-issuing banks were directly affected by the legislative changes, as they lost the stable seigniorage revenue. We consequently study the effects of this legal reform in a difference-in-differences (DiD) setup, using the non-note-issuing banks as the control group.

Legislative changes related to issuance monopoly of central banks serve as a fruitful laboratory for studying the effects of the private-public money swap on the banking sector. Note issuance has been a historically contentious issue due to the seigniorage revenues. Therefore, the note monopoly of central banks was often decided after decades of heated discussions and failed proposals. As the timing and specific provisions of implemented laws can be considered exogenous to individual banks, the historical episode at hand offers a quasi-natural experiment through which the causal effects of differing regulatory frameworks on the commercial banking sector can be identified. This paper highlights a unique feature of the Swedish transition to central bank note monopoly: central bank's liquidity support to affected private banks. In order to compensate commercial banks for the loss of the issuance privilege, the Riksbank provided compliant banks with preferential liquidity support. This liquidity support persisted even if a bank changed its liability status or was merged with or acquired by another bank. It was designed to be withdrawn over time and only part of the banking sector had access to it, which provides an ideal empirical setting for analysing the effect of the swap and associated liquidity support on banks. We show that Riksbank's liquidity support at preferential rates was effective in mitigating the losses of former note-issuing banks. Before the end of 1903, when it was at its peak, it compensated treated banks for 70-97% of their decline in ROC (return-on-capital). However, since it did not fully replace the withdrawn notes on a one-to-one basis, the transition to alternative funding sources still led to a relative decline in affected banks' profits.

We do not find signs of financial disintermediation, but we show evidence of portfolio rebalancing due to (partially) collateralized central bank liquidity support. Loans from the Riksbank supported mortgage lending, as properties were probably deemed a good collateral. At the same time, lending rates on mortgages of affected banks went up, which could be an indication of increased risk-taking after the shock to banks' franchise value. However, we find no effect on the share of non-performing loans in the portfolio of previously note-issuing banks, as the collateralized framework targeted "safe" loans. Focusing on the 1907 crisis that was mostly imported from abroad and led to distress among around one fifth of Swedish banks, we show that former Riksbank lending was not associated with worse performance in the crisis, which supports the thesis that the preferential liquidity support did not lead to increased moral hazard issues, consistent with the findings in Grodecka-Messi et al. (2021).

While interpreting our results, it is important to address the endogeneity concerns in our empirical strategy. In the ideal difference-in-differences setup, the group assignment is random.

In our case, treated banks were note-issuing unlimited liability banks (ULBs), while control banks were deposit-funded limited liability banks (LLBs). The difference in banks' funding sources had implications for the composition of their balance sheets, and possibly, returns. While there may be unobservable characteristics that make the two types of banks different, due to the quality and frequency of the data, we can carefully control for differences in observables and their trends. We demonstrate that the parallel trend assumption is not violated for our variables of interests and we address endogeneity concerns by including a range of relevant bank-level controls, time and bank-fixed effects, as well as clustering the errors at the bank level. As a robustness checks, we employ propensity score matching to match the control group banks with treated banks. The main empirical findings still hold. Furthermore, our results are robust to sub-sampling, alternative sample selections, and considering other potential major changes in the banking sector.

The paper is structured as follows. In the remainder of the introduction, we place the paper in the context of the literature and outline our contribution. In Section 2, we provide a conceptual framework to systematically analyze the potential effects of the amendment to banking legislation. Section 3 presents the institutional background and aggregate evidence. In Section 4, we present the data and show the empirical results. Section 6 concludes.

Related Literature. The theoretical underpinning for our research is provided by Brunnermeier and Niepelt (2019) and Niepelt (2020) that study the shift from private to public money and provide an equivalence result for when the equilibrium allocations and prices are unaffected by the swap. It requires central bank funding to insulate the banking sector through transfers at the conditions of replaced funding prior to the swap. In practice, the conditions required for the equivalence result, as with any irrelevance results, are difficult to fulfill, due to the endogeneity of the monetary policy, existence of collateral constraints, transaction and information frictions.[1] Fernandez-Villaverde et al. (2021), studying the possibility of CBDC, also derive an equivalence result, but given the political economy forces at play, they conclude that CBDC in the form of central bank deposits would likely lead to a deposit shift from the commercial banking sector to the central banking sector. Keister and Sanches (2022) discuss how choosing interest rates necessary for the equivalence result to hold may result in a sub-optimal interest rate policy. A number of theoretical studies examine how the shift to a new central bank currency may affect private banks (Andolfatto, 2021; Chiu et al., 2023b; Whited et al., 2022, Williamson, 2021 and Keister and Sanches, 2022). These studies focus on the substitution between private and central bank deposits.[2] Our empirical setup differs from the rest of the literature as the historical shift from private (or mixed) to public printed money was complete, i.e. agents did not have a choice between different types of monies and the banks

[1]The cited papers investigate the introduction of CBDC, as a form of public and private money competition. However, the direct impact on the private banking sector is similar to the transition considered in our study. Both the introduction of retail CBDC and of central bank note monopoly constitute a shock to private banks' funding.

[2]On the monetary side, questions related to optimal quantity of money under different monetary arrangements are explored (de O. Cavalcanti and Wallace, 1999, Monnet and Sanches, 2015, Fernández-Villaverde and Sanches, 2019).

could not compete with the outside printed money by design. With the CBDC introduction, private banks can mitigate the migration of funds to the central bank by changing the interest rates accordingly. The historical episode related to the banknote monopoly allows us thus to focus on the direct effects of losing seigniorage revenue, providing the worst-case scenario of a private-public swap.

Given the specific nature of the transition from private to public money in Sweden, our paper, apart from contributing to the monetary literature, is also related to research on central bank liquidity support. Rieder (2023) provides an overview of lender-of-last-resort policies and concludes that historically, central bank liquidity support was not only activated during financial crises. Nonetheless, issues related to stigma from using central bank liquidity facilities and moral hazard linked to it, often arised (Gorton and Metrick, 2013; Bekkum et al., 2018; Bordo, 2014; Anbil and Vossmeyer, 2019; Vossmeyer, 2019; Hüttl and Kaldorf, 2024). Ours is a case of unstigmatized liquidity support: eligible banks could obtain preferential central bank credit that was reliant on their previous note issuance rather than other economic fundamentals. Still, it could potentially lead to moral hazard problems. We pose it as an empirical question whether central bank liquidity support leads to risky behavior and excess bank credit losses. The historical context of our study makes it particularly compelling. In 1907, an international crisis struck the Swedish banking sector, and the potentially increased risk taking by banks due to liquidity assistance could have further amplified the external shock.

An empirical examination of the effects of arrival of a new form of central bank money on note-issuing commercial banks has been performed for Canada in Grodecka-Messi and Zhang (2023). Making an analogy to CBDC discussions, the authors conclude that while introducing a CBDC would likely lead to private banks' losses, the financial intermediation would likely remain intact. Relatedly, using aggregate Swedish data, Ögren (2022) studies the implications of the note monopoly of Sveriges Riksbank on the provision of base money in the light of current debates on CBDCs. Xu and Yang (2024) study real effects of supplying safe private money in a U.S. context, linking historical evidence to current discussions on stablecoins. In the current paper, we contribute to this literature by zooming into the central bank liquidity assistance to private banks and the role it plays in the transition to the public monetary system.

2 Conceptual framework

To set the stage for our empirical analysis, let us briefly review the role of bank notes in the bank's profit generation for a note-issuing private bank. Table 1 presents a stylized balance sheet of a bank that has to hold gold reserves (a fraction less than 1 for the issued notes) to back up its private bank note issuance.

Let us assume that gold is booked at the book value, so that it does not generate any return. The cost of printing banknotes is considered negligible. Bank shareholders aim at maximizing the (pre-dividend) profit defined as following:

$$\Pi_t = i_{c,t} \times C_t - i_{d,t} \times D_t, \tag{1}$$

Table 1: Stylized balance sheet of a private note-issuing bank

Assets A_t	Liabilities L_t
Gold G_t	Banknotes N_t
Private loans C_t	Deposits D_t
	Equity E_t

with $i_{c,t}$ and $i_{d,t}$ defined as the average interest rates for loans and deposits. Note that by definition, total assets $A_t = G_t + C_t = N_t + D_t + E_t$. As such $D_t = A_t - N_t - E_t$, and the profit function becomes:

$$\Pi_t = i_{c,t} \times C_t - i_{d,t} \times (G_t + C_t - N_t - E_t). \tag{2}$$

Higher lending rates, lower deposit rates, lower gold holdings and higher equity and banknote issuance are clearly associated with greater profitability of the ULB. But what happens if a note issuing bank is suddenly banned from issuing notes? In the absence of liquidity assistance or central bank transfers, three potential outcomes for the funding structure of the affected bank may emerge:

1. The balance sheet mechanically shrinks. The 'missing' notes are not substituted by any type of funding, and lending goes down.

2. The bank substitutes notes by collecting new deposits. Their price will be likely higher than the cost of printing notes, so either the profit of the bank will be affected, or the bank alters interest rates on lending and/or deposits, along with its asset portfolio to shield the profits.

3. The bank substitutes notes by issuing new equity. This will also likely affect quantities and prices of different balance sheet items.

It is indisputable that the loss of seigniorage in the absence of central bank funding will affect the business models of the private banks. But what if they could be compensated for it? Brunnermeier and Niepelt (2019) and Niepelt (2020) consider such a scenario and show that if a central bank automatically provides substitute funding for banks at an appropriate price, the equilibrium allocations are unchanged. For the equivalence result to hold in our setting, the substitute funding must have the same cost as note issuance and be uncollateralized. Chen and Filippin (2025) demonstrate that if the substitute funding requires collateral, the swap may affect portfolio allocations of banks. Note that the aforementioned theoretical papers consider an equilibrium result and do not involve any discussion of transition or withdrawal of central banks' funds. Neither do they consider potential moral hazard problems linked to prolonged public financing of private banks. In reality, the equivalence conditions are unlikely to hold and thus it is expected that a shift from private to public money supply will generate some real effects. Even if banks do not shrink the balance sheets and change their pricing, the increase in the cost of funding due to the loss of seigniorage will likely affect their profits that ultimately belong to shareholders.

3 Institutional Background and Aggregate Evidence

In this section, we present the institutional framework around the banknote monopoly in Sweden, and provide aggregate evidence on the effects of the legislative reform regarding note issuance on the banking sector.

3.1 Money supply in Sweden in the 19th century

At the turn of the 20th century, both the Riksbank, established 1668 as an official bank of the Swedish parliament (Sveriges Riksdag), and Swedish commercial banks could issue money. In particular, the commercial banking sector consisted of two bank groups: joint stock note-issuing unlimited liability banks (ULBs) called *enskilda banker* (emerged in 1830s) and limited liability joint stock banks (LLBs) called *aktiebanker* (first established in 1864, with no right to issue notes). The Riksbank accepted deposits and issued credit but in contrast to private banks, its charter was not time-limited.

Ögren (2006) and Jonung (2021) provide a detailed account of the period of domestic currency competition in Sweden. Ögren (2006) highlights that through note issuance, ULBs contributed to the economic expansion in the country, given that Riksbank's note supply was subject to specie-convertibility constraints. Jonung (2021) points out that note-issuing banks were subject to increasing regulations and taxes. Private note issuance was mostly backed by ULBs capital, that, given the unlimited liability of shareholders, was considered to be safe. In fact, no ULB in Sweden ever defaulted on its obligation to redeem their notes. Before Sweden adopted the gold standard, Riksbank notes, along with commodities (gold, silver), constituted the reserves of commercial banks. Since 1874, when Sweden adopted the gold standard, ULBs had also to hold gold corresponding to 10% of their equity capital in connection to their note issuance (LLBs were not subject to this regulation).[3] Riksbank notes circulated as legal tender in the country, while commercial bank notes traded at par and could be redeemed into Riksbank notes (until 1874) and gold (from 1874 on) (Jonung, 2021). Private-note issuance was supported by the Crown and the nobility, but their influence in the Parliament declined over time, leading to more pro-monopolist sentiments.

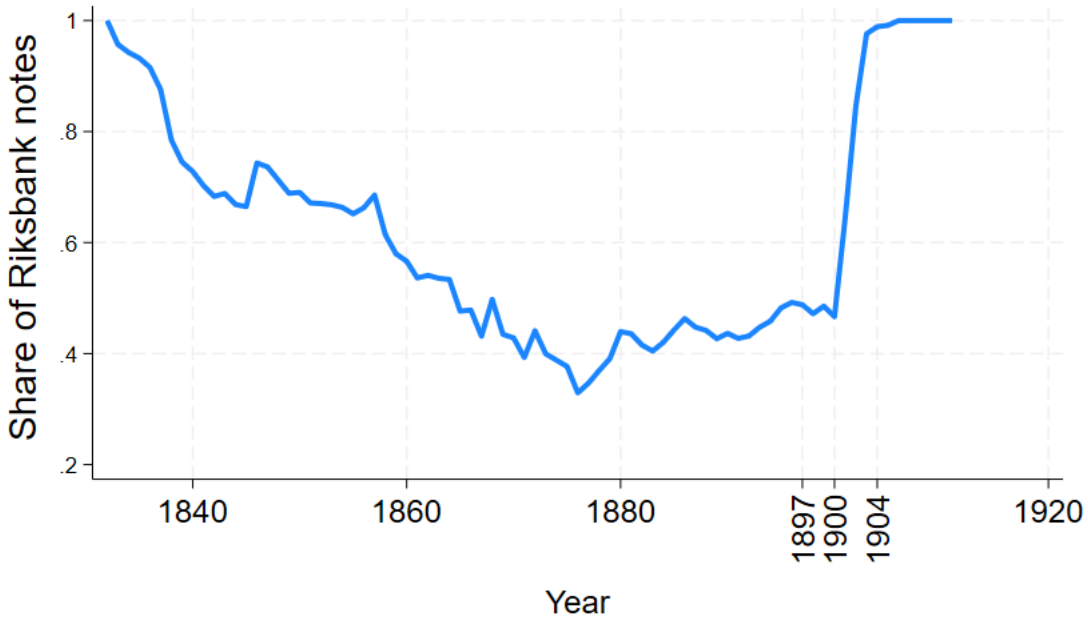
3.2 Riksbank banknote monopoly

Note issuance of private banks has been a topic of recurring debates in Sweden. The Riksdag 1844-1845 was very skeptical towards private note issuance (Jonung, 2021). Proposals to abolish private notes go back at least to 1850s, but most of them resulted only in some limitations on the private note printing business, like restricting the admissible denominations or taxing the note issuance (Wermlands Enskilda Bank, 1910). In 1881, a banking committee was established, which submitted a report two years later proposing a ban on the issuance of private notes. However, the 1883 proposal was not implemented. In 1889, a new banking

[3] Over time, deposits increased in importance as a source of financing even for ULBs, as regulation was mostly imposed on note-issuance, but not deposit-generation.

committee was formed, which also recommended the complete withdrawal of private notes by the end of 1898. That proposal, too, was never carried out (Beckman, 1912). Nonetheless, note issuance was an uncertain business and over time ULBs started relying more on deposits as a source of financing.

Legislation bestowing a monopoly of the note issue upon the Riksbank, being a result of a political decision, led to its gradual transformation into a modern central bank (Söderberg, 2018). The private commercial banks were given the right to tap into the Riksbank liquidity support, making the Riksbank an effective lender of last resort. The Law for the Bank of Sweden (Riksbank) from 12 May 1897 specified that the central bank should have the sole right of issuing banknotes. Private banks retained the right to issue their own notes until the end of 1903, and their already issued (outstanding) notes could remain in circulation until the end of 1906 (Flux, 1910, p. 156-171). Figure 1, based on Ögren and Edvinsson (2014), shows Riksbank's share of notes in public bank note circulation between 1832-1911. It is evident that the law change had a big impact on the domestic currency market.[4]



Source: Data published in Ögren and Edvinsson (2014).

Figure 1: Riksbank's note share in public bank note circulation, 1833-1911

In return for giving up the note issuance, the ULBs were granted access to favorable Riks-

[4]Kenny and Ögren (2021) focus on the role of different liability regimes of ULBs and LLBs around the 1897 Riksbank Act, comparing bank outcomes in December 1896, December 1900 and December 1903. In our paper, we use monthly data and show that most changes to bank outcomes occurred after 1903, when the banks de facto lost their seigniorage revenue and when Riksbank liquidity support was gradually withdrawn. Some of the results found in Kenny and Ögren (2021) are not confirmed in the monthly dataset, highlighting the importance of using monthly panel data, whenever available. Relatedly, Brave (2005), using annual data, studied the impact of Riksbank note issuance monopoly on financial intermediation of Swedish banks, concluding that it was unaffected.

bank credit that was available to them from 1899 to 1910, provided that they voluntarily gave up on note issuance before the legally binding deadline of December 1903 and conditional on maintaining their branch offices that were in operation on January 1, 1896. Were a note-issuing bank to change its liability status from ULB to LLB or to be taken over by another bank, the continuing bank had access to the liquidity support of the original unlimited liability note-issuing bank (Sveriges Riksbank Law, 1897). Table 2 specifies the details of the liquidity support provided by the Riksbank in relation to the withdrawal of private banknotes depending on the time period considered. In the first period after the implementation of the law, according to the announcement in 1897, banks had access to open (collateralized) credit and rediscounting facilities at the Riksbank at preferential rates. The size of liquidity support was a function of banks' outstanding notes as of January 1, 1896. The original 1897 law foresaw that banks would retain their access to rediscounting facilities 1904-1908 on the same terms as in the period before under the condition that they do not close bank branches, but the support was supposed to be limited to the amount of 40 percent of their notes outstanding in January 1896 (as opposed to 50 percent before 1904). No collateralized credit was initially foreseen after 1904, and the rediscounting was supposed to end in December 1908. Banks never used the open credit option before 1901, indicating that it was not attractive to them and most of the 1897 transitional provisions were never implemented in practice. In response to that, the 3 May 1901 law update introduced a new form of liquidity support: uncollateralized credit. First account of such credit on the Riksbank balance sheet can be found in August 1901 and on the individual banks' balance sheets in October 1901. The liquidity support linked to changes in the currency market was to be gradually withdrawn starting from December 1903 until the end of 1910.[5]

Note that the preferential liquidity support was cheaper than equity or time deposit financing (see Tables 2 and 3), but it was more expensive than note issuance. Aggregate bank reports do not allow us to calculate bank-specific costs of supplying notes, but we can provide a rough estimate of this cost on the basis of narrative accounts. In the period of our study, private banks that issued notes had to face a 1% tax on the note issuance in a given year. In addition, they had to cover costs related to the printing and transport of notes. Evidence available in the archives of private banks suggests that the total cost of supplying notes for some private banks could be as high as 2.87% around 1900, far from being zero as the common narratives and model assumptions suggest (Grandinson, 1917, p. 86). Riksbank liquidity support was provided at an interest rate being a function of the current rate for the discounting of 3-months' bills of exchange. In period 1899-1910, when the private banks had access to preferential liquidity funding, this rate for the Riksbank oscillated between 4.5-6.5%, standing at 4.5 and 5% most of the time. The provisions of the 1897 law implied that the actual cost that the private banks had to pay to tap into the Riksbank liquidity stood thus at ca. 2.5-4.5% (2 percentage points

[5]We have the individual banks' balance sheet data for the end of each month. Therefore, in order to calculate the maximum available liquidity support by the Riksbank based on January 1 figures, we use the December numbers of the preceding year, i.e. December 1895 and December 1900.

Table 2: Details on liquidity support by the Riksbank due to the 1897 law and its 1901 update

Time period	Available facilities
Jan 1899-May 1901	1. Open collateralized credit[a] for the value up to 50% of banks' notes outstanding on January 1896.[b] 2. Right to rediscount bills at the Riksbank for the value up to 50% of banks' notes outstanding on January 1896.[c]
June 1901-Nov 1903	1. Open collateralized credit[d] for the value up to 10% of banks' notes outstanding on January 1901.[e] 2. Right to rediscount bills at the Riksbank for the value up to 25% of banks' notes outstanding on January 1901.[f] 3. Uncollateralized loan for the value up to 65% of banks' notes outstanding on January 1901.[g]
Dec 1903-Nov 1909	Liquidity support as specified for November 1903 should be reduced each year starting in December 1903 by one-eight part of its original amount.
Dec 1909 onwards	No specific liquidity support.

Note. Source: Flux (1910). Details are provided in the laws of May 27, 1897 and May 3, 1901. §41 of the Sveriges Riksbank Law (1897) specifies the liquidity support provided to individual note-issuing banks. All liquidity provisions were conditional on banks maintaining their branch offices that were in operation on January 1, 1896.

[a]The collateralized credit was against security approved by Riksbank directors. No more specific information regarding the quality of assets is provided.

[b]The credit had no fee, and an interest rate 2 percentage points below the current rate for the discount of three-months' bills of exchange (provided the rate is above 2 percent per year). Note that in older writings, the term *percent* was used to denote percentage points.

[c]Rate of discount could not exceed 2/3 of the usual rediscounting rate.

[d]The collateralized credit was against security approved by Riksbank directors. No more specific information regarding the quality of assets is provided.

[e]The credit had no fee, and an interest rate 2 percentage points below the current rate for the discount of three-months' bills of exchange (provided the rate is above 2 percent per year).

[f]Rate of discount could not exceed 2/3 of the usual rediscounting rate.

[g]Fee and interest as for the open collateralized credit.

below the actual rate).[6]

Figure 2 visualises how the number of note-issuing banks changed over time. At the passage of 1897 law, 27 commercial banks in Sweden had the ULB status and had the right to issue notes, and 28 of commercial banks were non-note-issuing LLBs. The vertical line in December 1903 indicates the legally binding deadline for the stop of note issuance by private banks, while December 1906 marks the legally binding deadline for complete withdrawal of privately circulating notes. Panel a) of Figure 2 shows the number of ULBs and LLBs 1894-1911. At first, all ULBs were issuing notes. Over time, as banks began to give up their note issuing privilege, the number of ULBs and banks with note-issue rights diverged. In January 1899, the first bank, Vesterbottens enskilda bank, complied, and restructured as an LLB (Bankaktiebolaget Stockholm-Öfre Norrland), giving up its notes and right to issue them.[7] Other banks started

[6]Note that in older writings, the term *percent* was used to denote *percentage points*.

[7]ULBs that restructure as LLBs without the break in their operation are treated as one bank in our sample. They change, though, the liability status in our dataset. ULBs that are merged with or taken over by another bank disappear from the sample, but the surviving bank takes over their right to the liquidity support. Our

complying after the passage of the May 1901 law. As of December 1903, the legally binding limit, all ULBs lost their right to issue notes (yellow dashed-dotted line goes down to zero). However, the majority of ULBs still had outstanding notes (black short-dashed line) that were circulating until August 1906, close to the December 1906 limit imposed by law. As ULBs were losing their note-issuing rights, some of them converted to LLBs (which explains part of the increase in the number of LLBs over time), others continued as ULBs.

Along with note-issuing banks giving up their note privilege, they were granted access to preferential Riksbank loans and Riksbank rediscounting facility.[8] Panel b) of Figure 2 illustrates that Riksbank loans were increasing until December 1903. Thereafter, the limits imposed by the 1901 law were to be reduced at regular intervals, resulting in a stepwise pattern. The median utilization rate of Riksbank loans was oscillating around 1 for most of the considered period, which suggests that banks were tapping into this cheap source of financing, particularly after Riksbank gained monopoly on note issuance in 1904.

3.3 Aggregate trends

Years 1894-1911 were a period of rapid development in the Swedish economy. The end of the 19th century marked the second industrial revolution in Sweden. The banking sector was expanding, with total assets, lending, and deposit showing growth (see Appendix A for aggregate figures). Increasingly more limited liability banks were created. The growth of the banking sector slowed down due to the 1907 crisis that led to the liquidation or takeover of around one fifth of Swedish banks. The crisis, imported from abroad, demonstrated itself mostly in the banking sector. In sections 4.6.1 and 4.7 we look into banks' performance around the crisis, complementing existing research in Grodecka-Messi et al. (2021).

4 Data and empirical results

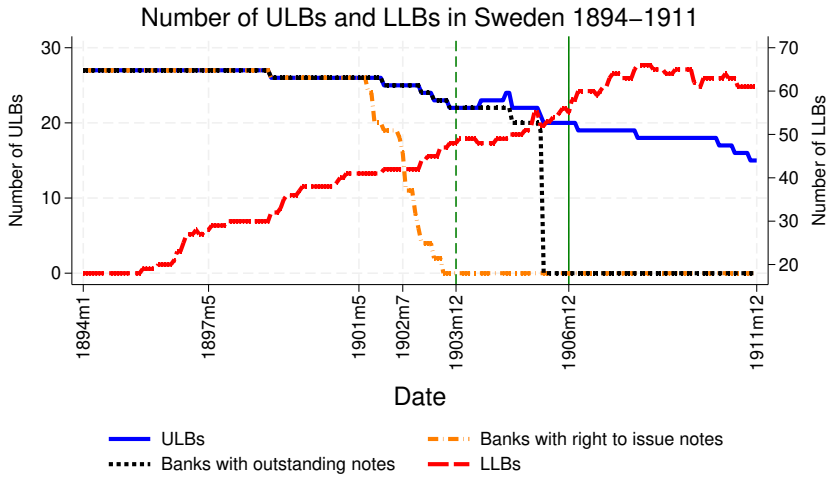
4.1 Data

The main data source is the "Summary of the Banks' Activities," *Sammandrag af Bankernas Uppgifter*, regularly published and readily available to the public even in the 19th century. For the purpose of this project, we digitized monthly balance sheet data for all Swedish commercial banks in the period 1894M1-1911M12. The December summary, apart from the balance sheet items, includes the profit and loss statements of the banks and it is a source of our annual profit data. In addition to balance sheet items and return data, we collect information on bank-specific lending and deposit rates across various types of loans and deposits.

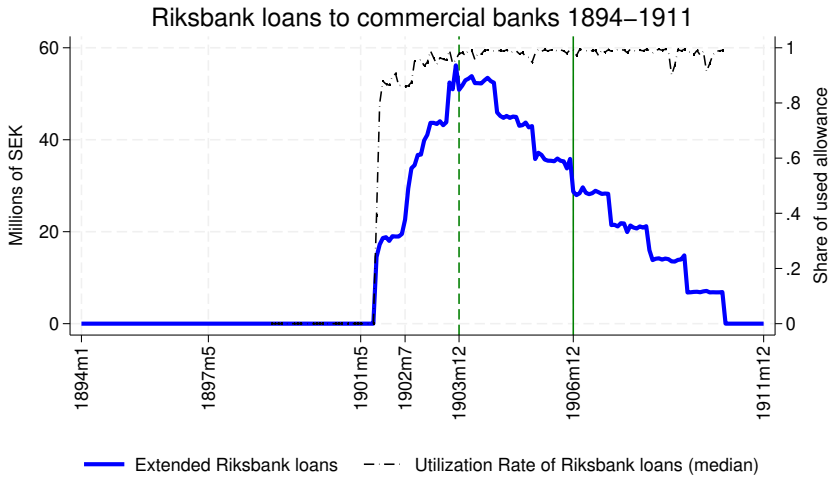
We start our sample at 1894 because in this year the royal charters of the Swedish banks were arranged for concurrent termination at the end of 1903 and a final tax increase on the note issue was put into effect. 1911 is the final year of our sample, because on 1st January

results are robust to using a balanced panel of banks, see section 5.

[8]Note that we cannot separately identify the discounted and re-discounted bills with the Riksbank from banks' balance sheet data, and hence, in our analysis we focus on preferential loans.



(a) Note-issuing banks in Sweden



(b) Riksbank loans

Source: The "Summary of the Banks' Activities, 1894M1-1911M12" (*Sammandrag af Bankernas Uppgifter*).

Figure 2: Private note issuance in Sweden and liquidity support by the Riksbank 1894-1911

Table 3: Summary statistics for the whole sample

	mean	sd	Min	Median	Max	N
	Yearly Sample					
Return on Capital (ROC)	0.10	0.05	0.00	0.10	1.03	1169
Dividend Ratio	0.07	0.44	0.00	0.06	15.04	1168
	Monthly Sample					
log(Assets)	16.01	1.51	11.51	16.13	19.72	14440
Cash Ratio	0.00	0.01	0.00	0.00	0.05	14440
Notes to Liabilities	0.02	0.05	0.00	0.00	0.21	14440
Lending to Assets	0.38	0.15	0.00	0.37	4.57	14440
Property Lending Ratio	0.19	0.12	0.00	0.16	0.85	14440
Share Lending Ratio	0.09	0.07	0.00	0.08	0.53	14440
Deposit Ratio	0.61	0.15	0.00	0.62	8.67	14440
Equity Ratio	0.22	0.09	0.04	0.20	2.79	14440
Non-performing Loans to Assets	0.00	0.01	0.00	0.00	0.55	14440
Riksbank Loan Ratio	0.01	0.02	0.00	0.00	0.12	14440
Current Account Int. Rate	2.30	0.42	1.25	2.00	4.25	14430
3 Month Deposit Int. Rate	3.76	0.61	2.00	3.50	6.00	13898
6 Month Deposit Int. Rate	4.36	0.60	3.00	4.50	6.00	13843
3 M Discounted Bill Int. Rate	5.47	0.81	3.00	5.50	8.50	14430
Property Loan Int. Rate	5.70	0.65	3.75	5.75	8.00	14428
Riksbank 3 M Discounted Bill Int. Rate	4.89	0.74	3.50	4.50	7.00	216

Note: The data are collected from the "Summary of the Banks' Activities, 1894M1-1911M12" (*Sammandrag af Bankernas Uppgifter*). The Dividend Ratio is the sum of dividends over Capital from the 1st of January. Non-performing Loans to Assets are Assets Contingent on Legal Proceedings and Foreclosures to Total Assets. Interest rates and interest rate margins are presented as percent.

1912, a new banking law came into effect in Sweden, which introduced capital requirements for banks and substantially changed the banking sector, see Grodecka-Messi et al. (2021).

Working with historical data of such a great detail may raise concerns about the quality of reporting. In this respect, Swedish commercial bank data is of exceptional quality. Wendschlag (2012) provides an overview of increased bank regulation in the 19th century. First bank charters were granted for ten years by the Ministry of Finance. Before 1846, banks were subject to onsite examinations from Stockholm authorities mostly in connection with charter renewals. Over time, the bank supervision became more independent of local officials and centralized. In the period of our study, a Bank Bureau at the Ministry of Finance was already operating.[9] In January 1907, an independent state agency, the Bank Inspection, responsible for supervision of commercial banks, was opened. At the end of the 19th century, monthly reports of Swedish commercial banks were not only scrutinized by the centralized regulator

[9]Since 1846, banks' boards were to provide quarterly financial statements to the Ministry of Finance under the physical supervision of a local civil servant representing the Crown. King could also order unsupervised inspections if any doubt persisted about the quality of the provided data. 1876, the position of a Bank Inspector was established, that, with help of an assistant, worked on-site to collect and compiled monthly bank reports that were then sent to the government. 1889, a Bank Bureau at the Ministry of Finance was created, and commercial bank supervision became centralized.

Table 4: Summary statistics for treated and control banks in separate periods

	Control		Treated		Differences	
	mean	sd	mean	sd	diff	t
			1894–1896			
Return on Capital (ROC)	0.10	0.05	0.11	0.04	-0.01	(-1.31)
Dividend Ratio	0.06	0.02	0.06	0.01	-0.00	(-0.90)
log(Assets)	15.27	1.41	16.52	0.71	-1.26***	(-23.71)
Cash Ratio	0.00	0.00	0.02	0.00	-0.01***	(-116.02)
Notes to Liabilities	0.00	0.00	0.13	0.03	-0.13***	(-160.20)
Lending to Assets	0.39	0.18	0.27	0.09	0.12***	(18.51)
Property Lending Ratio	0.20	0.12	0.11	0.06	0.09***	(18.94)
Share Lending Ratio	0.06	0.06	0.06	0.05	-0.00	(-0.61)
Deposit Ratio	0.63	0.18	0.56	0.10	0.07***	(9.95)
Equity Ratio	0.22	0.10	0.18	0.04	0.04***	(12.28)
Non-performing Loans to Assets	0.00	0.01	0.00	0.01	-0.00**	(-2.91)
Riksbank Loan Ratio	0.00	0.00	0.00	0.00	0.00	(.)
Propety Loan Int. Rate	4.84	0.45	4.77	0.32	0.08***	(4.18)
3 M Discounted Bill Int. Rate	4.71	0.69	4.38	0.40	0.33***	(12.30)
3 Month Deposit Int. Rate	2.99	0.26	2.82	0.27	0.17***	(13.73)
			1897–1905			
Return on Capital (ROC)	0.09	0.06	0.12	0.04	-0.03***	(-7.15)
Dividend Ratio	0.06	0.11	0.06	0.01	-0.00	(-0.30)
log(Assets)	15.35	1.41	17.07	0.74	-1.72***	(-66.39)
Cash Ratio	0.00	0.00	0.01	0.01	-0.01***	(-57.97)
Notes to Liabilities	0.00	0.00	0.07	0.06	-0.07***	(-63.29)
Lending to Assets	0.40	0.15	0.32	0.08	0.08***	(29.05)
Property Lending Ratio	0.20	0.12	0.15	0.06	0.05***	(21.85)
Share Lending Ratio	0.09	0.08	0.09	0.05	0.01***	(3.56)
Deposit Ratio	0.62	0.15	0.60	0.10	0.01***	(4.47)
Equity Ratio	0.23	0.09	0.18	0.05	0.06***	(33.91)
Non-performing Loans to Assets	0.00	0.01	0.00	0.00	0.00***	(8.99)
Riksbank Loan Ratio	0.00	0.00	0.02	0.03	-0.02***	(-38.21)
Propety Loan Int. Rate	5.57	0.41	5.45	0.42	0.12***	(12.23)
3 M Discounted Bill Int. Rate	5.47	0.66	5.23	0.59	0.23***	(15.57)
3 Month Deposit Int. Rate	3.74	0.48	3.74	0.47	0.00	(0.05)
			1906–1911			
Return on Capital (ROC)	0.09	0.04	0.12	0.05	-0.02***	(-4.86)
Dividend Ratio	0.10	0.82	0.06	0.02	0.04	(0.87)
log(Assets)	15.33	1.44	17.75	0.65	-2.42***	(-85.72)
Cash Ratio	0.00	0.00	0.00	0.00	0.00	(1.08)
Lending to Assets	0.44	0.17	0.38	0.09	0.06***	(16.76)
Property Lending Ratio	0.23	0.14	0.18	0.06	0.04***	(16.19)
Share Lending Ratio	0.10	0.08	0.12	0.05	-0.02***	(-8.52)
Deposit Ratio	0.62	0.20	0.64	0.08	-0.02***	(-5.51)
Equity Ratio	0.26	0.12	0.22	0.05	0.04***	(16.01)
Non-performing Loans to Assets	0.01	0.01	0.00	0.01	0.00***	(4.35)
Riksbank Loan Ratio	0.00	0.00	0.01	0.01	-0.01***	(-45.26)
Propety Loan Int. Rate	6.24	0.49	6.22	0.45	0.01	(1.04)
3 M Discounted Bill Int. Rate	6.01	0.75	5.71	0.67	0.30***	(14.43)
3 Month Deposit Int. Rate	4.11	0.54	4.07	0.50	0.04**	(2.66)

Note: The data are collected from the "Summary of the Banks' Activities, 1894M1-1911M12" (*Sammandrag af Bankernas Uppgifter*). Interest rates and interest rate margins are presented as percent.

but also jointly published as *Summary of the Banks' Activities* and republished by the journal *Ekonomisk Tidskrift*, readily available to the public (Grodecka-Messi et al., 2021).

Table 3 presents the summary statistics for the universe of commercial banks in the period 1894M1-1911M12. We have around 14 000 observations for variables on monthly frequency and more than 1 000 for return ratios. Table 4 provides summary statistics for the subperiods of our data, differencing between two types of banks. Control banks are banks that were LLBs at the passage of law in May 1897, Treated banks are all the remaining (LLB) banks. We see that before the passage of law, Treated and Control banks achieved similar levels of return ratios, but Treated banks were slightly larger, and offered lower deposit and lending rates. On the liability side, they were partially financed by notes (the average note to liability ratio stood at 13%), so their equity and deposit ratios were slightly lower than for the counterparts in the control group. Since note issuance was linked to certain reserve requirements, on the asset side, Treated banks held more gold than the Control banks, and lending constituted a lower share of their asset portfolio. In the second period (1897-1905), when some of the ULB banks stopped issuing notes, and got access to the preferential Riksbank support, we see an increase in return ratios for Treated banks, and a decrease for Control banks. Treated banks decreased their gold shares and increased lending, particularly against property collateral. After the withdrawal of last notes in circulation, in the last period of our study (1906-1911), we see that Treated banks increase their lending, equity and deposit ratios, and the lending rate against property collateral. Over time, the preferential Riksbank support was withdrawn, so the share of Riksbank loans to liabilities diminishes in the third subperiod. In the following sections, we study the effects of changes in law with the DiD regressions.

4.2 Identification and endogeneity concerns

The Riksbank note monopoly can be interpreted as a quasi-natural experiment that affected the banks differently through a number of channels. However, the note-issuing banks, identified as the treatment group, exhibit intrinsic differences compared to the banks that were not authorized to issue notes. As a result, these banks could respond differently to shocks and policy changes. Thus, a potential concern is that non-note-issuing banks are not an adequate control group for former note-issuing banks. The key identifying assumption underlying our empirical model based on Difference-in-Differences (DiD) is that treated banks would have developed in a similar way as the control group banks in the post-treatment period had they not been affected by the policy change. This assumption is not directly testable, but we can test a weaker form of the identification assumption, namely the parallel trend assumption.

The parallel trend assumption implies that the treated banks should develop in parallel trajectories to the counterparts in the control group. The legislative reform, its announcement and implementation, should affect the trend after the intervention, thus allowing the DiD technique to identify the causal impact from the experiment.

We test the parallel trend assumption for key variables of interests. We choose to focus on variables related to banks' profitability and lending, along with their interest-rate setting,

to directly address concerns arising in the CBDC debates. In the following, we present the results for the return on capital (ROC), bank lending to assets ratio, the property loan ratio (ratio of loans against property collateral to assets) and the interest rate on loans with property collateral. We examine closely loans with property collateral, as they dominated bank lending, accounting for ca. 49% of all commercial banks' loans in the studied period. Figure 3 shows the coefficient β_j for the chosen variables from the regression

$$y_{i,t} = \alpha + \sum_{\tau=1894}^{1911} \beta_\tau \text{Treat}_i \times \text{After}_{\tau,t} + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}, \tag{3}$$

on the annual sample. It can be considered a DiD regression with many placebo policy change dates. The 95% confidence bands of the coefficient estimates β_τ are also shown in the figure. 1903 and 1906 are considered as the potentially true treatment years, corresponding to the end of the note issuance rights for private banks, and the final withdrawal of circulating notes issued by private banks. These two dates are marked with dashed and long dashed vertical lines in each plot.[10]

Figure 3 shows that we cannot reject the null hypotheses of parallel trends between treated and control banks for the variables of interest. The plots imply that there are no significant pre-treatment differences in trends before the 1903 treatment date, which supports our choice of LLBs as a valid control group. Our DiD regressions uncover the effects of policy changes by computing the average deviation of the trends after the respective structural change.

In addition, the legal reform that terminated the note issuance rights and ended the circulation of private bank notes can be viewed as exogenous to individual banks' profitability and business decisions. Even though the banks are not directly comparable in the levels of some key variables, for instance the average property loan ratio, these characteristics of the banks are essentially irrelevant for determining whether a bank is treated. Moreover, the probability of the banks being treated cannot be directly related to the expected outcome or the pre-treatment characteristics of the treated bank. We demonstrate it further in the next few sections.

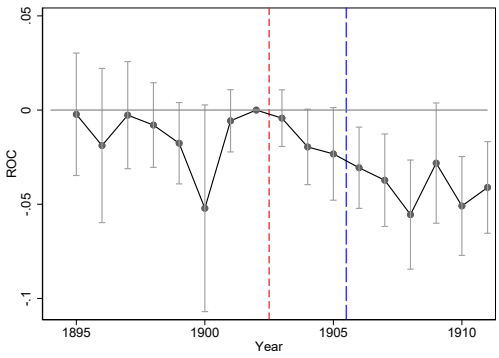
By demonstrating that pre-treatment trends are parallel for banks in the treatment and control group respectively, we can narrow down the potential sources of endogeneity. That is, any alternative explanation for our results not only has to be plausible in and of itself, but must also be consistent with parallel pre-treatment trends.

4.3 The effects of the stop of new note issuance: 1903

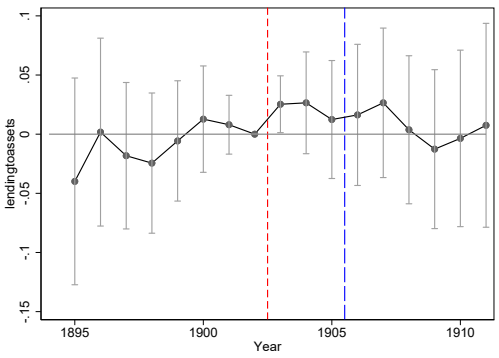
In the first step of our analysis, we run the DiD regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}. \tag{4}$$

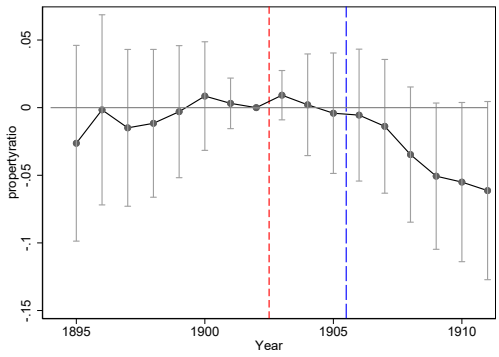
[10]The time of the announcement of legal changes, 1897, could be considered an alternative treatment date, along with 1899, when banks first got access to Riksbank liquidity. Aggregate trends reveal that most changes happened around the 1903 date, as it was the actual Riksbank banknote monopoly, and not its announcement. We show results for alternative treatment dates in Appendix B.



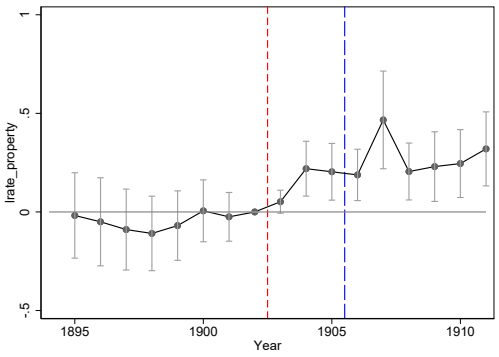
(a) Return on Capital



(b) Total Bank Lending to Assets



(c) Property Loan Ratio



(d) Property Lending Interest Rate

Note: The figures show the coefficient β_j for the dependent variables from the regression

$$y_{i,t} = \alpha + \sum_{\tau=1894}^{1911} \beta_\tau \text{Treat}_i \times \text{After}_{\tau,t} + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

which be considered a DiD regression with many placebo policy change dates. We consider two potential treatment date, 1903 and 1906, corresponding to the end of the note issuance rights for private banks, and the final withdrawal of circulating notes issued by private banks. These two dates are marked with red dashed and blue long dashed vertical lines.

Figure 3: Returns and lending activities of banks over the period 1894-1911, placebo test

where δ_i are the bank fixed effects, η_t are the time (year-month) fixed effects. The treatment dummy and the event dummy variables are absorbed by the fixed effects. We include bank-level control variables $X_{i,t}$ including the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio.[11] RB Loan is the ratio of the Riksbank loans to total bank liabilities.[12] Profit data is available at yearly frequency, while all other variables are monthly. The standard errors are clustered at the bank-level. Our findings are robust to other ways of computing standard errors.

The dependent variable $y_{i,t}$ is return on capital (ROC), lending-to-assets ratio, property lending ratio (ratio of lending against property collateral to total assets) and property lending

[11]For regressions using the lending ratio as the outcome variable, we use the logarithm of total asset, the dummy for unlimited liability banks, the cash ratio, equity ratio, and the ratio of Riksbank loans to total liabilities.

[12]In order to alleviate concerns about the reverse causality, we take a lag (j) of 12 (in the case of annual profit data) or 1 (in the case of monthly lending data) months.

interest rate, in line with section 4.2. The treatment dummy takes the value of 1 for all the banks that were note-issuing banks (ULBs) in May 1897, at the time of the passing of the banking law, and 0 otherwise. For the benchmark treatment time ($After$), we consider *August 1903*, when the last ULBs gave up their note issuance privilege. Alternatively, once could consider *May 1897*, when the banking law was passed and the changes announced, *January 1899*, when the banks first can got access to preferential Riksbank loans, or *April 1906*, the first month in which commercial banks not only had zero note issuing rights, but also retrieved all their outstanding notes from the circulation. Since the importance of privately issued notes declined after 1903 (see the Riksbank note share in all banknote circulation in Figure 1), we treat 1903 as our benchmark treatment date, and comment on the 1906 results in a separate subsection 4.5.[13]

The results for our main variables of interest are presented in Table 5. We show that from and after August 1903, treated banks experienced relatively lower profitability, indicating that the loss of seigniorage was costly for them, despite the liquidity support by the Riksbank. In particular, affected banks are suffering from a reduction of 2.5 percentage points in ROC after the end of their note issuance rights in 1903, compared with the control group.[14] In economic terms, the treated banks experienced a 23% drop in profitability after the stop in new note issuance. The (lagged) Riksbank loans are significantly and positively associated with profits, indicating that Riksbank loans cushioned part of the seigniorage losses.[15] Between 1902-1910, Riksbank liquidity compensated for around half of the decline in ROC due to the loss of note issuance rights. If we concentrate only on the period up until December 1903, when the Riksbank liquidity support to the private banks reached its peak, Riksbank loans were able to compensate for 69.26% of ROC decline. Looking at the lending-to-assets ratio and lending against property collateral that constituted 49% of all lending and was thus the most important type of lending, we see no significant effects from the policy change. No evidence of bank disintermediation is found, similar to the results for Canada in Grodecka-Messi and Zhang (2023). As in the case of the ROC, we document, however, that Riksbank liquidity support was important in keeping lending up. Every 1 percentage point increase in the Riksbank loan ratio would increase the property loan ratio by 0.6 percentage points for the treated banks. On average, the Riksbank loan increased the property lending ratio by 3%. Even though the majority of Riksbank lending to banks was uncollateralized, parts were reliant on collateral that had to be approved by Riksbank directors. As a result, the liquidity support may have induced banks to reshuffle their asset portfolio towards safer collateralized investments. Finally, column (4) demonstrates that the treated banks increased the interest rates for loans with property collateral by 3 percent with respect to the pre-treatment average interest rates before 1897.

[13]The (insignificant) results for alternative potential treatment dates are presented in Appendix B.

[14]We tried different definitions of ROC, to alleviate the concern that mechanical changes in banks' capital structure lead to the decrease of profitability. The results are similar if we choose to normalize the profit with one-year lagged capital in the calculation of ROC.

[15]When it comes to other control variables, we find that higher equity ratios (i.e. less leverage) and higher share of non-performing assets are associated with lower profitability. We leave out the coefficients of other control variables for readability, but they are available upon request.

Table 5: Effects of the loss of note issuance rights on bank outcomes: after 1903

	(1)	(2)	(3)	(4)
	ROC	Lending-to-Asset	Prop. L. Ratio	Prop. L. Int.Rate
Treat x After	-0.025***	-0.011	-0.017	0.153***
	(0.008)	(0.031)	(0.025)	(0.049)
Lagged RB Loan	0.216**	0.458*	0.602***	-1.829***
	(0.084)	(0.268)	(0.145)	(0.688)
adj. R^2	0.429	0.711	0.736	0.880
N	1099	14321	14321	14318
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: This table reports the effect of losing note issuance rights on bank outcome variables using the DiD regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

Higher Riksbank loans mitigated those increases.[16] An increase in lending rates was one of the possible solutions that banks could take in order to safeguard their returns, as discussed in section 2. Higher lending rates are usually associated with higher risk-taking, but in the case of Swedish banks, it demonstrated itself in a still fairly safe market of loans with real-estate as the collateral. Consequently, we do not find evidence of increased riskiness of treated banks or banks that had access to the preferential loans of the Riksbank, as demonstrated in sections 4.6.1 and 4.7.

4.4 Bank-specific treatment intensities and treatment dates

In the second step of our analysis, we investigate the heterogeneity in banks' treatment. We focus on two different dimensions of the treatment heterogeneity: bank-specific treatment intensities and individual treatment dates.

4.4.1 Bank-specific treatment intensities

The extent to which banks depended on funding via note printing differed among institutions. Consequently, the reform banning note issuance may have affected banks to varying

[16] No evidence for a substantial change in deposit interest rates after 1903 is found, so we leave these results out.

degrees. In the regression analysis, the treatment dummy variable can therefore be replaced with a continuous measure of treatment intensity. In order to account for it, we run the regression

$$y_{i,t} = \alpha + \beta \text{Treatment Intensity}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}. \quad (5)$$

$TreatmentIntensity_i$ is defined as the ratio of outstanding bank notes to the maximum right to issue notes (being a function of the reserves backing note issuance) of a given bank as of last of December 1895 (the original 1897 law treated January 1st, 1896 as the benchmark date for determining the maximum provision of liquidity to each bank). Accordingly, our measure of treatment intensity is based on data prior to the announcement of the new regulation and before the banks had an opportunity to react to it. We include bank fixed effects and time fixed effects in the regression, so the separate terms of $TreatmentIntensity_i$ and $After_t$ are absorbed in the regression.

The regression results for banks' outcomes are reported in Table 6. The results confirm the outcomes presented in the standard DiD setting in the previous section: While the significance of our estimates does not change, the coefficients are larger. We document that the profits of banks with higher treatment intensity are affected more, as shown column (1) of Table 6. The effects on the loans as the fraction of the banks' assets and the property lending ratio are still insignificant. When it comes to interest rates, also for the continuous treatment measure we find that lending rates for loans with property collateral increase. For all four outcomes presented in Table 6, Riksbank liquidity support played an important role, dampening the decline in profitability and the increase in the interest rates and supporting the financial intermediation as expressed by the lending ratios.

4.4.2 Bank-specific treatment dates

Following the passage of the 1897 law, enskilda banks were allowed to determine when to give up their note issuance, provided it occured before the final deadline of December 1903. As evidenced in Figure 2 a), banks relinquished their note-issuing privileges at different times, primarily in connection with applications for new charter. The charters of enskilda banks were set to expire at the end of 1903, and according to the law, banks were required to apply for the charter renewal no later than eight months prior to the expiration of their existing charters. Nonetheless, banks had the option to apply for a short-term charter permitting note issuance until December 1903. Most, however, chose not to, viewing Riksbank preferential liquidity support as an attractive alternative to issuing notes (Wermlands Enskilda Bank, 1910; Beckman, 1912).[17] To account for bank-specific treatment dates, we define an individual treatment measure, $Treatment_i^{issue}$, which takes the value of 1 from the month in which a formerly

[17] In Appendix C, we examine different cohorts of compliers and document that it was not possible to predict the timing of the stop in note issuance or the month of the withdrawal of notes with bank observables.

note-issuing bank gave up its issuance of new notes and 0 otherwise.

$$y_{i,t} = \alpha + \beta \text{Treatment}_i^{issue} \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}. \quad (6)$$

The additional controls are the same as in the above Equation 4. Bank- and time fixed effects are also included.

Table 7 presents the results for bank outcomes with individual treatment dates. Somhehow surprisingly, we find that once we control for the concrete month of the stop of issuance of new notes, the new law did not have an impact on banks' outcomes. Riksbank loans continue to be important for our results, though. We frame it as a puzzle: why do individual treatment dates yield no significant results? We explore the possibility that it was the withdrawal of circulating notes, rather than the stop of note issuance that mattered for former note-issuing banks. Consequently, we focus on the 1906 treatment date in the next section 4.5.

4.5 The effects of the private note withdrawal: 1906

Swedish note-issuing banks complied with the 1897 law at different times. Figure 4 documents how many ULB banks stopped issuing notes (panel a) and withdrew their notes completely from circulation (panel b) in a given year. It is evident that even though the majority

Table 6: Treatment intensity and banks' outcomes

	(1)	(2)	(3)	(4)
	ROC	Lending-to-Asset	Prop. L. Ratio	Prop. L. Int.Rate
Treat Intensity x After	-0.038***	-0.015	-0.016	0.215**
	(0.011)	(0.042)	(0.033)	(0.068)
Lagged RB Loan	0.230***	0.458*	0.605***	-1.856**
	(0.081)	(0.271)	(0.148)	(0.702)
adj. R^2	0.430	0.705	0.734	0.880
N	1099	14328	14328	14319
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: This table reports the relationship of treatment intensity, defined as the ratio of outstanding bank notes to the maximum issuance rights of each bank, and bank outcome variables using the regression

$$y_{i,t} = \alpha + \beta \text{Treatment Intensity}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

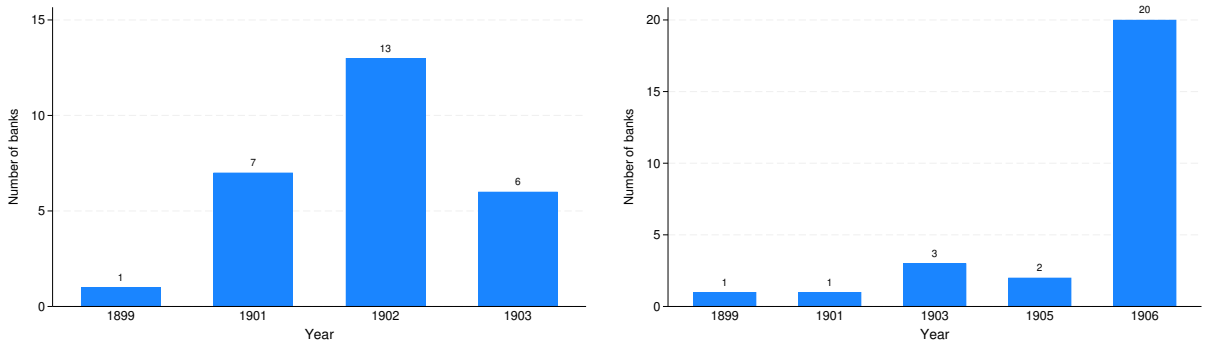
Table 7: Individual treatment dates: effects on banks' outcomes

	(1)	(2)	(3)	(4)
	ROC	Lending-to-Asset	Prop. L. Ratio	Prop. L. Int.Rate
Treatment^{issue} x After	-0.011	-0.026	-0.030	0.113
	(0.012)	(0.046)	(0.033)	(0.088)
RB Loan	0.138*	0.550	0.712***	-2.304***
	(0.078)	(0.381)	(0.232)	(0.835)
adj. R^2	0.424	0.705	0.735	0.878
N	1099	14328	14328	14316
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: This table reports the effect of losing note issuance rights on bank outcome variables using the DiD regression but with different treatment date for each bank:

$$y_{i,t} = \alpha + \beta \text{Treatment}_i^{issue} \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

Banks were allowed to determine when to give up their note issuance, before the final deadline of December 1903. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.



(a) Year of issuance stop

(b) Year of note withdrawal

Source: The "Summary of the Banks' Activities, 1894M1-1911M12" (*Sammandrag af Bankernas Uppgifter*).

Figure 4: Compliance year by note issuance stop and note withdrawal

of banks stopped issuing new notes in 1902 (and hence got access to the Riksbank liquidity support thereafter), almost all the banks waited with withdrawing their notes until 1906, the legally imposed limit.[18] We are thus interested in seeing how our estimated coefficients change once we take April 1906, the first month in which no privately issued bank notes circulated, as our treatment date. Additionally, analogous to section 4.4.2, we test how bank-specific note withdrawal dates affect the outcomes. Table 8 summarizes the results.

We find that the negative impact on probability for the 1906 treatment date appears stronger than the results using 1903 as the treatment date. Interestingly, for 1906 treatment dates, Riksbank liquidity is mostly insignificant. Before interpreting these results, one needs to keep in mind that after 1903, the proportion of notes to bank liabilities was negligible as demonstrated in Figure 5. Banks did continue to circulate their notes until 1906, but the share of notes in their liabilities was very low (see Figure 5). It is thus surprising that the profitability effect becomes larger with 1906 treatment date in contrast to the 1903 date.

If not note withdrawal, then what can explain our results? The answer lies in Riksbank liquidity support that is at the heart of theoretical papers on the private and public money equivalence. If we compare the plot showing the ROC in Figure 3 with the plot demonstrating Riksbank loans to commercial banks (Figure 4 b), it becomes evident that the profitability of banks closely tracks Riksbank liquidity support to them. We see a hump-shape in ROC corresponding to hump-shaped Riskbank transfers. Even if the banks stop issuing new notes before the end of 1903, it is ultimately the slow withdrawal of preferential Riksbank loans that drives their results down. Our empirical evidence leads thus support to theories presented in

[18]It is important to note that between May 1897 and May 1901, only one bank complied (in 1899). This was the bank for which note issuance on January 1st, 1896 was the valid referral point for the liquidity support limit. All the remaining banks stopped issuing new notes after May 1901, and thus, for them, note issuance from January 1st, 1901, was the referral number. We provide summary statistics for compliers at different dates in Appendix C. In Appendix C, we also test whether one could have predicted banks' individual compliance date on the basis of observables. The short answer is no and we refer an interested reader to the appendix.

Table 8: Effects of the loss of note issuance rights on bank outcomes: after 1906

	(1) ROC	(2) Lending-to-Asset	(3) Prop. L. Ratio	(4) Prop. L. Int.Rate
	Treatment in April 1906			
Treat x After_{1906}	-0.027***	-0.019	-0.024	0.138***
	(0.007)	(0.027)	(0.020)	(0.048)
Lagged RB Loan	-0.028	0.276	0.382**	-0.607
	(0.079)	(0.244)	(0.167)	(0.729)
adj. R^2	0.432	0.705	0.735	0.879
	Individual Treatment (withdrawal of circulating notes)			
Treatment^{circ} x After	-0.026**	-0.011	-0.017	0.103**
	(0.008)	(0.028)	(0.020)	(0.050)
Lagged RB Loan	0.009	0.368	0.470***	-1.080
	(0.082)	(0.243)	(0.151)	(0.655)
adj. R^2	0.431	0.705	0.734	0.878
N	1099	14328	14328	14316
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: This table reports the effect of withdraw notes in circulation on bank outcome variables using the DiD regressions. Panel A reports the dummy variable definition of treatment in April 1906.

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

And Panel B reports the results of different treatment dates for different banks:

$$y_{i,t} = \alpha + \beta \text{Treatment}_i^{circ} \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

Banks were allowed to determine when to withdraw their note in circulation, before the final deadline of December 1906. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

Brunnermeier and Niepelt (2019) and Chen and Filippin (2025). To support our interpretation of empirical results, in the following section, we focus explicitly on the role of Riksbank liquidity support in the transition.

4.6 Riksbank liquidity support and bank outcomes

Riksbank liquidity support is potentially an essential factor in explaining banks' profits, loan issuance and loan pricing after the Riksbank banknote monopoly. In this section, we corroborate our findings about the importance of central bank liquidity support by showing that affected banks indeed used Riksbank loans as a substitute for the "missing" notes. Riksbank loan, being

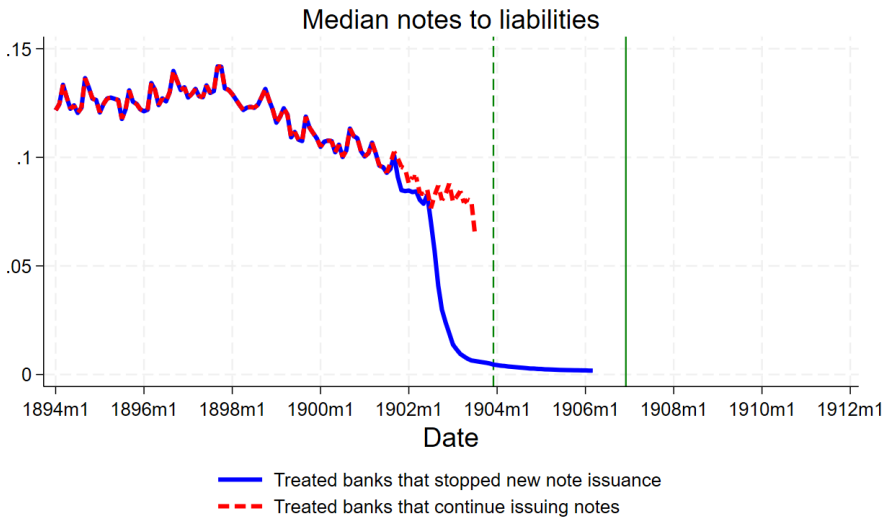


Figure 5: Median notes to liabilities of treated banks

priced two percentage points below the market rate, was a cheaper source of funding than time deposits or equity (see Table 4 for statistics on the price of bank funding).

First, we run regression to disentangle the effect of Riksbank loan on the performance of banks using the regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \varphi \text{After}_t \times \text{RB Loan}_{i,t-j} + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}, \quad (7)$$

where $\text{Treat}_i \times \text{After}_t$ directly measures the effect of the legal change. The other term $\text{After}_t \times \text{RB Loan}_{i,t-j}$ captures the direct effect of the Riksbank loan after the change.

Table 9 presents the regression results for our outcome variables of interest. The main results hold. The treated banks suffer a profitability drop, with reduced ROC, and charge higher interest rates on loans collateralized with property. In addition, we confirm that the Riksbank liquidity support was crucial for treated banks after the 1903 treatment date, mitigating the loss of profitability, as demonstrated in Column (1). The direct effect of losing note issuance rights is estimated at -3.10 p.p. Riksbank liquidity support could partially shield banks from this decline. On average, it contributed to an increase of ROC of approximately 1.46 p.p., offsetting about half of the seigniorage loss. Prior to January 1904 (when the Riksbank liquidity support started being withdrawn), preferential central bank funding compensated for as much as 97% of the decline in treated banks' profitability.[19] On the other hand, the property loan interest rates increase by 0.172 p.p. after the legal change, which accounts for ca. 3.6% increase in the average interests rates. Moreover, regression results confirm that preferential Riksbank loans supported lending against property collateral. Overall, the effects of legal changes and associated Riksbank liquidity support were both economically and statistically significant during the transition period.

[19]The average value of the Riksbank liquidity support is 0.0316 between 1903 and 1910. Multiplying this with 0.463 yields an average effect of 1.46 p.p. Between 1901 and 1903, for banks tapping into Riksbank liquidity, its average value corresponds to 0.0647, which, when multiplied with the same coefficient, results in a compensating effect of 97%.

Table 9: The role of Riksbank Liquidity Support

	(1)	(2)	(3)	(4)
	ROC	Lending-to-Asset	Prop. L. Ratio	Prop. L. Int.Rate
Treat x After	-0.0310***	-0.0265	-0.0417	0.172***
	(0.00937)	(0.0430)	(0.0323)	(0.0568)
After x Lagged RB Loan	0.463***	0.550	0.928***	-0.980
	(0.174)	(0.508)	(0.349)	(1.130)
adj. R^2	0.430	0.711	0.732	0.880
N	1099	14321	14321	14319
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: This table reports the role of the Riksbank preferential liquidity support on bank outcome variables using the regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \varphi \text{After}_t \times \text{RB Loan}_{i,t-j} + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, and non-performing loans ratio. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

Once the commercial banks stopped issuing notes, provided that they wished to maintain the same size of the balance sheet, they had to substitute notes with alternative sources, which we expect to have been Riksbank loans. To formally test this hypothesis, we estimate the following regression:

$$\Delta y_{i,t} = \alpha + \beta \Delta Notes_{i,t} + \gamma X_{i,t} + \delta_i + \eta_t + \epsilon_{i,t}, \tag{8}$$

where $\Delta y_{i,t}$ stands for the difference of chosen items on the liability side of banks' balance sheets and $\Delta Notes_{i,t}$ is the change in notes in circulation. $X_{i,t}$ is a vector of control variables including the ULB dummy, the cash ratio, logarithm of total assets, lending to assets ratio, and the equity ratio. Standard errors are clustered at the bank level, and we take into account bank and time fixed effects.

Table 10 presents the results. We find that when notes in circulation go down, they are substituted by the Riksbank loans. Other items on the liability side of the banks are not significantly linked to the change in Notes.[20] For brevity, we only report the coefficient for Riksbank loans. The highly statistically significant coefficient of -0.644 indicates that when banks lower their notes in circulation by 1, the Riksbank loans increase by 0.64, remarkably close to the 65% limit initially imposed by the law. It is an indication of the binding limit and importance of "haircuts" in lending. Banks actively utilized Riksbank liquidity support to compensate for the

[20]The coefficient on postal notes is significant, but positive, so there is no substitution going on there.

Table 10: Substitution between notes and Riksbank loans

	(1)
	ΔRB loans
ΔNotes	-0.644***
	(0.134)
adj. R^2	0.263
N	2655
Add. Controls	YES
Bank FE	YES
Time FE	YES
Std. Err.	BANK

Note: This table reports the substitution effect of the Riksbank's liquidity support and banks' loss of notes issuance right using the regression

$$\Delta y_{i,t} = \alpha + \beta \Delta Notes_{i,t} + \gamma X_{i,t} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are the change of the Riksbank's loan for bank i at month t through the liquidity support program. The key variable of interests is the change of notes in circulation for the bank. Other bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, and non-performing loans ratio. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

loss of note issuance. On one hand, this enabled them to adjust their portfolios and mitigate losses; on the other, it may have increased their dependence on preferential funding.

Note that the above regression only takes into account the period when private banks stopped new note issuance but still had outstanding notes. Given that banks' assets continued to increase after that, it remains a question whether the growth was deposit- or equity-financed. It turns out that former note-issuing banks issued relatively more equity than the control banks, as Figure 6 documents. The figure plots the coefficient of regression 3 in which we run the placebo test. This conclusion is confirmed by narratives from private bank archives (Wermlands Enskilda Bank, 1910; Beckman, 1912). Former note-issuing banks started increasing their equity in order to close the gap between their and LLBs equity ratios. They wanted to be able to better compete with big LLB banks and equity financing was probably deemed as more stable and reliable compared to deposit financing. Table 11 confirms the narratives formally in a regression setting, with the benchmark August 1903 as the treatment date.

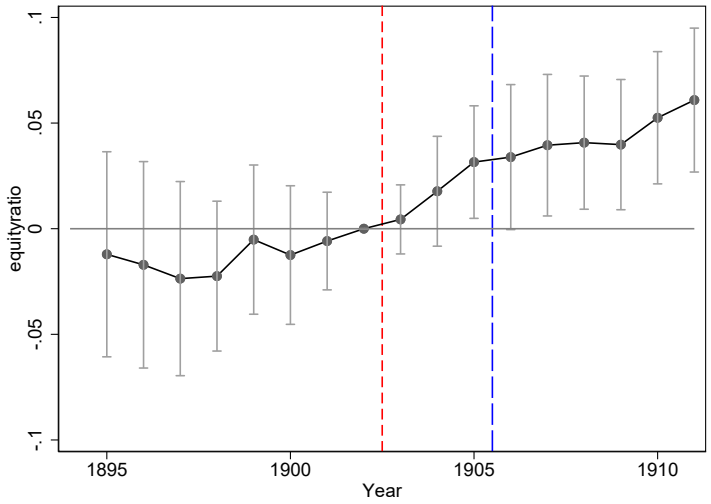


Figure 6: Equity ratio of banks over the period 1894-1911, placebo test

Table 11: Banks' equity and deposit ratio

	(1) Equity Ratio	(2) Deposit Ratio	(3) Equity Ratio	(4) Deposit Ratio
Treat x After$_{Aug,1903}$	0.042**	-0.012	0.031**	-0.084
	(0.016)	(0.155)	(0.014)	(0.134)
RB Loan	-0.190	-1.610	-0.352*	-2.792
	(0.173)	(2.256)	(0.181)	(2.105)
adj. R^2	0.655	0.954	0.689	0.960
N	1106	1106	14322	14322
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Time Freq.	YEAR	YEAR	MONTH	MONTH
Std. Err.	BANK	BANK	BANK	BANK

Note: This table shows the effect of losing notes issuance rights on banks' equity ratio and deposit ratio using the regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are banks' equity ratio and deposit ratio. We check the regression results with yearly and monthly frequency of the bank data. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, and non-performing loans ratio. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

4.6.1 Riksbank liquidity support and bank risk taking

As established in previous sections, Riksbank loans helped cushion profit losses associated with the loss of seigniorage and supported lending secured by property collateral. We now turn to examining the impact of Riksbank loans on the risk-taking of banks and their subsequent performance. This analysis is particularly relevant, given that 1907 marks the onset of a financial crisis, both internationally and in Sweden. Previous research shows that borrowing from the Riksbank was not a significant predictor of bank distress in that crisis, and that asset choices of banks were more associated with distress. In particular, Grodecka-Messi et al. (2021) show that high share of non-performing assets and high share of lending against shares were distress contributors. They take into account all commercial banks that existed at the eve of the crisis in April 1907, including newly founded banks that would not have access to Riksbank liquidity support unless they were a restructured former ULB bank. In the following analysis, we take into account only banks that existed at the passage of the banking law in May 1897.

We run the regression

$$y_{i,t} = \alpha + \beta X_{i,t} + \eta \text{RB loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}, \tag{9}$$

where the control variables include the cash ratio, logarithm of total assets, and the ULB dummy, while RB loan is the share of Riksbank loans to total liabilities.

Table 12 shows how Riksbank loans correlate with different types of bank outcomes before and after April 1907 (the last pre-crisis month as defined in Grodecka-Messi et al., 2021). The main variable of interest is the lagged ratio of Riksbank loans to assets. We do not find evidence of increased bank risk-taking and sequential worse performance in crisis times due to preferential Riksbank support. We show, however, that Riksbank liquidity in crisis times supported banks' lending, in particular against property collateral.

4.7 The effect of 1907 Financial Crisis

As noted in the previous subsection, the final years of our sample coincide with the 1907 financial crisis. Although all our regressions include time fixed effects, in this subsection we aim to assess whether our main findings are driven primarily by observations from the crisis period.

To examine this, we conduct an additional analysis by augmenting our benchmark 1903 specification with an interaction term testing whether treated banks were differentially affected by the crisis. The $Crisis_t$ is a dummy variable that takes the value of 1 between the dates May 1907-December 1909 (following the narratives in Grodecka-Messi et al., 2021) and 0 otherwise. The regression takes the form:

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \phi \text{Treat}_i \times \text{Crisis}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t}. \tag{10}$$

The results are presented in Table 13. We can see that the coefficients on the interac-

Table 12: Bank outcomes and the Riksbank liquidity support

	(1)	(2)	(3)	(4)	(5)	(6)
	ROC	NPA	LtoA	Prop.%	Share%	Prop. Int.Rate
	Before May 1907					
RB Loan_{t-1}	0.029	-0.022	0.019	0.129	0.086	-1.170
	(0.084)	(0.019)	(0.235)	(0.179)	(0.132)	(0.797)
adj. R^2	0.384	0.324	0.783	0.741	0.769	0.832
N	721	9804	9804	9804	9804	9803
Add. Controls	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK	BANK	BANK
	After May 1907					
RB Loan_{t-1}	-0.002	0.112	2.023**	1.660***	-0.291	1.375
	(0.323)	(0.146)	(0.862)	(0.494)	(0.657)	(2.680)
adj. R^2	0.648	0.432	0.847	0.935	0.810	0.792
N	383	4518	4518	4518	4518	4516
Add. Controls	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK	BANK	BANK

Note: This table reports the role of the Riksbank preferential liquidity support on bank outcome variables using the regression

$$y_{i,t} = \alpha + \beta X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are banks' Return on Capital (ROC), Non-Performing Loan to Asset Ratio (NPA), Lending to Asset ratio (LtoA), Property Lending Ratio (Prop.%), Share Lending Ratio (Share%), and Property Interest Rate between January 1894 and December 1911. We check the regression results with yearly and monthly frequency of the variable depending on the availability. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, and non-performing loans ratio. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

Table 13: The role of 1907 crisis for the results

	(1)	(2)	(3)	(4)
	ROC	Lending-to-Asset	Prop. L. Ratio	Prop. L. Int.Rate
Treat x After	-0.022***	-0.012	-0.015	0.144***
	(0.008)	(0.031)	(0.025)	(0.049)
Treat x Crisis	-0.009	0.001	-0.002	0.032
	(0.006)	(0.009)	(0.006)	(0.026)
Lagged RB Loan	0.187**	0.462*	0.615***	-1.714**
	(0.082)	(0.262)	(0.147)	(0.685)
adj. R^2	0.429	0.711	0.730	0.880
N	1099	14321	14321	14318
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: We test the effect of the 1907 financial crisis on the results using the regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \phi \text{Treat}_i \times \text{Crisis}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The $Crisis_t$ is a dummy variable that takes the value of 1 between the dates May 1907-December 1909. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, and non-performing loans ratio. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

tion term with the crisis variable are not significant, which indicates that treated banks were not differently affected by the crisis. Our main results with the 1903 treatment date remain unchanged.

5 Robustness checks

In the previous sections, we use different regression specifications to illustrate the effects of losing note issuance rights on the profitability and business activities of Swedish commercial banks. The legal changes around the Riksbank banknote monopoly provide an interesting setting with multiple policies potentially affecting the treated banks. To check the robustness of our results, we re-run our benchmark regression with restricted samples and subsamples and we run a number of regressions with multiple interaction terms, as well as multiple treatment dates.

5.1 Subsamples with bank selection, matching, and different periods

Our sample covers a long time period between 1894 and 1911, so there are new banks entering the sample over time. In order to prevent that the entries from new banks affect the

estimation results, we do two separate exercises, restricting our sample to banks that existed in January 1894, and in January 1897.

The regression specification follows

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

as in the Section 4.3. The results are reported in the Appendix D.

The results with the sample from January 1894 and January 1897 appear to be consistent with the main findings in the regression 4. Banks that lost the note issuance rights experienced lower returns (ROC) than their untreated counterparts, and their lending activities remained unaffected.

One potential concern is that not all banks in the defined control group are proper controls for former note-issuing banks. For instance, they do not satisfy the parallel-trends assumption or the findings are biased due to inadequately chosen entities in the control group. To gauge and mitigate this concern, we use propensity score matching to ensure that we compare the profitability and lending of treated banks with the control group banks that are similar in size (logarithm of total assets) and have similar equity ratios. Our main empirical findings hold in the matched sample.[21]

5.2 Interacted control variables

We further expand our baseline DiD regression to include the interaction terms of our control variables and the indicator of the after treatment periods After_t, so we can cleanly identify the effects of the policy changes isolated from other changes in banks' activities:

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} \times \text{After}_t + \eta \text{RB Loan}_{i,t-j} \times \text{After}_t + \delta_i + \eta_t + \epsilon_{i,t}. \quad (11)$$

Table 14 presents the regression results for our outcome variables of interest. Once control variables are interacted with the After treatment (1903) dummy, the negative result for ROC is still significant, and the return ratios are positively correlated with lending from the Riksbank for the 1903 treatment date. We confirm that Riksbank loans mitigated treated banks' decline in profitability and were associated with a shift towards lending against property collateral.

5.3 The role of the liability status of shareholders

Lastly, we consider the role of the liability status of shareholders for the results. Treated banks in our sample all had the ULB status at the passage of 1897 law. However, some of them converted to LLB, maintaining their right to preferential liquidity support. We test whether the liability regime under which shareholders operated mattered for banks' reaction to the ban on banknote issuance. We do not find a differential effect on bank-risk taking for ULB banks that changed their liability status. Neither the liability status itself (for which we control in all

[21] Results from this robustness check are available upon request.

Table 14: Effects on banks' outcomes with expanded interactions

	(1)	(2)	(3)	(4)
		Lending-	Prop.L.	Property
	ROC	to-Asset	Ratio	Int.Rate
Treat x After	-0.030***	-0.034	-0.082	0.109
	(0.010)	(0.082)	(0.073)	(0.072)
Lagged RB Loan	-0.209	0.156	-0.007	-1.219
	(0.145)	(0.290)	(0.191)	(1.069)
Lagged RB Loan x After	0.520***	0.616	1.001**	-0.864
	(0.182)	(0.538)	(0.386)	(1.274)
adj. R^2	0.433	0.711	0.748	0.880
N	1104	14323	14323	14320
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: We test the effect of banks' losing notes issuance rights on banks outcomes using the regression

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} \times \text{After}_t + \eta \text{RB Loan}_{i,t-j} \times \text{After}_t + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. We further expand the interaction to include the interaction between control variables and the after treatment dummy After, to capture any structural difference in the control variables. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loan ratio, and the lagged Riksbank loan. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

of our regressions), or its interaction with variables turn out to be important for our analysis. We leave out these non-significant results from the paper.

6 Conclusion

This paper presents the first empirical evidence on the role of central bank liquidity in shaping private banks' profitability and lending behaviour during the transition from a private to a public monetary system. We exploit the Swedish central bank's currency monopoly that was implemented in 1903 (and fully effective by the end of 1906) as a quasi-natural experiment that allows us to examine the effects of the end of currency competition on private banks in the presence of central bank transfers. Using monthly data on banks' balance sheets and interest rates, coupled with annual data from banks' return statements from 1894 to 1911, we investigate key issues related to bank credit, financial intermediation, financial stability, and currency competition. We find that liquidity support from the Riksbank to former note-issuing banks plays a crucial role in understanding their performance relative to unaffected peers. Only once this preferential support starts being withdrawn do private banks experience a significant decline in profitability. At the aggregate level, however, we find no evidence of bank

disintermediation. Overall, our findings underscore the effectiveness of central bank liquidity support during periods of structural transition.

The historical episode studied provides new insights into the role of central bank liquidity and associated moral hazard concerns. In 1907, an exogenous funding shock struck the Swedish banking sector, triggering a widespread banking crisis. We demonstrate that the Riksbank's liquidity support program did not increase financial stability risks. Instead, it may have encouraged banks to expand lending secured by property collateral while reducing exposure to riskier types of loans.

The rich cross-sectional and time-series data on Swedish banks enable us to draw important lessons for the modern banking system. Our study serves as an empirical test of the emerging literature on central bank liquidity support in the context of CBDC, see Brunnermeier and Niepelt (2019) and Chen and Filippin (2025). The historical setting around the establishment of central bank note monopoly offers a promising opportunity to examine the effects of lender-of-last-resort policies on financial stability. We leave more detailed investigations related to these policies for future research.

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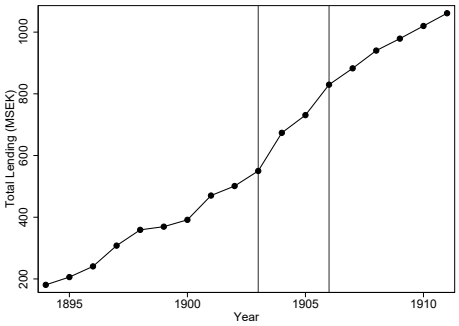
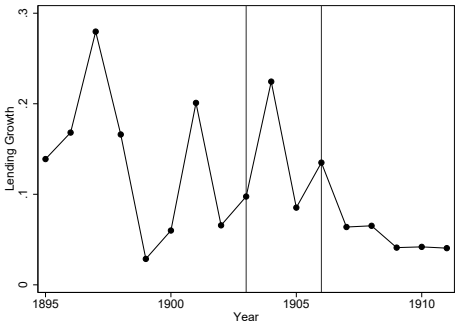
A Appendix: additional figures

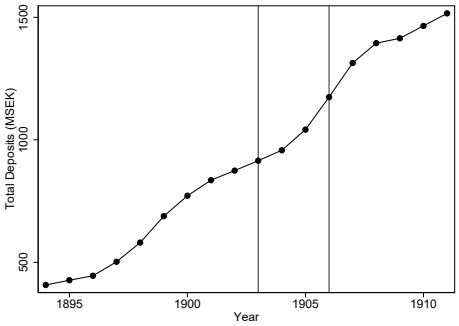
A.1 Aggregate trends in the banking sector



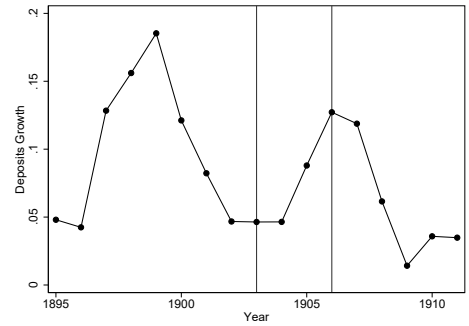
(a) Total lending



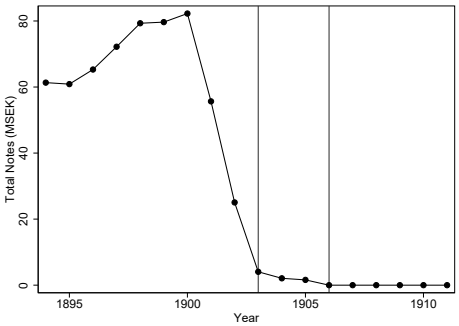
(b) Lending growth rate



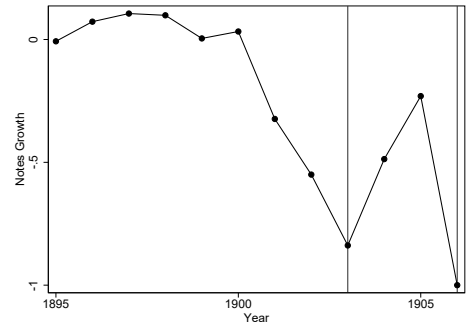
(c) Total deposits



(d) Deposit growth rate



(e) Total notes



(f) Notes growth rate

Figure A.1: Bank lending, deposits and notes (total, growth rate) over the period 1894-1911

B Appendix: other potential treatment dates

Table B1: Effects on banks' outcomes: other dates

	(1) ROC	(2) Lending-to-Asset	(3) Prop. L. Ratio	(4) Prop. L. Int.Rate
	Panel A: 1897 treatment date			
Treat x After	-0.005	0.010	0.012	-0.005
	(0.014)	(0.022)	(0.018)	(0.077)
Lagged RB Loan	0.118	0.469*	0.617***	-1.887**
	(0.075)	(0.273)	(0.146)	(0.721)
adj. R^2	0.425	0.711	0.736	0.879
	Panel B: 1899 treatment date			
Treat x After	-0.019	0.014	0.013	0.014
	(0.014)	(0.022)	(0.018)	(0.077)
Lagged RB Loan	0.115	0.470*	0.615***	-1.875***
	(0.074)	(0.273)	(0.148)	(0.715)
adj. R^2	0.428	0.711	0.736	0.879
N	1099	14321	14321	14318
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: This table reports the effect of losing note issuance rights on bank outcome variables using the DiD regression, but with two other potential policy change dates (Panel A for 1897, Panel B for 1899)

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

C Timing of compliance with law: Which banks gave up their note issuance first?

Timing of compliance with law Swedish note-issuing banks complied with law at different times. Table C1 provides the average value of selected variables for different vintages of compilers in May 1897, at the passage of the banking law, and in May 1901, at the update of the law. When it comes to the compliance with the end of note issuance, we see that the early complier (1899) had the lowest note to liability ratio (NtoLiab) in May 1897, even though it executed its note issuance rights to the highest extent. It was a relatively big bank with not too extensive lending and comparatively low share of non-performing assets. It had a ROA higher than the remaining banks. The banks that decided last to stop the issuance of new notes stand out as using most rights to issue notes in 1901 (even though their notes to liabilities were the lowest), having lowest equity ratio (ER), highest lending ratio (LtoA) and highest non-performing (NPA) loan share as of May 1897. At the same time, they were achieving relatively high ROE in 1897. When we look at different vintages of banks that completely withdrew their notes from circulation, the picture becomes less clear and only the relatively highest share of non-performing assets in 1897 stands out for late compliers as of May 1897. When looking at comparable numbers for May 1901, we focus on compliers from 1901 on. We see that the banks that were last to resign from their right to issue notes were most dependent on note issuance, they had the highest lending ratio and most non-performing assets as of May 1901. At the same time, their ROE and ROA in 1901 were relatively low. Once we look at the banks who withdraw their notes from circulation last, we see that their ROE and ROA were actually among the highest, while their non-performing loans were not high. Thus, the link between different observables and the time of compliance is not clear and we test it's robustness running a simple regression analysis.

We run a predictive regression on the year of compliance:

$$y_{i,t} = \alpha + \beta \text{Treatment Intensity}_{i,t-1} + \gamma X_{i,t-1} + \epsilon_{i,t}, \tag{12}$$

where $y_{i,t}$ refers either to the difference of bank i's compliance year for the end of issuance right or withdrawal of outstanding notes, in comparison with the earliest compliance year. Controls include the extent of usage of note issuance right in 1896 and 1901 and the notes to liabilities ratio. The other control variables $X_{i,t-1}$ include lagged equity ratio, log of total assets, and lending to assets. In the regression, we take into account all our data until May 1901. We cannot include bank fixed effects because they would be co-linear with the treatment date. We cluster our results at the bank level. The regression results are presented in Table C2.

The first three columns present results for the banks' stop in private bank note issuance, and the columns (4) – (6) for the compliance by withdrawal of outstanding bank notes. Columns (1) and (4) present the results linked to bank i's reliance on issuing notes, measured as the fraction of note issuance to the legal maximum rights in 1896, and columns (2) and (5) to a similar definition but computed with the statistics in 1901. Columns (3) and (6) show results

Table C1: Summary statistics of compliant banks by compliance year in May 1897 and May 1901

	TI_{1896}	TI_{1901}	NtoLiab	ER	Log(TA)	LtoA	NPA	ROE	ROA
	Bank data for May 1897: the passage of the law								
	End of Note Issuance								
1899	78,92%	0,00%	11,28%	18,70%	17,26	29,09%	0,09%	8,25%	1,79%
1901	74,99%	73,04%	14,03%	19,18%	16,69	31,00%	0,12%	9,11%	1,46%
1902	63,18%	73,58%	12,61%	17,88%	16,40	26,83%	0,25%	8,12%	1,51%
1903	72,82%	84,64%	12,52%	16,66%	16,95	34,56%	0,37%	9,19%	1,53%
	Withdrawal of Outstanding Loans								
1899	78,92%	0,00%	11,28%	18,70%	17,26	29,09%	0,09%	8,25%	1,79%
1901	80,93%	42,38%	16,23%	20,76%	17,21	23,61%	0,20%	12,46%	1,53%
1903	73,80%	81,49%	12,48%	22,16%	16,80	31,47%	0,09%	9,82%	1,72%
1905	76,41%	73,30%	14,64%	18,18%	15,81	29,17%	0,24%	6,50%	1,21%
1906	66,40%	77,11%	12,72%	17,15%	16,62	29,84%	0,27%	8,48%	1,49%
	Bank data for May 1901: the update of the law								
	End of Note Issuance								
1899	78,92%	0,00%	0,00%	32,47%	17,83072	25,00%	0,18%	5,31%	1,76%
1901	74,99%	73,04%	10,48%	15,56%	17,21408	29,82%	0,27%	7,80%	1,33%
1902	63,18%	73,58%	10,29%	16,05%	16,81052	28,09%	0,31%	7,80%	1,31%
1903	72,82%	84,64%	10,73%	15,94%	17,33567	31,52%	0,33%	6,01%	0,93%
	Withdrawal of Outstanding Loans								
1899				32,47%	17,83072	25,00%	0,18%	5,31%	1,76%
1901	80,93%	42,38%	7,53%	21,35%	17,96242	27,23%	0,19%	8,01%	1,78%
1903	73,80%	81,49%	10,02%	15,06%	17,35723	32,27%	0,38%	7,25%	1,22%
1905	76,41%	73,30%	13,15%	17,88%	16,24553	29,19%	0,51%	8,00%	1,34%
1906	66,40%	77,11%	10,38%	15,55%	17,02621	29,03%	0,28%	7,32%	1,19%
1906	66,40%	77,11%	12,72%	17,15%	16,62	29,84%	0,27%	8,48%	1,49%

Note: The data are collected from "Summary of the Banks' Activities, 1894M1-1911M12" (*Sammandrag af Bankernas Uppgifter*).The table provides the average value of selected variables for different vintages of compilers in May 1897, at the passage of the banking law, and in May 1901, at the update of the law. The variables include Treatment Intensity (TI), Note to liability ratio (NtoLiab), Equity Ratio (ER), logarithm of Total Assets (Log(TA)), Lending to Asset ratio (LtoA), Non-performing Loan ratio (NPA), Return on Equity (ROE) and Return on Assets (ROA).

Table C2: Determinants of earlier compliance of banks

	(1)	(2)	(3)	(4)	(5)	(6)
	compliance^{issue}			compliance^{circ}		
Treatment Intensity$_{1896}$	-17.248			-51.417*		
	(13.154)			(26.317)		
Treatment Intensity$_{1901}$		15.768			31.056	
		(12.751)			(36.896)	
Notes to Liability			15.727			91.666
			(74.543)			(140.575)
N	2349	2349	2349	2349	2349	2349
adj. R^2	0.047	0.043	0.022	0.148	0.110	0.098
Add. Controls	YES	YES	YES	YES	YES	YES
Bank FE	NO	NO	NO	NO	NO	NO
Time FE	YES	YES	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK	BANK	BANK

Note: This table reports the regression to check the determinants of banks' early compliance with the law. Columns (1)–(3) examine the decision to stop issuing notes earlier than the deadline, while columns (4)–(6) examine the decision to withdraw notes in circulation earlier than the final deadline. We run the regression on the year of compliance:

$$y_{i,t} = \alpha + \beta \text{Treatment Intensity}_{i,t-1} + \gamma X_{i,t-1} + \epsilon_{i,t},$$

where $y_{i,t}$ refers either to the difference of bank i's compliance year for the end of issuance right or withdrawal of outstanding notes, in comparison with the earliest compliance year. Only time fixed effects η_t can be included in the regression. The control variables include the extent of usage of note issuance right in 1896 and 1901, notes to liabilities ratio. The other control variables are lagged equity ratio, log of total assets, and lending to assets. In the regression, we take into account all our data until May 1901. Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

for the notes to total liability ratio, which can be viewed as another key measure of how much a bank relied on the note issuance. First of all, lower usage of note issuing rights as of 1896 was associated with later compliance. However, when we look at the usage of note issuing rights as of 1901, the opposite is true but with statistically insignificant results. Other considered variables do not seem to be consistently significant, so on the basis of the data, it would be very hard to predict which bank would comply when. We also run an ordered probit model to predict the ordering of compliance for each banks. The results are very similar.

To sum up, the predictive regression exercise suggests that the banks' decision to comply with the law cannot be predicted with the treatment intensity of the bank or other relevant bank characteristics.

D Appendix: robustness checks with different sub-samples

Table D1: Effects on banks' outcomes: the 1894 sample

	(1) ROC	(2) Lending-to-Asset	(3) Prop. L. Ratio	(4) Prop. L. Int.Rate
	Panel A: 1903 treatment date			
Treat x After	-0.022**	-0.041	-0.034	0.138**
	(0.010)	(0.058)	(0.052)	(0.057)
Lagged RB Loan	0.149	0.121	0.329**	-1.607**
	(0.101)	(0.262)	(0.150)	(0.777)
adj. R^2	0.315	0.630	0.658	0.878
	Panel B: 1906 treatment date			
Treat x After	-0.026***	-0.041	-0.032	0.127**
	(0.009)	(0.049)	(0.041)	(0.061)
Lagged RB Loan	-0.010	-0.140	0.127	-0.796
	(0.089)	(0.326)	(0.258)	(0.827)
adj. R^2	0.318	0.630	0.657	0.878
N	655	8453	8453	8442
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: The robustness check results are shown here using the sample of banks that existed in January 1894. This table reports the effect of losing note issuance rights on bank outcome variables using the DiD regression. Panel A shows the results for the 1903 treatment date, and Panel B shows the results for the 1906 treatment date.

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

Table D2: Effects on banks' outcomes: the 1897 sample

	(1) ROC	(2) Lending-to-Asset	(3) Prop. L. Ratio	(4) Prop. L. Int.Rate
	Panel A: 1903 treatment date			
Treat x After	-0.022**	-0.018	-0.025	0.144**
	(0.008)	(0.041)	(0.035)	(0.051)
Lagged RB Loan	0.154*	0.115	0.329***	-2.057***
	(0.089)	(0.224)	(0.128)	(0.763)
adj. R^2	0.362	0.641	0.679	0.877
	Panel B: 1906 treatment date			
Treat x After	-0.023***	-0.016	-0.028	0.147**
	(0.007)	(0.037)	(0.029)	(0.056)
Lagged RB Loan	-0.031	-0.006	0.176	-0.909
	(0.081)	(0.264)	(0.208)	(0.773)
adj. R^2	0.362	0.641	0.679	0.877
N	791	10158	10158	10147
Add. Controls	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Std. Err.	BANK	BANK	BANK	BANK

Note: The robustness check results are shown here using the sample of banks that existed in January 1897. This table reports the effect of losing note issuance rights on bank outcome variables using the DiD regression. Panel A shows the results for the 1903 treatment date, and Panel B shows the results for the 1906 treatment date.

$$y_{i,t} = \alpha + \beta \text{Treat}_i \times \text{After}_t + \gamma X_{i,t} + \eta \text{RB Loan}_{i,t-j} + \delta_i + \eta_t + \epsilon_{i,t},$$

where the bank fixed effects δ_i and time fixed effects η_t are included in the regression. The dependent variables are Return to Capital (ROC), Lending-to-Asset ratio, Property Loan to Total Assets ratio, and the Property Lending Interest Rate between January 1894 and December 1911. The profit variable (ROC) is at yearly frequency and the others at monthly frequency. The bank-level control variables $X_{i,t}$ include the logarithm of total asset, the dummy variable of unlimited liability banks, the cash ratio, the lending ratio, equity ratio, non-performing loans ratio, and the ratio of the Riksbank loans to total bank liabilities (RB Loan). Standard errors clustered at the bank-level are in parentheses. *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

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Sveriges Riksbank
Visiting address: Brunkebergs torg 11
Mail address: se-103 37 Stockholm

Website: www.riksbank.se
Telephone: +46 8 787 00 00, Fax: +46 8 21 05 31
E-mail: registratorn@riksbank.se