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Nils Herger

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Unregulated and regulated free banking. The case of Switzerland reinterpreted*

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Abstract

The free-banking history of Switzerland is commonly subdivided into a period with unfettered competition (1826 - 1881) and strong banknote regulation (1881 - 1907). This paper suggests that unrestricted competition between private note-issuing banks gave rise to a fragmented paper-money system, which suffered from a lack of standardised, and commonly accepted, banknotes. Minimum-reserve requirements and mutual-acceptance rules were introduced to standardise banknotes. Rather than overissuing, these regulatory interventions restricted the flexibility (or "elasticity") of the paper-money supply. It turned out that a central note-issuing bank was needed to supply adequate amounts of standardised banknotes.

JEL classification: E42; N14; N23

Keywords: central bank; free banking; note-issuing bank; Switzerland.

1 Introduction

Free banking refers to a money system, in which paper money is issued in a competitive manner by private note-issuing banks, rather than through a government monopoly with a central bank. Pure free-banking systems are even characterised by the absence of regulation, and other forms of government interference, as regards the quantity and quality of private banknotes (see Selgin and White, 1994, pp.1718-1719).

The debate on whether banks should be allowed to issue their own banknotes took mainly place during the nineteenth century. Thereby, together with the United States (see Rolnick and Weber, 1984.) and Scotland (White, 1984), Switzerland provided an important example of a country, where paper money was issued in a competitive manner (Weber, 1988; Neldner, 2003). However, the free-banking debate resonates until today, because competition of privately created money has shifted to demand deposits since the nineteenth century, and has recently received an impetus from the development of cryptic currencies (see e.g. Fernandez-Villaverde and Sanches, 2016). Furthermore, when the reputation of central banks has been damaged by high levels of inflation, as during the 1970s, private competition is on occasion advocated as a remedy for instable money (see e.g. Klein, 1974; Hayek, 1978).

Switzerland's free-banking history is particularly important, because it can be subdivided into a period with more or less unfettered competition between 1826 and 1881, and a period with strongly regulated competition between 1881 and 1907 (Baltensperger and Kugler, 2017, ch.8; Paillard, 1909, pp.189ff.). According to the current assessment, the corresponding economic experiences differed markedly. In particular, Weber (1988) suggests that the more or less unregulated regime was a success story, as it gave rise to a stable paper-money system

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with virtually no defaults of note-issuing banks. Conversely, according to Neldner (2003), the regime after 1881 was doomed to failure, because banknote regulation undermined the self-discipline against overissuing, which led to a depreciation of the Swiss franc and, in turn, paved the way to the establishment of a banknote monopoly under the auspices of the Swiss National Bank (SNB).

This paper provides a reinterpretation of the Swiss experiences with free banking. In particular, despite the self-discipline before 1881, it should not be overlooked that unfettered competition can keep the monetary system fragmented, or disintegrated (Friedman and Schwarz, 1986). When e.g. multiple banknotes of different quality circulate alongside each other, transaction and inspection costs are relatively high, which undermines the functions of paper money as broadly accepted means of payment and commonly recognised unit of account (see also Baltensperger, 2012, p.279). Against this background, it is not surprising that Switzerland lagged behind in the development of paper money, when compared with other industrialised countries (see e.g. Ritzmann, 1974, pp.37ff.). The lack of integration in the paper-money market can be overcome through government intervention turning banknotes into a homogenous product and a commonly accepted means of payment. This does not per se warrant a central note-issuing bank, but can also be achieved through regulatory interventions. In particular, minimum-reserve requirements and rules obliging banks to convert, on demand, all banknotes at par value ensured that they were as good as monetary metal. Furthermore, even though paper-money systems with a homogenous pool of banknotes are prone to overissuing (see Klein, 1974, pp.432ff.), this problem can, in principle, be regulated away, e.g. by imposing quotas (Ritzmann, 1996, p.200). Upon a close inspection of the amount of banknotes in circulation as well as associated data, such as the development of inflation, interest rates, and exchange rates, it is indeed unclear whether paper money in Switzerland was overissued after 1881. It is also noteworthy that contemporaneous observers, such as Kalkmann (1900), Gygax (1901), Paillard (1909), or Jöhr (1915), did not lament the overissuing, but rather the lack of a sufficiently flexible—or what was then called "elastic"—supply of banknotes. The banknote regulation of 1881 was indeed followed by a marked reduction in the "elasticity" of the paper-money supply. Concretely, this meant that e.g. seasonal fluctuations in money demand were only partially accommodated by changes in supply. Although a flexible provision of money posed a challenge to all former metallic currency systems, the Swiss free-banking system with strong regulation after 1881 suffered probably from aggravated levels of "inelasticity". Historically, it was impossible to solve this problem by retaining the free-banking system. Indeed, a central-note issuing bank with the mandate to provide homogenous banknotes in a flexible manner was finally founded in 1907.

By developing a more nuanced historical account of the Swiss free-banking system, this paper touches on the broader issue that monetary systems can suffer from entrenched trade-offs between providing homogenous forms of money, preserving competition in the money market, and supplying adequate amounts of money (e.g. elastic supply/no overissuing). For the case of free banking, the paper illustrates the corresponding trade-offs by a theoretical model, where banks face a liquidity-management problem when issuing banknotes against interest-bearing assets and liquid reserves.

The paper is organised around the regulated and unregulated periods of free banking. In particular, Section 2 looks at the historical and theoretical implications of the unregulated regime between 1826 and 1881. Section 3 turns to the corresponding aspects of the regulated regime between 1881 and 1907. Section 4 briefly discusses the role of central note issuing and the historical path towards the foundation of the SNB in 1907. Finally, Section 5 draws some general conclusions from Switzerland's experiences with unregulated and regulated free banking.

2 Unregulated free banking in Switzerland between 1826 and 1881

2.1 Historical background: Unfettered competition and the creation of the Swiss Franc

This section discusses free banking in Switzerland between 1826 and 1881. In contrast to the establishment of officially supported central banks in neighbouring France (in 1800), Austria-Hungary (in 1816), Germany (in 1876), and Italy (in 1893), in Switzerland it was not until the foundation of the Swiss National Bank (SNB) in 1907 when dozens of private note-issuing banks lost the right to issue paper money (see e.g. Jöhr, 1915). This did not mean that they could supply arbitrary amounts of paper money, because banknotes represented promises to pay, on demand, a specific amount of currency; at the time monetary metal in the form of bullion or coins. However, until the middle of the nineteenth century, Swiss banks were even free to choose the currency into which their notes can be converted (see Baltensperger and Kugler, 2017, pp.134-135). Owing to the lack of a national currency as well as the low quality of cantonal monetary systems, early Swiss banknotes were typically denominated in foreign units, such as French francs and South German gulden (Weber, 1988, p.400).

Until the foundation of the modern Swiss Confederation in 1848, currency and money fell into the jurisdiction of the cantons (e.g. provinces) (Jöhr, 1915, pp.15ff.). However, inspired by classical liberal ideas that gained popularity and had already reformed long-established governments by the aristocracy and the guilds in economically advanced cantons such as Bern, Geneva, and Zurich, the Swiss constitution of 1848 called for an integration of the currency system, but preserved the freedom of enterprise in banking (see e.g. Baltensperger, 2012, pp.79ff.). During the subsequent decades, it became clear that this combination encapsulates policy conflicts, which dominated the monetary debate until the foundation of the SNB. Concretely, in 1850, the Swiss Franc was introduced as national currency unit, which was modeled after the bimetallic system of France, where one franc was officially worth 4.5 grammes of silver or 0.29 grammes of gold, implying an official silver-to-gold exchange rate of 15.5 to 1 (see Baltensperger and Kugler, 2017, p.27; Paillard, 1909, p.9).[1] In 1865, this monetary integration was deepened when Switzerland joined the "Latin Monetary Union", which constituted a multilateral agreement with Belgium, France, and Italy (later also Greece joined) to align their currency systems through the mutual acceptance of coins, which were subject to internationally agreed silver-to-gold mint-pars of 15.5 to 1 (Baltensperger and Kugler, 2017, pp.26-29; Paillard, 1909, pp.21ff.). Because e.g. Belgian, French, and Swiss franc coins were essentially equivalent, the official exchange rate between the corresponding currencies stood at one-to-one. The international monetary cooperation of Switzerland went even so far that most Swiss-franc coins were minted in France (Baltensperger, 2012, p.82). In contrast to the standardisation in coinage, the Swiss paper-money system remained highly fragmented. Although the introduction of a national currency abolished competition as regards denomination, in the sense that banknotes convertible into Swiss francs became the norm, the cantons retained the responsibility for banking supervision and licensing. Reflecting a widespread laisser-faire attitude, by and large unfettered competition in note-issuing continued until the 1880s (see Baltensperger and Kugler, 2017, pp.135ff.).

The first phase of more or less unregulated free banking in Switzerland was characterised by an underdeveloped and fragmented paper-money system. Banknotes of different quality circulated mainly locally, and represented a store of value, rather than a broadly accepted means of payment (Paillard, 1909, p.190; Jöhr; 1915, pp.80ff.). Figure 1 provides an overview

[1] Initially, the Swiss Franc was a pure silver currency (Baltensperger, 2012, pp.82-83). However, the decline in the market price for gold relative to silver during the 1850s set Gresham's law in motion meaning that officially undervalued gold coins flooded into circulation in France and, hence, also Switzerland (Paillard, 1909, pp.10ff.). In 1860, the Swiss franc became officially a bimetallic currency (Paillard, 1909, p.20).

of the development of paper money in Switzerland between 1826 and 1913. During the early years of this period, despite the rapid industrialisation and integration of the Swiss economy, there was virtually no growth in the amount of banknotes in circulation after they were first issued in 1826. It was not until the 1870s, when a marked increase in the popularity of paper money occurred. A major cause for this increase was the Franco-Prussian war between 1870 and 1871, which isolated Switzerland from the French money market and the currency reserves of the Banque de France. The result was a short, but quite severe, liquidity crisis (Baltensperger, 2012, pp.86-87). The political and economic risks of a monetary system relying on foreign coinage became clear and provided a point of departure for subsequent reforms towards central note issuing (Ritzmann, 1974, pp.92-93). Furthermore, the aftermath of the Franco-Prussian war witnessed the advent of the classical gold standard as international monetary system (Eichengreen, 2008, pp.15ff.). From the mid 1870s onwards, the corresponding demonetisation of silver was associated with an ongoing decrease of the silver price. For a bimetallic currency, such as the Swiss franc, this activated Gresham's law, with the relatively cheaper silver coins—according to the mint-par—flooding into circulation. However, as silver coins are heavy compared with their value, they were a cumbersome, and hence an unpopular, money for settling large transactions. These problems fostered the popularity of banknotes, which provided an obvious substitute for heavy coins (Paillard, 1909, p.191; Gygax, 1901, pp.379-380; Ritzmann, 1974, p.42).

2.2 A theoretical model of unregulated free banking

This section provides a theoretical framework for an unregulated free-banking system. The corresponding model draws heavily on Miron (1986). In particular, contemplate m note-issuing banks indexed by subscript $j = 1, \ldots, m$ that issue banknotes N^s_{jt} at time t against holding assets either in the form of metallic reserves R_{jt} or bonds B^s_{jt}, which pay an interest rate of i_{jt}. During the nineteenth century, bills of exchange, which were accepted by a given bank at the so-called discount rate, were the leading fixed-income financial instrument.[2] Taken together, the balance-sheet restriction is given by

$$R_{jt} + B^s_{jt} = N^s_{jt}. \tag{1}$$

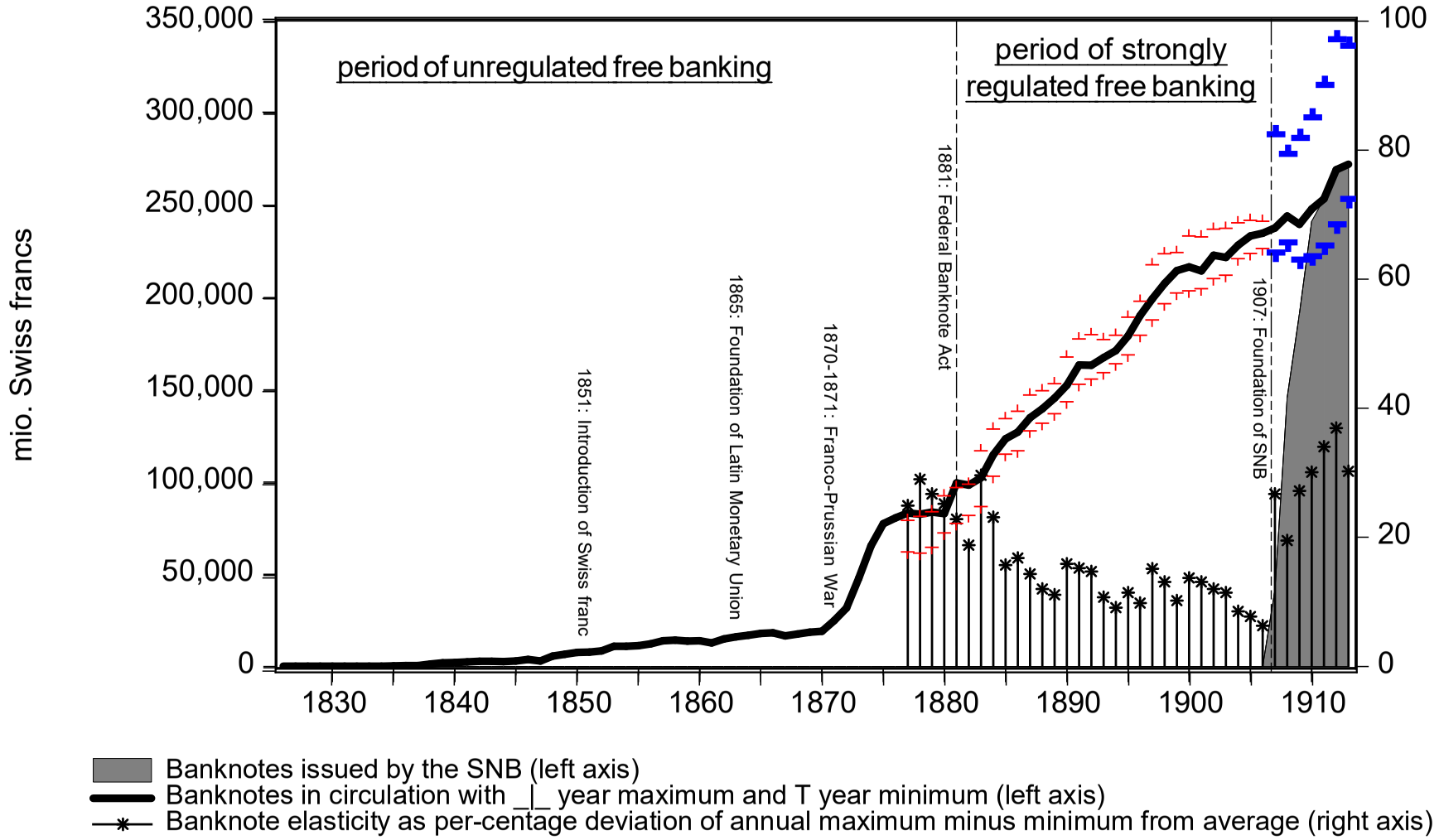
Banknotes are claims on reserves. Note-issuing banks are confronted with a liquidity management problem, as they must hold liquid reserves to cover banknote conversions, whose development is uncertain, but would like to maximise profits by investing in interest-bearing assets.

2.2.1 Seasonal demand for banknotes

To capture the demand for banknotes, assume that each note-issuing bank is matched with a representative household with income Y_{jt}. Income fluctuates across time t due to e.g. seasonal cycles in economic activity. However, income can either be held in the form of metallic currency C_{jt} (e.g. gold or silver coin), with proportional storage cost equal to γ, or banknotes N^d_{jt} issued by note-issuing bank j. Metallic currency is a universally accepted means of payment (or perfectly liquid). Conversely, depending on their quality, banknotes are only accepted as a means of payment with a certain probability $\alpha_j \in [\gamma, 1]$. Hence, there is a trade-off between the cost of storing value in the form of coins and the illiquidity of paper money. In particular, conditional on whether banknotes are accepted to make purchases, and given that $C_{jt} = Y_{jt} - N^d_{jt}$, household consumption c_{jt} is constrained by

[2] According to Article 1 of the British Bills of Exchange Act of 1882, a bill of exchange was "an unconditional order in writing, addressed by one person to another, signed by the person giving it, requiring the person [...] to pay on demand or at a fixed or determinable future time a sum certain in money to or to the order of a specified person, or to bearer." Hence, bills of exchange were transferable financial instruments, which could be sold to a third party, typically a bank, which purchased a bill at a discount in anticipation of receiving the final payment. The interest rate charged for this transaction was the discount rate (see Herger, 2018, p.3).

Figure 1: Banknotes in Switzerland (1826-1913)



Data source: Joehr (1915, pp.496;497;500).

$$c_{jt} = \begin{cases} (1-\gamma)(Y_{jt} - N^d_{jt}) & \text{with probability} \quad 1-\alpha_j \\ (1-\gamma)(Y_{jt} - N^d_{jt}) + N^d_{jt} & \text{with probability} \quad \alpha_j. \end{cases}$$

Assuming a logarithmic expected utility function of $U(c_{jt}) = [1-\alpha_j]\ln[(1-\gamma)(Y_{jt} - N^d_{jt})] + \alpha_j \ln[(1-\gamma)(Y_{jt} - N^d_{jt}) + N^d_{jt}]$, and maximising this expression with respect N^d_{jt} yields a demand function for banknotes given by

$$N^d_{jt} = \frac{\alpha_j - \gamma}{1-\gamma} Y_{jt} = \Lambda_j Y_{jt} \qquad \text{with} \quad 0 < \gamma \leq \alpha_j \leq 1. \tag{2}$$

Banknote demand is a function of income Y_{jt}. Furthermore, the parameter $\Lambda_j = (\alpha_j - \gamma)/(1-\gamma)$ summarises the liquidity of notes issued by bank j. This liquidity depends on the degree to which specific banknotes are a broadly accepted means of payment, as well as the costs of holding metallic currency as an alternative means of payment. In particular, when the notes of bank j are universally accepted, e.g. $\alpha_j = 1$, they are perfectly liquid, e.g. $\Lambda_j = 1$, and all income is held in paper money. However, if banknotes are not universally accepted, e.g. $\alpha_j < 1$, they are imperfectly liquidity, e.g. $0 < \Lambda_j < 1$, which lowers their demand. Conversely, high storage cost γ for metallic currency make paper money more attractive. Of note, as in Miron (1988, p.127), the demand for paper money in (2) does not depend on nominal interest rates.[3] As discussed in more detail in Section 3, the theory of the demand for banknotes matters, because the corresponding regulation was mainly introduced to increase their popularity.

2.2.2 Discount market and bills of exchange

Because the focus of this paper lies on the interrelationships between banknotes and liquid reserves in a free-banking system, the demand for interest-bearing bonds B^d_{jt} is here simply assumed to be fixed at a value of one, that is

$$B^d_{jt} = 1. \tag{3}$$

This assumption greatly simplifies the analysis.[4]

2.2.3 Banknote conversion and liquidity cost

Similar to sight deposits in modern banking, note issuing during the nineteenth century involved liquidity risks from offering promises to pay metallic currency on demand (Miron, 1986, p.126).[5] To analyse these risks, let v_{jt} denote the change in the demand for banknotes of representative household j relative to its banknote holdings of N_{jt}.[6] From the perspective of the note-issuing bank, $v_{jt} < 0$ represents a net-issuing of banknotes, and $v_{jt} > 0$ represents net-conversions, which are more delicate, because they have to be covered by metallic reserves. The total claim on reserves at note-issuing bank j equals

$$W_{jt} = N_{jt} v_{jt}. \tag{4}$$

Conversion risk results from unexpectedly large exchanges of banknotes against reserves. As early as Edgeworth (1888), v_{jt} has been assumed to obey a normal distribution with mean μ_j and variance σ^2_j, which provides a statistical measure for uncertainty. Then, conversion risk at note-issuing bank j equals

[3] This concurs with Gerlach and Kugler (2018, p.4), who find a statistically insignificant effect of interest rates on Swiss money demand during the 1851 to 1906 period.

[4] In Miron (1986, p.127), the demand for interest-bearing assets declines with the interest rate in a linear manner. It is easy to introduce this scenario into the current model. However, doing so does not change the essence of the results.

[5] A discussion on liquidity risks in banking can be found in Baltensperger (1982) and Freixas and Rochet (2008, pp.273ff.). Selgin and White (1994) provide a corresponding discussion for a free-banking system.

[6] See Baltensperger and Milde (1987, p.34) for a similar approach to analysing the withdrawal risks of sight deposits.

$$\phi_{jt}^2 = N_{jt}^2 \sigma_j^2. \tag{5}$$

A voluminous literature on modern banking suggests that the cost of holding reserves depends on factors such as the correlation of withdrawals, the costs of liquidating assets, and the availability of information about withdrawal behaviour (see e.g. Freixas and Rochet, 2008, pp.273ff.). To keep the model simple and to concur with Miron (1986, p.126), the cost of holding reserves depend here directly on "conversion risk" and the reserve ratio $rr_{jt} = R_{jt}/N_{jt} \in [0, 1]$ through a function given by

$$L(\phi_{it}^2, rr_{jt}) = \frac{\phi_{jt}^2}{2}(rr_{jt} - 1)^2. \tag{6}$$

Thus, liquidity cost is higher when banknote conversions are more uncertain, and when the reserve buffer $rr_{jt} = R_{jt}/N_{jt}$ is low. Under full-reserve holdings, e.g. $rr_{jt} = 1$, liquidity cost is zero, as the bank can deal with arbitrarily large banknote conversions. For the further discussion, it will be crucial that

$$\frac{\partial^2 L(\phi_{jt}^2, rr_{jt})}{\partial R_{jt} \partial N_{jt}} = -\sigma_j^2 \leq 0, \tag{7}$$

e.g. (6) encapsulates economies of scope between reserves R_{jt} and banknotes N_{jt}. In other words, a marginal increase in the amount of banknotes reduces the marginal cost of holding reserves (and vice versa). Intuitively, this result arises because it is easier to diversify (uncorrelated) conversion risk in a larger pool of banknotes.

2.2.4 Banknote supply and reserve management: The problem of fragmented paper money

Under unfettered competition, banks supply banknotes N_{jt}^s according to profit-maximising considerations without constraints by government regulation. Specifically, for each note-issuing bank j, the expected profit merely reflects the difference between the revenue from investing in interest-bearing bonds B_{jt}^s, and the liquidity cost $L(\phi_{jt}^2, rr_{jt})$ of (6), that is

$$\pi_{jt}^e(R_{jt}, N_{jt}^s) = i_{jt} B_{jt}^s - \frac{\phi_{jt}^2}{2}(rr_{jt} - 1)^2. \tag{8}$$

The equilibrium values result from the first-order conditions of deriving (8) with respect to R_{jt} and N_{jt}^s, which are the choice variables, subject to the balance-sheet restriction of (1) and the market-clearing conditions for bonds, that is $B_{jt}^s = B_{jt}^d$, and banknotes, that is $N_{jt}^s = N_{jt}^d$. As derived in Appendix A.1, in an unregulated free-banking system, the equilibrium interest rate is given by

$$i_j^* = \sigma_j^2. \tag{9}$$

Hence, interest rates—or private discount rates—are here a reflection of the uncertainty of banknote conversions σ_j^2. This result concurs with the historical evidence. During the nineteenth century, discount rates were indeed the barometer of financial and political instability, because crises typically led to increasing claims on metallic reserves and were, hence, associated with upsurges in the discount rate (see e.g. Bagehot, 1873, pp.122ff.). The prime example for Switzerland was the outbreak of the Franco-Prussian War at the beginning of the 1870s, when discount rates increase markedly (see Baltensperger, 2012, pp.86-87).

Meanwhile, the equilibrium amount of banknotes is given by

$$N_{jt}^* = \Lambda_j Y_{jt}. \tag{10}$$

Of note, unregulated note-issuing banks find it profitable to accommodate the seasonal fluctuations and trends in paper-money demand. In nineteenth-century parlour, such flexibility

was referred to as an "elastic supply of paper money". For the discussion of banknote regulation of Section 3, it will be crucial to realise that such a flexible (or "elastic") supply requires ongoing adjustments of the reserve-ratio, which is given by

$$rr^*_{jt} = \frac{R^*_{jt}}{N^*_{jt}} = \frac{N^*_{jt} - B^*_{jt}}{N^*_{jt}} = 1 - \frac{1}{\Lambda_j Y_{jt}}. \tag{11}$$

In words, in the absence of regulatory constraints, note-issuing banks j find it worthwhile to vary their reserve ratios rr^*_{jt} across time t. For example, according to (11), an increasing money demand due to e.g. an upsurge in income Y_{jt} is typically matched by an increase in the optimal reserve ratio rr^*_{jt}. Intuitively, this relationship reflects the economies of scope of (7), which suggested that the marginal cost of holding reserves decrease, when the amount of banknotes in circulation increases.

Finally, inserting interest-rates of (9), the equilibrium amount of banknotes of (10), and the optimal reserve ratio of (11) into (8) reveals that the profit of note-issuing bank j is non-negative, that is

$$\pi^*_{jt} = \frac{\sigma_j^2}{2} \geq 0. \tag{12}$$

Taken together, an unregulated free-banking system offers a large degree of flexibility. Depending on banknote-conversion risk σ_j and local income conditions Y_{jt}, banks can issue notes of various quality, in terms of liquidity Λ_j, vary their reserve ratios rr^*_{jt}, and set different discount rates i^*_j. This flexibility implies that fluctuations in banknote demand are accommodated by changes in supply. The obvious downside of this flexibility is that a mishmash of more or less liquid banknotes circulate alongside each other. In other words, the market for paper money remains fragmented and many banknotes do not reach their full potential as means of payment (e.g. $\Lambda_j < 1$). As discussed in the next section, banknote regulation in Switzerland was mainly introduced to overcome this fragmentation.

3 Regulated free banking in Switzerland between 1881 and 1907

3.1 Historical background: Causes and consequences of the Banknote Act of 1881

After the introduction of the Swiss Franc in 1850 had removed competition in currency denomination, a next step towards the abolishment of the free-banking system was taken with the Federal Banknote Act of 1881, when unfettered competition was essentially replaced by a strongly regulated regime (Baltensperger, 2012, pp.95-97). It was the principal aim of banknote regulation to integrate the paper-money market by introducing commonly accepted, standardised, and secure Swiss-franc banknotes (Paillard, 1909, p.195). Above all, federal legislation forced note-issuing banks to convert all Swiss banknotes at par. Furthermore, to uphold minimum quality standards, banks were required to cover at least 40 per cent of their note circulation by metallic reserves, and at least 50 per cent by equity capital (Baltensperger and Kugler, 2017, pp.37-38). Finally, the form and design of banknotes was standardised, the freedom of cantons to raise banknote taxes was curtailed, and the federal government was given the right to limit the amount of paper money (see Jöhr, 1915, 143ff.). Conversely, the Banknote Act neither introduced a central bank with a public paper-money monopoly, nor granted banknotes legal-tender status (Baltensperger, 2012, p.100).

Banknote regulation can lead to overissuing. In particular, when banks are forced to convert not only their own, but all banknotes at par value, the public has no longer an incentive

to discriminate between different types, or brands, of paper money. This undermines the self-discipline against overissuing, because an indiscriminate supply of paper money affects also other note-issuing banks.[7] Against this background, according to Neldner (1996, 2003), the Banknote Act of 1881 necessarily tended to produce excess within Switzerland's free-banking system and was arguably responsible for lowering the internal and external value of the Swiss Franc.

According to Nelder (2003), the overissuing of paper money was manifested in a conspicuous depreciation of the Swiss franc. Indeed, the market exchange rate in Switzerland on Paris increased substantially during the second part of the 1890s (see top panel of Figure 2).[8]

The weakness of the Swiss Franc of the late 1890s was associated with notorious levels of "silver drainage" (Paillard, 1909, pp.221f.). To understand why this outflow of silver occurred, it is important to realise that the Swiss franc was only officially equivalent to the French franc through the mint-par of $S^* = 1$ (see Sec. 2.1). In a metallic currency system, market exchange rates S_t could deviate up to a certain point from the mint-par without triggering gold or silver arbitrage transactions, because international transfers of monetary metal were costly (see e.g. Eichengreen, 2008, pp.24.ff.). Normally, the foreign exchange rate was closely intertwined with the money-market interest rate, rather than merely a reflection of gold and silver prices (Clare, 1902, p.87). Indeed, as shown by Figure 2, when comparing Switzerland with France, a relatively high level of domestic interest rates was typically associated with a high exchange rate, e.g. a depreciation of the Swiss franc relative to the mint-par (see also Herger, 2018).[9] However, when the so-called specie (or silver-export) point was reached, it became profitable to arbitrage monetary metal. For the case of Switzerland and France, with a specie point of around 100.20 (Neldner, 2003, p.392), exchanging 100 French francs into, say, 100.20 Swiss francs, approaching a note-issuing bank in Switzerland to exchange this amount at the mint-par into $100.20 \times 4.5 = 450.9$ grammes of silver (coins), and export this amount to end up with 100.2 French francs yielded a sufficiently large arbitrage profit to cover the corresponding transaction costs (see Kalkmann, 1990, pp.17ff.).[10] Owing to the constraints of the Banknote Act of 1881, especially the note-issuing banks located close to the French border (e.g. in Geneva) could do little against the silver drainage. In particular, they could not respond by raising the discount rate in the face of competition from banks located further away from the border, refuse to convert banknotes, or tolerate the loss of metallic reserves without violating the minimum-reserve requirement (Ritzmann, 1974, p.97). Ironically, note-issuers, such as the Banque du Commerce in Geneva, were occasionally forced to reimport, at a higher price, the very silver money they had paid out shortly before (Kalkmann, 1900, p.21; Ritzmann, 1974, p.97). Towards the end of the 1890s, silver drainage inflicted substantial losses on

[7] For early contributions on overissuing when banks cannot discriminate between their own and other banknotes, see McCulloch (1831) and Longfield (1840).

[8] The exchange-rate data of Switzerland refer to Zurich. Similar patterns can be observed when looking at the Geneva financial market.

[9] A standard interest-parity condition implies that

$$S_t - S_t^* \approx i_{jt} - i_t^F, \tag{13}$$

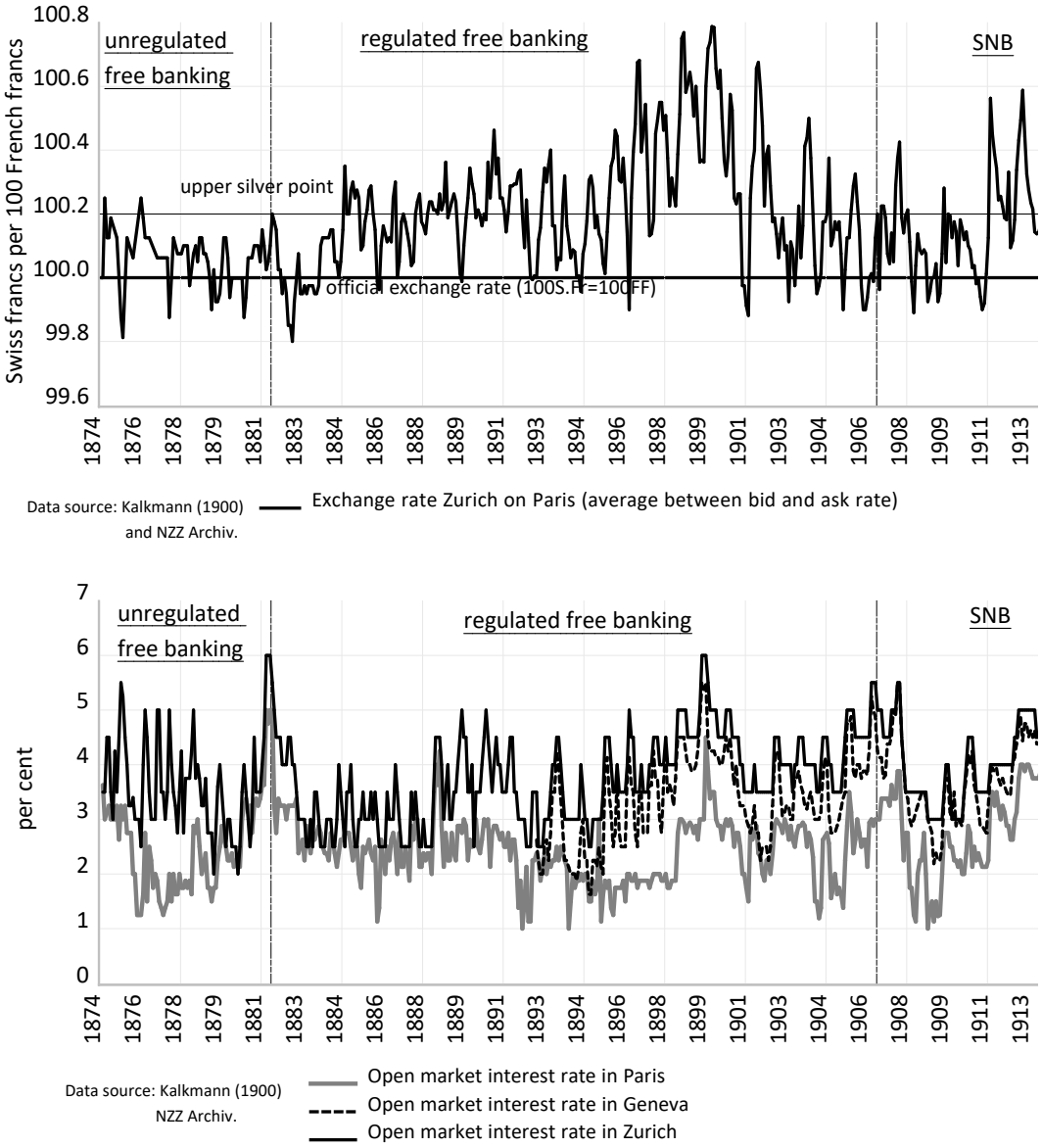
where i_{jt} denotes the domestic (Swiss) discount rate at note-issuing bank j at time t and i_t^F the foreign money-market discount rate (e.g. in France). For Switzerland, interest arbitrage occurred mainly with France, because large volumes of bills of exchange were issued to finance Switzerland's indebtedness towards France (Paillard, 1909, pp.228ff.; Geering, 1904). With the data of Paris and Zurich of Figure 2, a standard interest-parity regression yields

$$(S_t^{CH} - S_t^*) = \underset{(1.04)}{6.04} + \underset{(0.19)}{1.13}\,(i_t - i_t^F).$$

This suggests that there was indeed an almost perfect correlation between interest-rate differences and the exchange rate between Switzerland and France. This result concurs with Herger (2018), who found similar correlations between the exchange rates and interest rates of Britain, France, Germany, and the Netherlands.

[10] With respect to France, currencies were mainly arbitraged with silver, because the Banque de France charged a premium on gold withdrawals to discourage gold exports (see Kalkmann, 1900, pp.12ff.).

Figure 2: Exchange rates and interest rates in Switzerland (1874-1914)



some note-issuing banks, whereas others decided to close branches located near the French border (see Paillard, 1909, pp.223-224).

3.2 A theoretical model of regulated free banking

This section turns to the theoretical implications of banknote regulation, which was crucial for the Swiss experiences with free banking after 1881, but is ignored in the framework of Miron (1986).

3.2.1 New elements: Mutual banknote conversion and minimum-reserve requirements

To provide a perfect substitute for metallic currency, banknotes must be commonly accepted as means of payment. Recall from the theoretical banknote demand of (2) that an acceptance probability of $\alpha_j = 1 \ \forall \ j$ is warranted to obtain perfectly liquid banknotes, e.g. $\Lambda_j = 1 \ \forall \ j$. Further to the discussion of Section 3.1, mutual-acceptance rules and minimum-reserve requirements were the main regulatory instruments to popularise paper money in a free-banking system. How do these regulatory interventions change the free-banking model of Section 2.2?

Firstly, rules forcing banks to convert all banknotes alter the pattern of claims on reserves and, in turn, the cost of liquidity. The corresponding patterns, risks, and cost depend on variables such as the size of a note-issuing bank or its centrality within the market for paper money. To keep the model simple, claims on reserves from conversions of own banknotes N_{jt}, and those issued by other banks, denoted by N_{kt}, are assumed to be proportional to the market share s_j of bank j. Hence, total conversions are given by

$$\begin{aligned} \overline{W}_{jt} &= N_{jt}s_{jt}v_{jt} + N_{kt}s_{jt}v_{jt} \\ &= N_{jt}\omega_j v_{jt} \end{aligned} \tag{14}$$

where $\omega_j = s_j(1 + \varsigma_j)$ denotes the weight of bank j in the market for paper money and $\varsigma_j = N_{kt}/N_{jt}$ is a fixed share between other and own banknotes. Retaining the variance σ_j^2 of (5), conversion risk under banknote regulation is given by

$$\overline{\phi}_{jt}^2 = N_{jt}^2\omega_j^2\sigma_j^2. \tag{15}$$

Furthermore, the protection of reserves against conversions also changes. Above all, full-reserve holdings no longer offer perfect protection, because a note-issuing bank can be overwhelmed by claims from notes issued by other banks. To account for this possibility, the effect of the reserve ratio is simply downgraded by a fixed parameter $0 < \Omega < 1$. Hence, even if $R_{jt} = N_{jt}$, the liquidity cost in a regulated regime, as given by

$$L\big(\overline{\phi}_{it}^2, rr_{jt}\big) = \frac{\overline{\phi}_{jt}^2}{2}\big(\Omega rr_{jt} - 1\big)^2, \tag{16}$$

remain positive.

Secondly, banknotes cannot be fully liquid without satisfying minimum quality standards. Within the current simple model, quality is reflected by the reserve ratio rr_{jt}, which is connected with banknote liquidity Λ_j through (11). To uphold the quality of paper money, regulated free-banking systems typically imposed minimum-reserve requirements $\overline{rr}$, that is

$$\overline{rr} \leq \frac{R_{jt}}{N_{jt}}. \tag{17}$$

Like this, banks cannot free ride by issuing liquid paper money without contributing to the stability of the paper-money system by holding adequate amounts of metallic currency.

3.2.2 Overissuing and inelastic paper-money supply in theory

Introducing banknote regulation turns profit maximisation into a constrained optimisation problem given by

$$\begin{aligned} max \quad \pi_{jt}^e(R_{jt}, N_{jt}^s) &= i_{jt}B_{jt}^s - \frac{\overline{\phi}_{jt}^2}{2}\big(\Omega rr_{jt} - 1\big)^2 \\ s.t. \qquad & \overline{rr} \leq \frac{R_{jt}}{N_{jt}}. \end{aligned} \tag{18}$$

In an unregulated free-banking system, there are no minimum-reserve requirements, e.g. $\overline{rr} = 0$, and the mutual conversion weights are normalised to $\omega_j = 1$ and $\Omega_j = 1$. However, the solution of (18) depends on whether or not the minimum-reserve requirement is binding. The following discussion shows that there are major differences between the two scenarios.

Overissuing when minimum reserves are not binding: Minimum-reserve requirements are not binding, when banks voluntarily hold more reserves than required. As derived in Appendix A.2, with mutual acceptance rules, interest rates are given by

$$i^{\star}_{jt} = \big[\Omega + Y_{jt}(1-\Omega)\big](\omega_j^2\sigma_j^2). \tag{19}$$

Compared with the unregulated case of (9), under banknote regulation, interest rates depend not only on the uncertainty of banknote conversions σ_j, but also on the weight ω_j^2 of bank j within the market for paper money, the additional risk on reserves as reflected by Ω, and income Y_{jt}. With $\omega_j^2 = 1$ and $\Omega_j = 1$, (9) and (19) yield identical interest rates. However, the effect of banknote regulation is ambiguous as e.g. ω_j^2 and Y_{jt} are restricted to nonnegative values and, hence, can decrease or increase $i^{\star}_{jt}$ compared with the unregulated case of (9). Owing to such things as seasonal income fluctuations in Y_{jt}, interest rates tend to become more volatile. Taken together, the fact that there is no unambiguous effect of regulatory interventions on interest (discount) rates concurs by and large with the historical evidence of Section 3.1.

Banknote supply is given by

$$N^{\star}_{jt} = Y_{jt}\left[\frac{1}{\Omega} + 1 - \Omega\right] + (1-\Omega). \tag{20}$$

Because $0 < \Omega < 1$, the result of Neldner (2003) arises that regulated free banking results in overissuing in the sense that the equilibrium amount of banknotes $N^{\star}_{jt}$ exceeds the corresponding demand $N^{d}_{jt} = Y_{jt}$ of (2) (with $\Lambda_j = 1$). Intuitively, banks ignore the detrimental effect of issuing notes on the reserve holdings of their rivals. Hence, rules of mutual conversion undermine the self-discipline against issuing unnecessarily large amounts of banknotes compared with a scenario, where they only provide claims on own reserves. However, in (20), the paper-money supply is still elastic in the sense of responding to income fluctuations.

Finally, the profits of note-issuing, now given by

$$\pi^{\star}_{jt} = \sigma^2_{jt}\omega^2_{jt}\left[\frac{1}{2} + Y_{jt}(1-\Omega)\right] \geq 0, \tag{21}$$

remain nonnegative.

Inelastic money supply when minimum reserves are binding: From the theoretical discussion of unregulated free banking of Section 2.2., it is easy to grasp what happens when minimum-reserve requirements turn into a binding constraint. According to (11), an elastic money supply is associated with fluctuations in the optimal reserve ratio. Therefore, when reserve holdings are restricted by regulation, the paper-money supply might become less elastic. Conversely, legal limits on reserves permit the regulator to constrain the amount of money, which is a possibility that has been ignored by Nelder (2003) when emphasising the problem of overissuing.

To uncover the corresponding theoretical connections, when $\overline{rr}$ is binding, the equilibrium interest rate derived in Appendix A.3 is given by

$$i^{*}_{j} = \omega_j^2\sigma_j^2\left[\frac{1-\Omega\overline{rr}}{1-\overline{rr}}\right]^2 \geq 0, \tag{22}$$

and is mainly a function of conversion risk and the minimum-reserve ratio, but depends no longer on income Y_{jt}.

In a similar vein, due to the constraints of banknote regulation, note-issuing banks do not retain the flexibility to accommodate a fluctuating demand for paper money. In particular, within the current context, after imposing a reserve ratio of (17), the equilibrium amount of banknotes, which is given by

$$N_j^* = \frac{1}{1-\overline{rr}}, \tag{23}$$

depends only on the reserve ratio $\overline{rr}$. In contrast to the view of Neldner (2003), when reserve-requirements are binding, a regulated free-banking system does not necessarily lead to overissuing. The legislator can in principle determine the amount of banknotes in circulation through $\overline{rr}$.[11] However, removing the problem of overissuing through adequate regulation creates a new problem; namely the inelastic supply of paper money. In particular, insofar as income Y_{jt} no longer appears in (23), the profit-maximising supply of banknotes does not respond to fluctuations in money demand. Intuitively, note-issuing banks do not adjust their banknote supply, when they cannot freely adjust their reserves ratios.

Profits, which are given by

$$\pi_{jt}^* = \frac{\sigma_{jt}^2 \omega_{jt}^2}{2}\left[\frac{1-\Omega\overline{rr}}{1-\overline{rr}}\right]^2 \geq 0, \tag{25}$$

are again nonnegative, but lower than in (12) and (21) given that $0 < \Omega_j < 1$. In other words, when minimum-reserve requirements are binding, regulation is costly.

3.3 Was overissuing or an inelastic money supply the real problem?

Depending on the actual constraints imposed by minimum-reserve requirements, both overissuing and an inelastic banknote supply are conceivable side-effects of a regulated free-banking system. Which of these problems was more important during the Swiss free-banking period is ultimately an empirical question. In this regard, although Neldner (1996, 2003), Baltensperger (2012, pp.109-111), and Baltensperger and Kugler (2017, p.44) blame the weakness of the Swiss franc after 1881 on overissuing, this view can be challenged when looking at the historical development of the banknote market and the exchange rate in Switzerland during the 1880s and 1890s (see also Ritzmann, 1996). Turning to the historical evidence, as shown by the left panel of Figure 3, between 1880 and 1913, the amount of paper money per capita in Switzerland was substantially lower than in Belgium and France (see also Wolf, 1888, pp.80-81). Of note, although France and Belgium had very similar currency systems than Switzerland, their banknotes had long been issued under the public monopoly of, respectively, the Banque de France and the Banque Nationale de Belgique. Hence, it is difficult to argue that the peculiar free-banking system in Switzerland led to overissuing (see also Paillard, 1909, pp.196ff.). Secondly, under the Banknote Act of 1881, the federal government had the right to limit the amount of paper money in circulation. Hence, if overissuing was the main problem, Ritzmann (1996, p.200) has raised the question as why the Swiss government did not simply tighten the banknote quotas. Compared with plans to abolish the free-banking system, this would have been relatively uncontroversial. Thirdly, it is also noteworthy that the exceptional weakness of the Swiss franc and high

[11] Theoretically, it would possible to set reserve ratios such that the money supply equals demand of $N_j^* = Y_{jt}$. However, the corresponding ratio, given by

$$\overline{rr}_{jt} = 1 - \frac{1}{Y_{jt}}, \tag{24}$$

would have to change constantly with income fluctuations similar to (11). Such changes reflect a monetary policy of a central bank, rather than the fixed rules of banknote regulation.

levels of silver drainage occurred mainly between 1896 and 1902 (see Figure 2). Otherwise, on average, the Swiss-to-French-franc exchange rate barely deviated from the par value of 100 (the fluctuations were anyway small when compared with modern exchange-rate movements). When the Swiss free-banking system after 1881 posed a structural problem, why did excessive levels of drainage not occur throughout the 1880s and 1890s?[12] Finally, an excessive issuing of paper money should be associated with relatively high rates of inflation. However, although only patchy price data are available, the decades before the year 1900 were actually characterised by entrenched deflation (Ritzmann, 1996, p.199). Then again, the fact that there was more deflation in Switzerland than e.g. in France (see right panel of Figure 3) does not sit well with the notion of overissuing within the Swiss free-banking system.

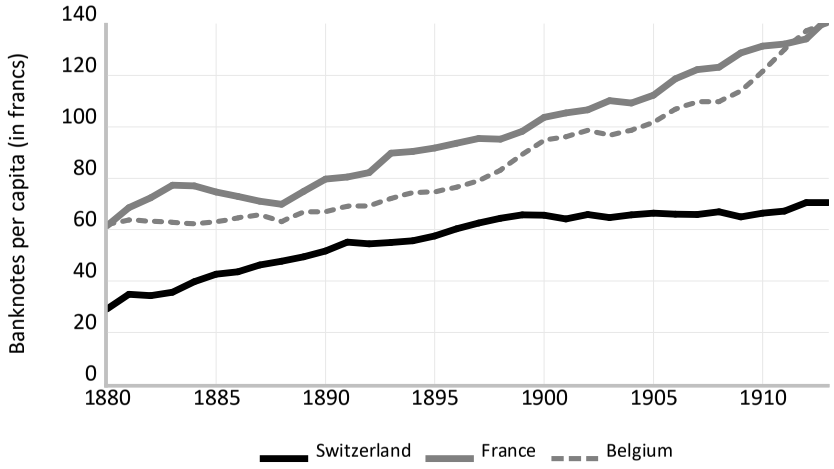
Consistent with the model of Section 3.2, when minimum reserves are binding, contemporaneous sources, such as Kalkmann (1900, pp.28ff.), Gygax (1901), Paillard (1909, pp.199ff.), and Jöhr (1915, pp.308ff.), emphasise the lack of "elasticity" of the banknote supply to absorb demand fluctuations as the main caveat of a regulated free-banking system (see also Ritzmann, 1996, p.200).[13] Similar to modern monetary systems, nineteenth-century payments witnessed seasonal and business-cycle fluctuations. For example, the demand for money in Switzerland regularly increased in June and November when large volumes of financial securities matured (Paillard, 1909, pp.198-199; Kalkmann, 1900, p.54.). As regards banknotes, there was typically an oversupply during the first half of the year and a shortage during the second half (see e.g. Kalkmann, 1900, p.29, Nüscheler, 1912, pp.3ff.). Looking back to Figure 1, the introduction of the Banknote Act of 1881 was indeed followed by a reduction in the elasticity as reflected by the annual spread between the minimum and maximum amount of banknotes in circulation. Apparently, regulatory constraints, such as minimum-reserve requirements, can exacerbate the inelastic supply of paper money.[14] Unsurprisingly, the inflexibility, and the associated shortages of paper money, were seen as a major obstacle for trade and investment (Paillard, 1909, p.225: Baltensperger, 2012, p.103). Against this background, high interest rates and silver drainage were not only a problem per se, but reflected broader inefficiencies of the money and payment system under regulated free banking.

[12]Kalkmann (1900, pp.25ff.) and Paillard (1909, pp.226ff.) have attributed the weakness of the Swiss franc around the year 1900 to balance-of-payments problems. Furthermore, silver currencies were subject to aggravated international shocks during the 1890s. In particular, the United States tried to remonetise silver in 1890, but abandoned this plan in 1894 (Friedman and Schwarz, 1963). During the second part of the 1890s, the Indian rupee moved from a silver currency system towards a gold-exchange standard with respect to sterling (see Herger, 2019). Taken together, these developments created much uncertainty in silver and bimetallic currencies during the second part of the 1890s.

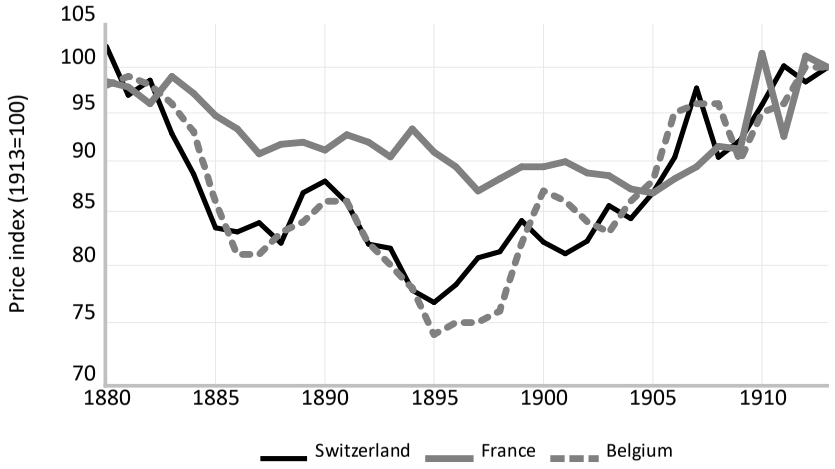
[13]Neldner (1996, p.189) quotes Jöhr (1915, p.193) to suggest that the weakness of the Swiss franc was at the time attributed to "the flooding of the country with paper money" and the "relentless note printing press". However, Jöhr (1915, p.193) goes on to argue that "there must be serious doubts as regards the correctness of these claims, if one considers, that the average note circulation since the abolishment of the note-issuing right of the old note-issuing banks has not decreased, but [...] continued to increase. The growth of note-issuing, the amount of circulating paper money [...] cannot be the sole cause for the bad state of the currency. I am rather inclined to interpret the quick expansion of the banknote circulation as a consequence of the bad monetary constitution of the country".

[14]Kalkmann (1900, p.28) suggests that banknote taxes also led to an inflexible supply of paper money. Because these taxes had to be paid on the basis of emission quotas, rather than the amount of banknotes actually put in circulation, note-issuing banks had arguably an incentive to fully exhaust their quotas (see also Baltensperger, 2012, p.103; Baltensperger and Kugler, 2017, pp.41-42). Then again, it would have been easier to remedy this problem by amending the Banknote Act of 1881, rather than entering the political controversies of establishing a central note-issuing bank. Furthermore, it was quite common to collect banknote taxes based on emission quotes before 1881 (see Jöhr, 1915, p.83). Hence, taxes can probably not explain why the flexibility in the supply of banknotes declined after 1881.

Figure 3: Banknotes per capita and aggregate prices in Belgium, Switzerland, and France (1880-1913)



Data source: Compiled from Flandreau and Zumer (2004) DB11 and DB15.



Data source: Flandreau and Zumer (2004) DB13.

4 The end of free banking: The debate on central-note issuing and the foundation of the Swiss National Bank

This section turns to the end of free banking in Switzerland and sheds light on the reasons why central note-issuing was introduced. In general, the abolishment of the freedom to issue banknotes occurred when competition in the market for paper money was replaced by a government monopoly, which automatically produces standardised banknotes that are usually broadly accepted. Although central banks have nowadays virtually everywhere obtained the exclusive right to issue paper money, their triumphant advance was by no means a foregone conclusion during the nineteenth century. Rather, the establishment of public banknote monopolies was often met by widely held concerns as regards the dangers of increasing government power in monetary affairs (see e.g. Herger, 2019, pp.12ff.). These concerns resonate until today, especially when central-bank policies have led to monetary and financial instability. The high inflation of the 1970s and Hayek's (1978) call for a denationalisation of money is probably the most prominent example for this.

Arguably, the impotence of the free-banking system to stabilise the Swiss-franc exchange rate during the period of notorious silver drainage between 1896 and 1902 plaid a major role in overcoming the strong opposition against central-note issuing in Switzerland (see Paillard, 1909, p.225; Ritzmann, 1974, p.96; Baltensperger and Kugler, 2017, pp.41-45). In particular, whereas a constitutional amendment giving the Swiss confederation the sole right to issue banknotes was already passed in 1891, proposed legislation to establish a central bank was rejected by a popular referendum in 1897 and a second attempt was already defeated in parliament in 1900 (Jöhr, 1915, pp.251ff.). Further to the discussion above, the opponents successfully invoked the dangers of a centralisation of government power in monetary affairs (Jöhr, 1915, pp.259ff.). However, a third attempt succeeded in 1905, and the SNB opened its counters in 1907, which marked the end of free banking in Switzerland (see Baltensperger, 2012, pp.101-103).

The transition towards a public banknote monopoly after 1907 supports the conclusion that the free-banking system in Switzerland mainly lacked an elastic money supply, rather than suffering from overissuing. In particular, when free banking would necessarily result in overissuing, the foundation of the SNB should have reduced the amount, or at least lowered the growth, of banknotes in circulation. However, looking back to Figure 1 of Section 2.1. does not suggest that such a reduction took place after the year 1907.[15] Conversely, the SNB was able to quickly replace private banknotes and to raise the annual maximum of paper money, which reflects an increase in the elasticity of paper money.

Some elements of the free-banking system were retained after the introduction of central note issuing in Switzerland. In particular, the SNB was obliged to convert banknotes upon demand into metallic currency at the old mint-par. Furthermore, the legal requirement to cover banknotes with at least 40 per cent metallic reserves was retained. Owing to the identical minimum-reserve requirements and similar conversion rules, under profit maximisation, a government monopoly yields similar theoretical results than a regulated free-banking system. In particular, denoting variables pertaining to the central bank with subscript c, a paper-money monopoly involves the normalisation of $\omega_c = \Omega = 1$, because notes necessarily flow back to the bank. Considering the case of binding minimum-reserve requirements of Section 3.2, profit maximisation would yield an interest rate of

[15] When estimating a standard money-demand equation given by

$$\ln(N_t/P_t) = \beta_0 + \beta_1 \ln(GDP_t) + \beta_2 \ln(i_t) + \beta_3 \ln(N_{t-1}/P_{t-1}) + \epsilon_t,$$

where N_t/P_t denotes the real demand for banknotes, GDP denotes income, i_t denotes the short-term interest rate in Switzerland and ϵ_t is the usual error term, for the 1880 to 1913 period, a conventional Chow-test does not allow to reject the hypothesis of having no structural break at the year 1907 (Chow F-stat: 1.865).

$$i_c^* = \sigma_j^2, \tag{26}$$

and an equilibrium amount of banknotes per representative household of

$$N_c^* = \frac{1}{1 - \overline{rr}}. \tag{27}$$

Hence, a monopoly does not per se bring back an elastic paper-money supply or avoid overissuing. However, within a public monopoly, the government can instruct the central bank to issue banknotes according to the needs of commerce, that is $N_{ct} = Y_{jt}$, rather to maximise profits. Taken together, in contrast to unrestricted and regulated free-banking systems, the central note-issuing bank is able to provide standardised and perfectly liquid paper money in a flexible manner.

Against this background, it is perhaps not surprising that the original legal mandate instructed the SNB to regulate the money market, to increase the efficiency of the payment system, and to provide Swiss-franc banknotes in a flexible manner (Paillard, 1909, pp.231ff.; Baltensperger, 2012, p.134-135). In particular, Article 2 of the Federal Act on the Swiss National Bank of 1905 said that "The national bank has the main task of regulating the circulation of money within the country and facilitating the settlement of payments". According to Article 18, banknotes had to be provided "according to the needs of commerce" (see also Jöhr, 1915, pp.303ff.). In other words, similar to the Federal Reserve System of the United States, the SNB was primarily set up as a reserve bank, which was supposed to increase the flexibility in the supply of money, to enhance the management of reserves, and to iron out excessive exchange and interest-rate fluctuations (see Miron, 1986, pp.129-130; Bordo, 2018, p.104). Conversely, the desire to earn seignorage, which was a key consideration for setting up early central banks such as the Bank of England, was arguably less important (Jöhr, 1915, p.302).

5 Conclusion: The dilemma of free banking

From the historical experiences of Switzerland and according to the simple model discussed in this paper, free-banking systems seem to suffer from a dilemma between offering an ideal quality and quantity of paper money. In particular, although unregulated free banking gives note issuers a large degree of freedom and implies that they find it profitable to adjust the quantity of issued banknote to changing demand, the corresponding competition is also likely to lead to a fragmented paper-money system. When banknotes of different quality circulate alongside each other, they only partially fulfill the monetary functions of a universally accepted means of payment. To overcome this problem, regulatory measures can impose common quality standards and, hence, give rise to homogenous and commonly accepted banknotes that better fulfill the functions of money. However, the regulatory interventions to achieve this, such as minimum-reserve requirements or mutual-conversion rules for banknotes, can adversely affect the quantity of banknotes in terms of leading to overissuing or an inelastic supply. Historically, the establishment of a government monopoly in paper money through central-note issuing banks provided an escape from free-banking systems that were unable to offer standardised paper money in flexible manner. By virtue of the currency monopoly, and thanks to the absence of profit maximisation, central banks can indeed issue homogenous banknotes according to the needs of commerce. Of course, central banking is associated with a concentration of public power in monetary affairs. The corresponding caveats are well known.

The dilemma of free banking provides also the basis for a possible reinterpretation of the Swiss experiences with banknote competition between 1826 and 1907. Hitherto, the literature on free banking in Switzerland has only partially acknowledged the corresponding dilemmas. In particular, although banknotes were arguably secure before the introduction

of federal regulation in 1881, private competition hindered the integration, and hence led to an underdevelopment, of the market for paper money. After 1881, banknotes became a more popular means of payment, but the regulated free-banking system suffered from a notorious failure to provide adequate amounts of banknotes (especially to accommodate seasonal fluctuations in economic activity). Ultimately, it became clear that a combination between uniform banknotes and an elastic supply of paper money required the foundation of the Swiss National Bank.

Although this paper has focused on the trade-offs resulting from private banknote competition, the dilemma of free banking has also potential implications for modern monetary systems. In particular, there is no reason why the economic problems observed during the free-banking episode in Switzerland cannot arise with recent innovations in monetary technology, such as cryptic currencies.

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A Derivations

A.1 Unregulated free banking

Inserting the balance-sheet restriction of (1) into the profit function (8) yields

$$\begin{aligned}\pi^e_{jt}(R_{jt}, N^s_{jt}) &= i_{jt}B^s_{jt} - L(\phi^2_{jt}, rr_{jt}) \\ &= i_{jt}(N^s_{jt} - R_{jt}) - \frac{N^2_{jt}\sigma^2_j}{2}\left(\frac{R_{jt}}{N^s_{jt}} - 1\right)^2.\end{aligned}$$

The first order conditions are given by[16]

$$\frac{\partial \pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial R_{jt}} = -i_{jt} - N^s_{jt}\sigma^2_j\left(\frac{R_{jt}}{N^s_{jt}} - 1\right) = 0 \tag{A.1}$$

$$\frac{\partial \pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial N^s_{jt}} = i_{jt} - \left[N^s_{jt}\sigma^2_j\left(\frac{R_{jt}}{N^s_{jt}} - 1\right)^2 - \sigma^2_j\left(\frac{R_{jt}}{N^s_{jt}} - 1\right)R_{jt}\right] = 0. \tag{A.2}$$

Inserting (A.1) into (A.2) and solving for R_{jt} yields

$$R_{jt} = N^s_{jt} - \frac{i_{jt}}{\sigma^2_j}. \tag{A.3}$$

Imposing market clearing, e.g. $B_{it} = B^d_{jt} = B^s_{jt} = 1$ and $N_{jt} = N^s_{jt} = N^d_{jt} = \Lambda_j Y_{jt}$ and using (A.3) yields

$$B_{jt} = N_{jt} - R_{it} = \Lambda_j Y_{it} - \Lambda_j Y_{jt} + \frac{i_{jt}}{\sigma^2_j} = \frac{i_{jt}}{\sigma^2_j} = 1. \tag{A.4}$$

Solving for i_{jt} yields

$$i^*_j = \sigma^2_j. \tag{A.5}$$

Inserting (A.5) back into (A.3) yields

$$R^*_{jt} = N_{jt} - \frac{\sigma^2_j}{\sigma^2_j} = \Lambda_j Y_{jt} - 1.$$

Hence,

$$N^*_{jt} = R^*_{jt} + B^*_j = \Lambda_j Y_{jt} - 1 + 1 = \Lambda_j Y_{jt}.$$

Finally, inserting N^*_{jt}, R^*_{jt}, and i^*_j into the profit function yields

$$\pi^*_{jt} = \sigma^2_j - \frac{\Lambda^2_j Y^2_{jt}\sigma^2_j}{2}\left(\frac{\Lambda_j Y_{jt} - 1}{\Lambda_j Y_{jt}} - 1\right)^2 = \frac{\sigma^2_j}{2}.$$

A.2 Regulated free banking when minimum reserves are not binding

With changed conversion risk $L(\overline{\phi}^2_{jt}, rr_{jt})$ of (16), the profit function is

[16] As $\frac{\partial^2 \pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial R^2_{jt}} \leq 0$, $\frac{\partial^2 \pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial N^2_{jt}} \leq 0$, and $\frac{\partial^2 \pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial R^2_{jt}} \frac{\partial^2 \pi^e_{jt}(R_{jt}, N^S_{jt})}{\partial N^2_{jt}} - \left(\frac{\partial^2 \pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial R_{jt} \partial N^s_{jt}}\right)^2 \geq 0$, the first order conditions reflect a profit maximum.

$$\begin{aligned}\pi^e_{jt}(R_{jt}, N^s_{jt}) &= i_{jt}B^s_{jt} - L(\overline{\phi}^2_{jt}, rr_{jt}) \\ &= i_{jt}(N^s_{jt} - R_{jt}) - \frac{N^2_{jt}\omega^2_j\sigma^2_j}{2}\left(\Omega\frac{R_{jt}}{N^s_{jt}} - 1\right)^2.\end{aligned}$$

The first order conditions are given by

$$\frac{\partial\pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial R_{jt}} = -i_{jt} - N^s_{jt}\omega^2_j\sigma^2_j\left(\Omega\frac{R_{jt}}{N^s_{jt}} - 1\right) = 0 \tag{A.6}$$

$$\frac{\partial\pi^e_{jt}(R_{jt}, N^s_{jt})}{\partial N^s_{jt}} = i_{jt} - \left[N^s_{jt}\omega^2_j\sigma^2_j\left(\Omega\frac{R_{jt}}{N^s_{jt}} - 1\right)^2 - \omega^2_j\sigma^2_j\left(\Omega\frac{R_{jt}}{N^s_{jt}} - 1\right)\Omega R_{jt}\right] = 0. \tag{A.7}$$

Inserting (A.6) into (A.7) and solving for R_{jt} yields

$$R_{jt} = \frac{N^s_{jt}}{\Omega} - \frac{i_{jt}}{\omega^2_j\sigma^2_j\Omega}. \tag{A.8}$$

Imposing market clearing, e.g. $B_{it} = B^d_{jt} = B^s_{jt} = 1$ and $N_{jt} = N^s_{jt} = N^d_{jt} = Y_{jt}$ and using (A.8) yields

$$B_{jt} = N_{jt} - R_{it} = Y_{it} - \frac{N^s_{jt}}{\Omega} - \frac{i_{jt}}{\omega^2_j\sigma^2_j\Omega} = 1.$$

Solving for i_{jt} yields

$$i^\star_j = [\Omega + (1-\Omega)Y_{jt}]\omega^2_j\sigma^2_j. \tag{A.9}$$

Inserting (A.9) back into (A.8) yields

$$R^\star_{jt} = \frac{Y^s_{jt}}{\Omega} - \frac{i_{jt}}{\omega^2_j\sigma^2_j\Omega} = \frac{Y^s_{jt}}{\Omega} - \Omega + (1-\Omega)Y_{jt}.$$

Hence,

$$N^\star_{jt} = R^\star_{jt} + B^\star_j = \frac{Y^s_{jt}}{\Omega} - \Omega + (1-\Omega)Y_{jt} + 1 = Y_{jt}\left[\frac{1}{\Omega} - (1-\Omega)\right] + (1-\Omega).$$

Finally, inserting $N^\star_{jt}$, $R^\star_{jt}$, and $i^\star_j$ into the profit function yields

$$\begin{aligned}\pi^\star_{jt} &= [N^\star_{jt} - R^\star_{jt}]i^\star_{jt} - \frac{N^2_{jt}\sigma^2_j\omega^2_j}{2}\left[\Omega\frac{R^\star_{jt}}{N^\star_{jt}} - 1\right]^2 \\ &= [\Omega + (1-\Omega)Y_{jt}]\sigma^2_j\omega^2_j - \frac{\sigma^2_j\omega^2_j}{2}[\Omega(R^\star_{jt} - N^\star_{jt})]^2 \\ &= [\Omega + (1-\Omega)Y_{jt}]\sigma^2_j\omega^2_j - \frac{\sigma^2_j\omega^2_j}{2}\left[\frac{Y_{jt}}{\Omega} - \Omega + (1-\Omega)Y_{jt} - \frac{Y_{jt}}{\Omega} - (1-\Omega)Y_{jt} - (1-\Omega)\right]^2 \\ &= \frac{\sigma^2_j\omega^2_j}{2}\left[\frac{1}{2} + (1-\Omega)Y_{jt}\right].\end{aligned}$$

A.3 Regulated free banking when minimum reserves are binding

The required reserve ratio $\overline{rr} = (\overline{R}_{jt}/\overline{N}_{jt})$ enters as an additional constraint and implies that $\overline{N}_{jt} = R_{jt}/\overline{rr}$. Hence, the profit function is

$$\begin{aligned}\pi^e_{jt}(N^s_{jt}) &= i_{jt}B^s_{jt} - L(\bar{\phi}^2_{jt}, \overline{rr}) \\ &= i_{jt}(N^s_{jt} - \overline{rr}N^s_{jt}) - \frac{N^2_{jt}\omega^2_j\sigma^2_j}{2}\left(\Omega\overline{rr} - 1\right)^2.\end{aligned}$$

The first order condition with respect to N^s_{jt} is

$$\frac{\partial \pi^e_{jt}(N^s_{jt})}{\partial N^s_{jt}} = (1 - \overline{rr})i_{jt} - N^s_{jt}\omega^2_j\sigma^2_j(\Omega\overline{rr} - 1)^2 = 0.$$

Solving this for N^s_{jt} yields

$$N^s_{jt} = \frac{i_{jt}(1 - \overline{rr})}{\omega^2_j\sigma^2_j(1 - \Omega\overline{rr})^2}. \tag{A.10}$$

Imposing market clearing, e.g. $B_{it} = B^d_{jt} = B^s_{jt} = 1$ and using (A.10) yields

$$B_{jt} = 1 = N_{jt} - R_{jt} = N_{jt} - \overline{rr}N_{jt} = \frac{i_{jt}(1 - \overline{rr})^2}{\omega^2_j\sigma^2_j(1 - \Omega\overline{rr})^2}.$$

Solving for i_{it} yields

$$\bar{i}^*_{jt} = \omega^2_j\sigma^2_j\left[\frac{1 - \Omega\overline{rr}}{1 - \overline{rr}}\right]^2.$$

Inserting this back into (A.10) yields

$$\overline{N}^*_j = \frac{1}{1 - \overline{rr}}.$$

Inserting this into the profit function yields

$$\begin{aligned}\pi^*_{jt} &= \omega^2_j\sigma^2_j\left[\frac{1 - \Omega\overline{rr}}{1 - \overline{rr}}\right]^2 - \frac{\omega^2_j\sigma^2_j}{2(1 - \overline{rr})}\left(\Omega\overline{rr} - 1\right)^2 \\ &\quad \frac{\omega^2_j\sigma^2_j}{2}\left[\frac{1 - \Omega\overline{rr}}{1 - \overline{rr}}\right]^2.\end{aligned}$$