The Reichsbank, commitment credibility and the rules of the game in 1876-90

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20 May 2017 (amended version)

Abstract: The paper studies the policy reaction function of Germany's central banking system in 1876-90. The German Imperial Bank (Reichsbank) was one of the dominant central banks during the last quarter of the nineteenth century and beginning of the twentieth century. Its monetary policy behaviour therefore played an important role in supporting and consolidating the international gold standard. At the same time, there was repeated concern in Germany that its policy stance was insufficiently supportive of domestic activities. The paper demonstrates that the Reichsbank during 1876-90 maintained broadly the rules of the game of the gold standard but shifted increasingly towards accommodating though only modestly national policy objectives in 1887-90 while strengthening adjustment to adverse gold shocks. This coincided with a weakening of the Bank of England bank rate settings for the Reichsbank's policy formulation. The paper also shows that the Privatnotenbanken, in contrast to their pledges, had not supported the Reichsbank's policy. The paper uses new monthly data and advanced statistical estimation based on vector auto-regression models to offer a detailed analyses of the Reichsbank's policy reaction function during the beginning of its operations and amid difficult economic conditions in Germany. The Reichsbank's dual accommodation of national and international objectives under the gold standard affirms doubts about the relevance of the classical exchange rate trilemma. The paper supports earlier findings that strong perceived commitment credibility offers monetary policy autonomy under the gold standard.

JEL Classification: E52, E58, F45, N23

Keywords: Reichsbank, Privatnotenbanken, monetary policy, rules of the game.

1. Introduction

The paper studies the policy reaction function of Germany's central banking system in 1876-90. The German Imperial Bank (Reichsbank) was one of the dominant central banks during the last quarter of the nineteenth century and beginning of the twentieth century. The Reichsbank's monetary policy behaviour therefore played an important role in supporting and consolidating the international gold standard. However, while there is ample narrative account of the operations of the Reichsbank, there is relatively little statistical evidence about its conduct of monetary policy. The present paper offers new monthly data and uses advanced statistical estimation methods to analyse the Reichsbank's monetary policy reaction function during the first years of its operations and amid difficult economic conditions in Germany in 1876-90. The paper finds that the Reichsbank's maintained a certain degree of policy discretion while upholding the "rules of the game" of the classical gold standard becoming in 1887-90 more focused on domestic objectives, largely irresponsive to external interest rate shocks while strengthening its commitment credibility to the gold standard. Nineteenth century Germany may therefore offer valuable lessons for monetary policy autonomy under fixed exchange rates.

The Reichsbank was established as part of broad-based monetary reforms in Germany accompanying the establishment of political union and formation of the German Empire in 1871. The reforms comprised in 1871-73 adoption of monetary union and the gold standard (Münzgesetze) and in 1875 the bank act (Bankgesetz)

to regulate central banking in a mixed system with the Reichsbank at federal level and private banks of issue (Privatnotenbanken) at federal state level.[1]

Germany experienced a significant economic slowdown and prolonged largely unexpected economic stagnation following the international economic and financial crisis of the panic of 1873 through 1886 (Gründerkrise). The newly founded Reichsbank was confronted de facto with a dual objective of adhering to the gold standard and supporting the recovery of the German economy. The implementation of monetary policy was complicated amid large gold drains during the early years of the Reichsbank's operations. The German Imperial Parliament (Reichstag) often put pressure on the bank to support domestic economic activity. At the same time, the Reichsbank was in competition with the Privatnotenbanken for setting monetary conditions.

The operations of the Reichsbank have been reviewed comprehensively (Hellferich, 1898; Pohl, 1982; National Monetary Commission, 1910a; Seeger, 1968). The policy of the Reichsbank was mostly studied with focus on adherence to the rules of the game of the classical gold standard. Bloomfield (1959), Giovannini (1986), McGouldrick (1984), Morys (2013) find that the Reichsbank adhered mostly to the rules of the game. Those findings are consistent in scope with the studies of the Bank of England under the gold standard (Committee on Currency and Foreign Exchanges after the War, 1918; Dutton, 1984; Jeanne, 1995; Pippenger, 1984). The study of the rules of the game form part of fundamental inquiries into the classical gold standard (Bordo, 1981; Bordo & Kydland, 1995; Eichengreen, 1995). The study

[1] Germany initiated coinage harmonisation under the Customs Union (Zollverein) and subsequent coinage treaties. In 1873, Germany still had 7 different currency standards and more than 60 different paper currencies in circulation, see e.g. Wiss (1896).

is also tied to the rules versus discretion debate in monetary policy (Clarida et al., 2000; Dwyer, 1993; Fischer, 1988; Simons, 1936; Taylor, 1999) and commitment, reputation and credibility in monetary policy (Kydland & Prescott, 1977; Obstfeld & Taylor, 2002; Rogoff, 1987). The relevance of the rules of the game remain contested in a framework of exchange rate target bands (Krugman, 1991; Svensson, 1994).

The rules of the game are congruent with the trilemma debate and monetary policy autonomy in a contemporary context (Obstfeld et al., 2004, Rey, 2016). Obstfeld et al. (2005) argue that the gold standard did not offer extensive monetary policy independence while Bordo and MacDonald (1997) following Svensson (1994) find that the credibility commitment to gold convertibility allowed central banks to temporarily depart from following the rules and pursue domestic policy goals independent of the concern for convertibility.

The contribution of the paper is to offer new evidence about the Reichsbank's monetary policy conduct and interactions with the Privatnotenbanken using new data and advanced statistical estimation techniques. The paper demonstrates that the Reichsbank maintained the rules of the game of the gold standard but was also able to pursue though more modestly domestic policy objectives. The findings show that the Reichsbank performed a shift towards national objectives in 1887-90 while strengthening adjustment to adverse gold shocks.[2] This also coincided with a weakening of the impact of the Bank of England bank rate settings for the Reichsbank's policy formulation. The findings thus support earlier studies that the rules of the game were often violated (Bordo & MacDonald, 1997) and offer

[2] At the same time as the Reichsbank accumulated a larger gold reserve, it may have become less susceptible to external disturbances similar to the Banque de France (Bordo & MacDonald, 1997).

additional insight into the relationship between commitment credibility and domestic policy accommodation. The paper also shows that the Privatnotenbanken in contrast to their pledges did not support the Reichsbank in the event of gold outflows. The results of the paper are in line with the notion that some monetary policy autonomy can be preserved in large part even under fixed exchange rate regimes (Bordo & Flandreau, 2001; Bordo & MacDonald, 1997; Krugman, 1991; Svensson, 1994).

The paper uses monthly data to test the policy reaction function of the Reichsbank and the Privatnotenbanken based on a structural vector autoregression model. The statistical analysis follows a contemporary framework to test monetary policy reaction functions by Clarida and Gertler (1996) rather than maintain a narrow approach limited to monetary policy rate adjustment and external intertest rate transmission (Obstfeld et al., 2005).[3] As such, the paper complements conventional statistical analyses on the rules of the game of the classical gold standard for Germany (McGouldrick, 1984; Morys, 2013; Sommariva & Tullio, 1986).

The paper focuses on the period 1876-90 covering initiation of operations of the Reichsbank in January 1876 and the end of the scheduled life of the original bank act in December 1890. The period coincided with adverse economic conditions in 1873-86 and a recovery in 1887-90.

[3] Bordo and MacDonald (1997) use a comprehensive structural vector autoregression model approach including non-financial variables but limited reporting for Germany to financial variables for responses to U.K.-related shocks.

The second section reviews fundamental principles of monetary policy and the rules of the game under the gold standard. The third section provides the data and statistical analysis and the last section offers concluding remarks and links the results of the paper to the contemporary debate about monetary policy credibility and monetary policy autonomy.

2. Rules of the game

The classical gold standard from circa 1875 to 1914, as is well known, had a national and an international dimension.[4] The former implied that national currencies were tied to a fixed unit of gold and that monetary policy was subordinated to ensuring. convertibility of central bank notes into gold.[5] The latter prescribed that central banks followed the "rules of the game" or a prescriptive monetary policy consistent with facilitating orderly balance of payments adjustments through net gold exports to accommodate external shocks. The Bank of England was attributed a leading role in managing the international gold standard amid the importance of London as a financial and gold centre.[6]

[4] For an explanation of the classical gold standard, see e.g. Bordo (1984). Bloomfield (1959, pp. 9-10): "The exchange rates of the various countries moved within narrow limits approximating their respective gold points without the support of exchange restrictions, import quotas, or related controls […]. Only a trifling number of countries were forced off the gold standard, once adopted, and devaluations of gold currencies were highly exceptional. Yet all this was achieved in spite of a volume of international reserves that, for many of the countries at least, was amazingly small in spite of only a minimum of international cooperation, or of international agreements or commitments, on monetary matters. […]."

[5] Bloomfield (1959, pp. 23-24): "It is of course undeniable that the dominant and overriding objective of monetary policy in the various gold standard countries was to maintain the convertibility of the national currency directly or indirectly into gold at the legal parity, i.e. to maintain approximately fixed exchange rates against other gold currencies. […]."

[6] See e.g. Bordo (1984).

The rules of the game, as is well known, refer to balance of payments adjustment under the Hume price-specie-flow mechanism.[7] International payments imbalances would lead to changes in money supply that affect domestic prices and reverse the flow of goods as to eliminate the payments imbalance.[8] Under the rules, central banks facilitated this adjustment through changes in their monetary policy stance subordinating to the adjustment process objectives of domestic stabilisation or countercyclical domestic policies.

In a normative framework under the rules of the game, central banks observing a decline in gold reserves responded with a contraction in domestic credit. Domestic credit was normally controlled largely by adjustments in the central bank's discount rate. An increase in the discount rate would reduce lending and induce an increase in the market rate. The rise in interest rates would facilitate balance of payment adjustment by attracting capital from abroad and reduce domestic absorption.

The rules of the game can be interpreted to different degrees of narrowness:[9] i) under the most narrow definition, the central bank adjusts its discount rate to

[7] See e.g. Dutton (1984).

[8] Bloomfield (1959, pp. 9-10): "We are commonly told, among many other things, that the various gold standard countries faithfully played the "rules of the game"; that the adherence to such rules was a factor of major importance in the successful functioning of the system; that the system worked more or less "automatically", with a minimum of discretionary action by the authorities, except in the case of the Bank of England which is alleged to have skilfully "managed" the gold standard system as a whole; that there was a remarkable "smoothness" in the functioning of the mechanism […]."

[9] The definitions are from Sommariva and Tullio (1986). The definitions are consistent with "Cunliffe Committee Report" (Committee on Currency and Foreign Exchanges after the War, 1918, pp. 3-6) advanced the notion that the gold standard operated on the basis of some automaticity: "There was therefore an automatic machinery by which the volume of purchasing power in this country was continuously adjusted to world prices of commodities in general. […] The recognised machinery for this purpose is the Bank of England discount rate" The report emphasises the reserve ratio as main policy

changes in the liquidity ratio, the ratio between reserves and bank notes and other reservable liabilities; ii) under a broader definition, the central bank changes its domestic assets in the same direction as changes in its foreign assets to help the balance of payments adjustment process; and iii) under the broadest definition, the central bank changes its discount rate to adjust its balance sheet anti-cyclically.[10]

The Reichsbank acknowledged implicitly the notion of the "rules of the game."[11] It had a firm notion of its influence on and the importance of the level of gold reserves and the effect of its policy on key target variables arguing that "you can only earn respect for your currency if you are willing to increase the discount rate as high as need be until the public recognises that one is willing to protect its metal."[12] The relationship between economic activity and the level of the interest

indicator and distinguishes between external drain and domestic credit: "When the balance of trade was unfavourable […], it became profitable to export gold. The would-be exporter bought his gold from the Bank of England […] with the results that […] the ratio of reserves to liability consequently fell. If the ratio [is reduced] in a degree considered dangerous, the Bank raised its rate of discount. […] When apart from a foreign drain of gold, credit at home threatened to become unduly expanded […] the expansion of credit […] involves an increased demand for legal tender currency. In this case also the demand for such currency fell upon the reserve of the Bank of England, and the Bank was thereupon obliged to raise its rate of discount in order to prevent the fall in the proportion of that reserve to its liabilities."

[10] The conduct of counter-cyclical policy may appear as inconsistent with the fundamental notion of the rules of the game as the rule would imply that monetary policy is subordinated to maintaining gold convertibility, see e.g. Dutton (1984)

[11] The notion "rules of the game" was not a period concept but emerged as an ex-post rationalisation of central bank monetary policy under the gold standard; see e.g. McKinnon (1993) notes that the expression "rules of the game" is often attributed to a reference in *The economic consequences of Mr Churchill* by John Maynard Keynes (1925).

[12] Translated from German. President of the Reichsbank Herman von Dechend in a testimony to the Reichstag (Deutscher Reichstag, 1881b, p. 122): "Man kann seiner Valuta nur Respekt verschaffen, wenn man sich nicht genirt, ordentlich mit dem Diskont in die Höhe zu gehen, bis die Leute sehen, daß man sein Metall zu schützen weiß." See also von Dechend in a testimony to the Reichstag on the importance of the discount rate policy to preserve the gold stock (Deutscher Reichstag, 1891, p.1184): "Das wesentlichste und wichtigste Mittel aber, den Goldvorrath auf der erfordlichen Höhe zu halten, ist die Diskontopolitik, und die ist von der Reichsbank so geübt worden, daß, wie ich sagen kann, unser Kredit noch keinen Augenblick angezweifelt worden ist."

rates was also recognised.[13] The perception that period monetary policy was only to a limited extent aligned with modern monetary policy frameworks seems inconsistent with the period monetary policy debate led by the Reichsbank's.[14]

The monetary policy framework of the Reichsbank and Privatnotenbanken was defined by the 1875 bank act. The act stipulated a dual mandate for the Reichsbank and a narrower mandate for the Privatnotenbanken. Both institutions were obligated to reserve bank notes to one third by lawful German money, Federal government notes, gold or foreign coins and the rest in discounted bills of exchange and to redeem their bank notes on demand for lawful German money. The Reichsbank was also mandated to facilitate money circulation and payments throughout Germany and mobilise credit in addition to other operations for the Federal government. The Reichsbank was permitted to establish branches across Germany and the Privatnotenbanken in their respective states. The co-existence of the Reichsbank and Privatnotenbanken was a unique feature of the legislative framework and German central banking system in the conduct of monetary policy.

National Monetary Commission (1910, p. 357) in interviews with Otto von Glasenapp, Vice-President of the Reichsbank, and Karl von Lumm, Director, of the Reichsbank: "The real remedy [to increase gold imports] is to raise the rate of discount […]."

[13] See e.g. comment made by Ludwig Bamberger, member of parliament and leading protagonist for the establishment of the Reichsbank, on the adequacy of the Reichsbank's discount rate for commerce and trade during a parliamentary debate on 3 March 1881 (Deutscher Reichstag, 1881a, p.123): "Der offizielle Zinssatz ist im ganzen auch im vorigen Jahre nicht sehr hoch gewesen, und ich glaube, daß im Durchschnitt mit dem Satze […] weder Handel noch Gewerbe geschädigt worden sind."

[14] Several authors dismiss the notion of a period monetary policy comparable to a contemporary monetary policy prior to World War I. (Bloomfield, 1959, pp. 23-24): "[C]entral bank policy as a means of facilitating the achievement and maintenance of reasonable stability in the level of economic activity and of prices was scarcely thought about before 1914, and certainly not accepted, as a formal objective of policy. […] But central banks were of course not unaware of, or entirely insensitive to, the effects of their actions upon the level of business activity and the state of business confidence." Also see e.g. Eichengreen (1995, p. 6): "Even observers who connected unemployment to the state of trade rarely related aggregate fluctuations to interest rates or monetary conditions. They had limited appreciation on how central bank policy affected the economy."

The Reichsbank framed its monetary policy on the basis of bank note convertibility and credit accommodation: "The most important and likewise the most difficult task of the Bank is to bring about the greatest possible equalisation of fluctuations in money demands and to be at all times in a position to redeem its notes and to meet its other demand liabilities. The maintenance of the Bank's solvency coincides with the maintenance of the imperial standard. The notes issued by the Bank form so large a part of the total Germany currency that a refusal to redeem them for sterling money and the subsequent depreciation of the notes would bring about a collapse of the German monetary system."[15]

Member of the Reichsbank Directorate Koch indicated that the Reichsbank since inception in 1876 through 1899 increased the discount rate 38 times of which 11 were aimed at preventing a specie outflow, 10 of which were prior to 1894; of the remaining 27 cases, 14 were in response to domestic money market conditions; the remaining 13 cases were instances where there was some concern of specie outflow but it was not the decisive one.[16]

The Reichsbank saw its policy largely as an outcome of economic conditions: "The different phases in the development of the Reichsbank correspond to the various periods of German economic activity; these phases are reflections of all economic activity. Here is shown distinctly what a decisive influence the general economic development exercises on the conditions of the central bank, and how

[15] National Monetary Commission (1910a, p. 202).

[16] Deutscher Reichstag (1899, p. 767).

much the latter's policy is dependent on the forces and powers dominating the rise of the whole national economic system."[17]

The Reichsbank was repeatedly criticised to neglect adverse domestic conditions often attributed to the constraints imposed by the gold standard. Members of the Reichstag recurrently aimed reintroducing silver and force the adoption of a bimetallic standard during the 1880s in large part on the basis that the gold standard was perceived to cause a deflationary bias, competitive disadvantage particularly vis-à-vis the United States and to seek harmonising currency relations with England amid a perceived rise of support for bi-metallic standard in England.[18]

The main policy instrument of the Reichsbank was the discount rate. The Reichsbank saw the discount rate as the main measure to ensure convertibility. It indicated that it largely dismissed the use of "gold devices" as a policy instrument.[19]

[17] National Monetary Commission (1910a, p. 217). Seeger (1968) indicates that the Reichsbank deviated from the rules of the game of the gold standard to accommodate domestic credit demand and that stricter adherence would possibly have had a negative impact on output.

[18] See e.g Deutscher Reichstag (1886), member of the Reichstag Ernst Leuschner and leading advocate of the introduction of bi-metalism argued that the limited gold stock will cause continued price deflation and harm economic conditions: "Diese Gefahren sind auch schon so groß geworden, das sie sichtbar zur Erscheinung kommen in der unerquicklichen Zuständen, welche unsere derzeitigen wirthschaftlichen Verhältnisse mit sich bringen. Niemand wohl kann in Abrede stellen, daß unsere gesammten Produktivstände durch die niedrigen Preise der Produkte in die allungünstigste Lage gekommen sind." A bill for the re-introduction of silver as legal tender was also proposed in February 1889 filed by leading members of the Reichstag including Graf Julius von Mirbach, Wilhelm von Kardoff, Ernst Leushner, see Deutscher Reichstag (1889b).

[19] National Monetary Commission (1910, p. 358) in interviews with Otto von Glasenapp, Vice-President of the Reichsbank, and Karl von Lumm, Director, of the Reichsbank: "The Reichsbank is not in favour of such measures [steps to prevent exports of gold] and it is very sure that such a thing will not happen again. We consider this measure absolutely wrong."

It was sensitive to public concerns about the bank's commitment to convertibility.[20] The Reichsbank considered important its ability to influence the market discount rate as quoted on the Berlin stock exchange and henceforth money market conditions generally.[21] The Reichsbank acknowledged the importance of the Bank of England in its rate setting decisions.[22]

The Privatnotenbanken pledged a policy of supporting the Reichsbank. At the same time they pursued their own objectives with a focus on local developments.[23] They acknowledged the importance of following the discount rate of the Reichsbank

[20] Von Dechend defended in the Reichstag the decision to increase the discount rate with reference to public perception about the strength of the mark (Deutscher Reichstag, 1881b, p.121): "[…] [W]ir haben den Diskontsatz heraufgesetzt nicht deshalb, weil uns die Mittel in Folge der Diskontierung unter Banksatz ausgegangen sind, auch nicht aus Furcht vor der Entziehung von Gold, sondern hauptsächlich um dem Treiben der Presse entgegen zu treten, als wenn unsere Valuta in Frage wäre."

[21] National Monetary Commission (1910a, pp. 136-137): "There can be no doubt that the discounting of bills below bank discount has by careful management helped to maintain for the Reichsbank the survey of bill circulation so necessary for a central bank of issue. The easily regulated private rate of discount enabled the Bank to be in constant touch with the money market and to influence the movements of the latter […]. Only when the discount transactions of the Bank are heavy in times of easy money, can we be sure, in case of a threatened drainage of gold or under other circumstance which make the raising of the interest rate desirable, that the Bank will exercise the desired effect on the discount rate of the Bourse [Berlin stock exchange]."

[22] See e.g. National Monetary Commission (1910a, p. 254) on the discount rate of the Reichsbank during the last quarter of 1889: "The [Reichsbank] was thus urged to follow the example of the Bank of England which in the last days of the year had raised its discount rate to 6 percent, although the London discount was lower than Berlin."

[23] Badische Bank (1880): "An der aufsteigenden Bewegung, welche das Jahr 1879 im Überigen charakterisierte, konnte unser Institut keinen Theil nehmen, da ihm die Bestimmung zufällt, seine Mittel vorzugsweise dem Diskont- und Lombardverkehre auf dem heimischen Gebiete in Bereitschaft zu halten." Bayerische Notenbank (1881): "Diese decentralisierte Thätigkeit (durch ein Netz an Zweiganstalten), mit welcher wir unsere volkswirtschaftliche Aufgabe am besten zu erfüllen glauben […]."

in particular through guarding against a gold outflow.[24] The institutions considered important to maintain a stance independent of the market discount rate.[25]

The principal operations of the Reichsbank and Privatnotenbanken was the discounting of bills of exchange. The acceptance of the bills of exchange was at the pre-announced discount rate. The operations were funded predominantly by the issuance of bank notes. Issuance was a function of meeting stipulated reserve requirements and the unreserved note quota. The breaching of the note quota attracted a note tax of 5 percent (Notensteuer) on the amount of unreserved notes in excess of the limit.[26] While the note quotas allowed banks to pursue expansionary monetary policy, that is, the issuance of unreserved note constituted a net injection of money, it also served to signal imprudent bank behaviour.

The Reichsbank was a public-private institution. Its shareholders were private individuals. The management of the institution was conducted by civil servants, the President, appointed by the Emperor for life, Vice-President and Directors, constituting the Directorate (Direktorium). The Imperial government de jure supervised its operations through the Advisory Board (Curatorium) made of senior government officials and political representatives from the Upper Chamber of Parliament (Bundesrat). The shareholders of the bank, constituted as the Central Committee (Ausschuss), are consulted on monetary policy measures but the final

[24] Bank für Süddeutschland (1889): "[…] die um diese Zeit erfolgte Erhöhung der offiziellen Rate der Reichsbank von 3% auf 4%, welche von diesem Institut—unter gleichzeitiger Einstellung seiner Discontirungen zum Privatsatz—vorgenommen worden ward, um der damals befürchteten Gefahr eines starken Goldexports wirksam zu begegnen."

[25] Bayerische Notenbank (1887): "Unsere decentralisierte Verfassung macht es uns möglich, uns von den niedrigen Privatsätzen der Börsenplätze einigermaßen unabhängig zu machen, ohne dass wir hierbei die auf die Qualität der Wechselbestände gebotene Rücksicht zu vernachlässigen brauchten."

[26] The Reichsbank repeatedly exceeded its non-reserved note issuance quota. Similarly, e.g. the Sächsische Bank paid the note tax every year in 1876-86.

say was with the Directorate. The Reichsbank maintained relative autonomy in its day-to-day operations and interventions by the government were very rare.[27] The institution saw itself as guided by public interests.[28] The Privatnotenbanken were private institutions normally with a profit sharing arrangement with their home federal states.

The implementation of monetary policy in 1876-80 occurred against the background of a gradual adoption of the gold standard and persistent perceived commitment problems to the gold standard.[29] The Reichsbank saw a decline in its gold holdings from a local high of 346 million mark in January 1876 to a local low of 151 million mark in October 1881.[30] The Reichsbank through 1886 remained on average in 1876-86 at 47 percent of its unreserved note quota compared with 80 percent for the Privatnotenbanken.[31]

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[27] National Monetary Commission (1910, p. 336) in interviews with Otto von Glasenapp, Vice-President of the Reichsbank, and Karl von Lumm, Director, of the Reichsbank: "In the Chancellor lies supreme power, although he has never exercised it but once in the history of the Bank."

[28] National Monetary Commission (1910, p. 343) in interviews with Otto von Glasenapp, Vice-President of the Reichsbank, and Karl von Lumm, Director, of the Reichsbank: "Our shareholders have secondary consideration."

[29] National Monetary Commission (1910a, p. 208): "The extent and difficulty of the Reichsbank's tasks at its establishment, an appreciation of which is essential in forming an opinion on its discount policy, are attributable to the development of German national economic activity in the last twenty-five years, to the incomplete state of German coinage, at that time still in the process of transformation, finally, to the Reichsbank's position in the whole German bank system, and to the apparent attempts of private banks of issue [Privatnotenbanken] to make difficult the execution of its policy."

[30] Data from Reichsbank (1900).

[31] National Monetary Commission (1910a, pp. 215-216): "In conjunction with the system of note tax, the following situation arises: since private banks of issue can shift to the Reichsbank each increased call for money, they are able to use the tax-free note contingents assigned to them up to the limit, in times of a quiet demand for money, by bidding below the discount rate of the Reichsbank, without fearing excesses of note contingent therefrom, and the private banks of issue have made use of this possibility to a great extent. The Reichsbank, on the other hand, which alone bears all fluctuations in the German money demand, must always hold, even in quiet times, such a strong reserve that it can meet the great fluctuations of all German money demands, although its average uncovered note circulation has in a number of years been less than that of the private banks of issue."

3. Methodology, data and statistical analysis

The identification of the monetary policy reaction function aims to establish how the Reichsbank set its discount rate and altered its reserve ratio on the basis of changes in key economic, external and market variables. The paper follows Clarida and Gertler (1996) for the identification of the empirical relationship between changes in the Reichsbank's policy instruments and changes in relevant economic and market variables.[32] The usual caveats for estimating a monetary policy reactions hold. The identification of the set of information to which the Reichsbank responds is problematic amid the lack of sufficient knowledge about the true information set, including the use of intermediate targets, and significantly constrained by data availability. The problem of simultaneity between the policy instrument and the information set, as the information set is influenced by the policy instrument and vice versa, necessitates the imposition of restrictions on the contemporaneous interactions, that may not reflect the true interactions, between the policy instrument and the economic and market variables.

The paper assumes that the monetary policy formulation of the Reichsbank and Privatnotenbanken was akin to a backward looking Taylor-rule. The Reichsbank repeatedly indicated that it reacts to current and past events. The Taylor rule, a reaction function linking the policy instrument to movements in endogenous variables, e.g. inflation, can be interpreted as representing the

[32] Clarida and Gertler (1996) analyse the policy reaction function of the Bundesbank, the Reichsbank's successor institution.

contemporary version of the rules of the game. The backward looking Taylor rule, relies on past values of the endogenous variables, is estimated to respond best to the Reichsbank's policy formulation amid the narrative accounts of Reichsbank senior staff.[33]

The estimation of the monetary policy reaction function of the Reichsbank rests on the assumption that the Reichsbank adhered to its mandate and pursued strict convertibility and credit accommodation while maintaining high prudential standards. The convertibility is upheld by guarding against gold outflows that rests on the bank's gold reserve and can be approximated by differences in interest rates principally with the Bank of England. Its principal instrument is the discount rate but its monetary policy stance is also reflected in its reserve ratio, being the ratio of metal reserves to bank notes in circulation, where a high reserve ratio indicates a monetary policy tightening. The Privatnotenbanken are assumed to pursue principally domestic objectives of credit accommodation to maximise profits.

The paper uses monthly balance sheet data of the Reichsbank and Privatnotenbanken from March 1878 through December 1890. The data were digitalised as published in the monthly statistical series Central-Blatt für das Deutsche Reich by the Imperial Ministry of the Interior (Reichsamt des Inneren, 1875-1890).[34] The bank data comprise the reserve ratios. The gold stock of the Reichsbank was estimated on the basis of intra-annual data published by the

[33] On the narrative account, see reference to Member of the Reichsbank Directorate Koch above and e.g. footnote 17. For an explanation of the Taylor rule, see e.g. Asso et al. (2010) and Carlstrom and Fuerst (2000).

[34] The Reichsbank and the Privatnotenbanken under the publication obligations of the bank act were required to publish main balance sheet items on a weekly basis in the Deutscher Reichsanzeiger und Preußischer Staatsanzeiger (see Appendix for an example of a disclosure notification) that were compiled on a monthly basis in the Central-Blatt.

Reichsbank (Reichsbank, 1900) and monthly data on metal reserves as published in Central-Blatt für das Deutsche Reich.[35] The data cover the Reichsbank and the largest Privatnotenbanken. The discount rates of the Reichsbank, Bank of England and the Berlin market discount rate were digitalised as published by the Reichsbank in Vergleichende Notenbankstatistik (Reichsbank, 1925).

The economic variables include tax revenue and wholesale prices. Economic activity is approximated by monthly tax revenue data comprising German federal taxes on salt (Salzsteuer) and beer (Brausteuer) and were digitalised as published monthly from March 1878 in the Central-Blatt für das Deutsche Reich.[36] The tax revenue exclude customs revenues due the important increase in tariffs in 1879 with the custom tariff act (Zolltarifgesetz) that may not warrant consistency of the revenue base over the observation period. The wholesale prices are also used as proxy for domestic price developments cover 10 items of agricultural and industrial products for Germany digitalised as published monthly from January 1879 in Monatshefte zur Statistik des Deutschen Reichs (Kaiserliches Statistisches Amt, 1877-1890).

The analysis distinguishes between the periods 1876-86 and 1887-90. The assumed break in the relationship of the series rests the adoption in 1887 of the discount rate convention between the Reichsbank and the Privatnotenbanken to

[35] The Reichsbank did not publish ist gold stock. See e.g. von Dechend explaining to the Reichstag that both the federal government and the Reichsbank do not consider it appropriate to distinguish between gold and silver holdings (Deutscher Reichstag, 1889a, p. 600).

[36] The federal states of Baden, Bayern and Württemberg were exempt to contribute to the spirits (Branntweinsteuer) and beer duties. The spirits duty is not included as the three states started contributing to the spirits duty from 1887 onwards. Other indirect taxes on sugar (Rüberzuckersteuer und Zuckermaterialsteuer) and tobacco (Tabacksteuer) have been omitted due to strong dependence on harvest outcomes.

harmonise the use of the official discount rate as offered by the Reichsbank throughout the system.[37] The periods also coincided with Germany's business cycles with a trough in August 1886 and peak in January 1890.[38]

The development of inland taxes and wholesale prices in Germany in 1878-90 illustrate the difficult economic environment that emerged since the 1873 crisis. The economic developments in Germany in 1876-90 were marked by stagnation, severe deflation and recovery (Figure 1). The period followed rapid economic growth in 1870-74 during the foundation years of the German Empire and preceded sustained strong growth through 1900.[39] In 1870-74, output grew 4.4 percent on average per year. The growth of the German net social product slowed to 0.6 percent in 1875 and declined by 0.6 percent in 1876 and 1877 and following a brief rebound in 1878 declined again in 1879-80. In 1880, output was broadly similar to the level of 1874 and a profound pessimism dominated general sentiment amid the lack of

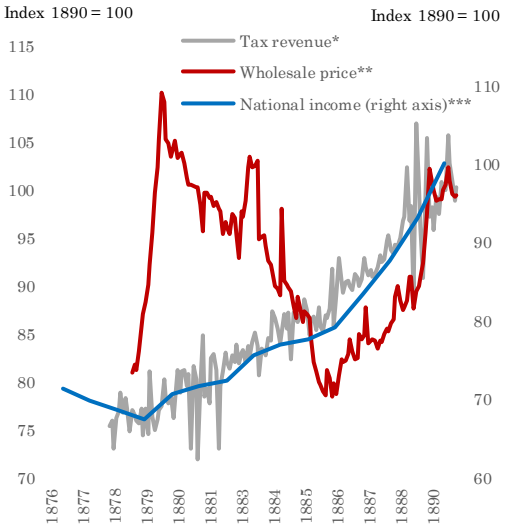
[37] The Reichsbank agreed in 1887 with the Privatnotenbanken that the latter will not discount at less than ⅛ percent below the prime discount rate of the Reichsbank as long as it does not exceed the Berlin stock exchange discount rate by more than ¼ percent and in the event of a gold drain not to discount by less than ⅛ percent below the official discount rate of the Reichsbank; see e.g. Heil (1900). This agreement was gradually abandoned by different Privatnotenbanken from 1888 onwards; see e.g. Der Deutsche Oekonom (1888). The harmonisation of all discount rates became law with the 1899 bank renewal act by which the Privatnotenbanken from January 1901 were obligated not to discount below the official rate of the Reichsbank when the official rate was at or exceeded 4 percent and not to discount below the Reichsbank rate by more than ¼ percent and not to discount below the Reichsbank's prime discount rate by more than ⅛ percent.

[38] Gordon (1952, p. 562) shows for Germany business cycle turning points troughs in January 1879 and August 1886 and peaks in January 1882 and January 1890. However, the peak in January 1882 was relatively minor and is ignored producing two cycles through 1886 and through 1890 consistent with Hoffmann (1965).

[39] For a detailed description of economic developments in nineteenth century Germany see e.g. Borchardt (1982), Carr (1969), Hoffmann (1965), Ogilvie and Overy (2003), Wehler (1985), Pierenkemper and Tilly (2004).

anticipation of the duration of the perceived crisis.[40] In 1881-86, the economy stabilised amid weak growth and initiated a sustained though uneven recovery from 1887 onwards.[41] The price deflation was prolonged with wholesale prices in 1890 still below their 1860 level and significantly lower than their 1873 local peak. The price and output trends were broadly consistent with international economic developments.[42]

Figure 1. Taxes and prices



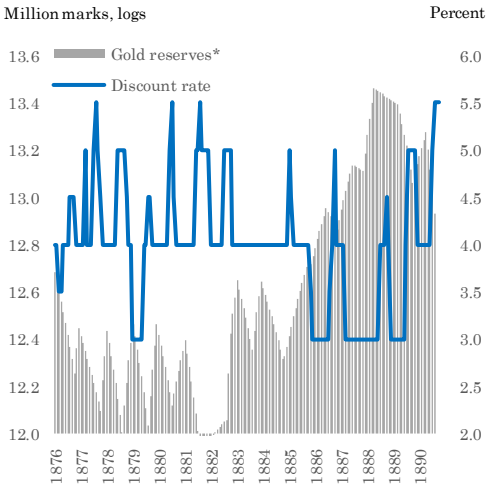
Source: Central-Blatt für das Deutsche Reich; Hoffman(1965); Statistik des Deutschen Reichs. Seasonally adjusted. *Federal revenue of salt (Salzsteuer) and beer taxes (Brausteuer). **10 items. *** Nettoinlandsprodukt.

[40] Wehler (1985, p. 33) describes the stagnation as follows: "The downturn in the economy halved the growth rates over a six-year period and led temporarily even to stagnation and a fall in production in some sectors. This was accompanied by a generally constant price deflation. The depression thus constituted the longest and most sudden interruption to German industrial growth up to that point."

[41] The timing of Germany's business cycle remains controversial amid poor data availability. Hoffmann (1965) offers a comprehensive review of economic developments in nineteenth century Germany; he assigns 1874-1880 as a period of stagnation or decline and 1886-1890 as a period of above-average growth. Burns and Mitchell (1946) present an early schedule for Germany's business cycle during the second half of the nineteenth century that is close to Hoffmann (1965) and also Wehler (1985) and has also been supported by Uebele and Ritschl (2009).

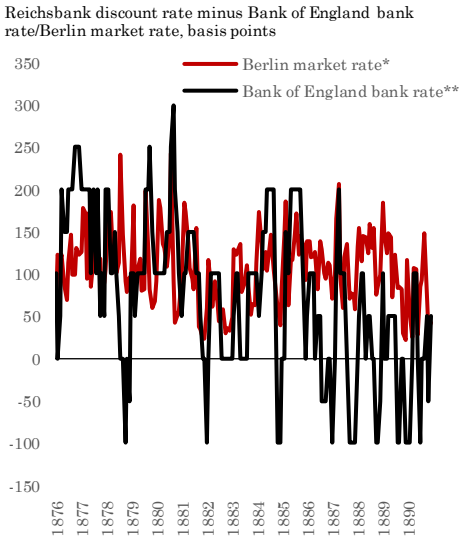
[42] Burns and Mitchell (1946) show that the peak and trough points for calendar years for the U.S., France, U.K. and Germany were 1873-78, 1873-78, 1873-79 and 1872-78, respectively and 1882-85, 1882-87, 1883-86 and 1882-1886, respectively.

Figure 2. Discount rate and gold



Source: Central-Blatt für das Deutsche Reich. * Linearly interpolated.

Figure 3. External and market rates



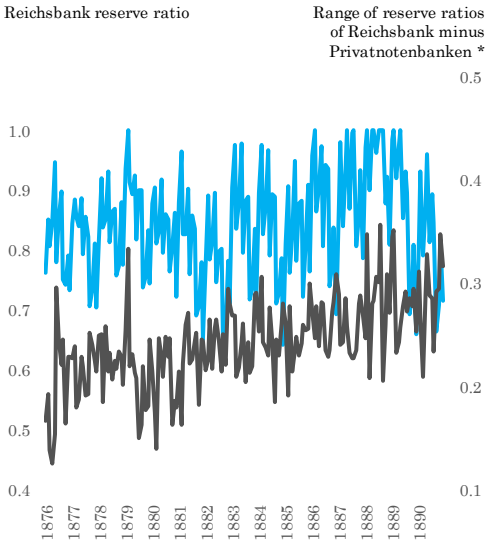
Source: Reichsbank (1925). *Reichsbank rate: end of period, Berlin market rate:period average. ** End of period.

The implementation of monetary policy of the Reichsbank in 1876-90 was marked by one period of relatively high discount rates and one of low discount rates. The Reichsbank maintained on average a discount rate in 1876-86 of 4.1 percent compared with 3.7 percent in 1887-90. The higher discount rate period was

accompanied by relatively low levels of gold reserves. The estimated gold stock on average in 1876-86 was 275 million mark compared with 559 million mark in 1887-90 (Figure 2).

The Reichsbank discount rate normally was the highest rate in Germany. The market discount rate quoted at the Berlin stock exchange was representative of prime borrowers and attracted a lower average rate. The rate spread between the Reichsbank discount rate and the Berlin market rate was 100 basis points in 1876-86 and 110 basis points in 1887-90. The Reichsbank maintained on average a higher discount rate than the Bank of England in 1876-86 of 100 basis points. The rate spread declined to zero in 1887-90 as the Reichsbank reduced its average discount rate while the Bank of England increased its average bank rate (Figure 3).

Figure 4. Reserve ratios



Source: Central-Blatt für das Deutsche Reich. * Badische Bank, Bank für Süddeutschland, Bayerische Notenbank, Sächsische Bank, Württembergische Notenbank.

The reserve ratios of the Reichsbank and Privatnotenbanken show marked differences in the levels of reserve ratios and increasing divergence in the system

between 1876 and 1890. The Reichsbank maintained the highest reserve ratio of 0.8 while the Badische Bank and Bank für Süddeutschland had the lowest of 0.4 on average in 1876-90. The reserve ratio of the Reichsbank shows important variations consistent with the frequent changes in the discount rate. The level of the reserve ratio was broadly constant in 1887-90 compared with 1876-86.

The adherence to the rules of the game of the gold standard by the Reichsbank can be approximated by simple descriptive statistics of the different definitions for the rules of the game including the negative correlation between the discount rate and the reserve ratio, the positive correlation between domestic assets and gold reserves and the correlation between the negative correlation between the discount rate and cyclically adjusted bank assets (Table 1).[43] The high negative correlation between domestic assets and the reserve ratio seems to confirm the first definition, indicating that the Reichsbank adjusted upwards its discount rate in the event of a decline in the reserve ratio. The second is also supported amid a positive correlation between domestic assets and gold reserves; it holds similarly amid a negative correlation between the discount rate and gold reserves. The third definition is ambiguous in the observation period. For the period 1876 to 1886, the discount rate declines with an increase in domestic assets adjusted cyclically by dividing domestic assets by seasonally adjusted tax revenues as a proxy for business cycle movements. For the period 1887-90, the discount rate increases with the cyclically adjusted assets. All three definitions affirm a different behaviour of the Reichsbank in 1876-86 compared with 1887-90 that except for the reserve ratio can be associated with a loosening of the rules of the game by the Reichsbank during the second period.

[43] See above reference to Sommariva and Tullio (1986).

Table 1. Rules of the game

Reichsbank	Reserve ratio **	Gold reserves ***	Domestic assets adjusted anti-cyclically ****
Correlation coefficient			
1876-86*			
Domestic assets		0.54	
Discount rate	-0.46	-0.60	-0.24
1887-90*			
Domestic assets		0.45	
Discount rate	-0.69	-0.35	0.25

Source: Central-Blatt für das Deutsche Reich; Reichsbank. *Monthly observations. **1876-90, notes in circulation to metal reserves. ***1876-90, estimated on basis linear interpolation of data for high, low and average annual gold stocks. ****1878-90 and 1878-86, bank assets divided by seasonally adjusted federal tax (beer and salt) revenues.

The paper tests the hypothesis that the Reichsbank is influenced by economic variables including output and domestic price developments, the market discount rate, its gold stock and the Bank of England bank rate distinguishing developments from March 1878 through December 1886 and from January 1887 through December 1890. The paper also tests the hypothesis that the Privatnotenbanken supported the Reichsbank against gold outflows.

The model estimation is based on a short-run SVAR approach that allows to make explicit identifying assumptions about the short-term causal contemporaneous relationships between the endogenous variables (see Appendix for the model specification). The SVAR represents a linear combination of a vector of endogenous variables, the variables of interest and their respective lags in addition to coefficient matrices and a random error vector.

The SVAR model is based on the identification of the errors of the system that are interpreted as exogenous shocks. The structural shocks of the model are identified by imposing restrictions to allow making inferences based on the dynamic impact of mutually uncorrelated (orthogonal) shocks. The restrictions are taken in

line with Clarida and Gertler (1996) to impose the ordering of the variables in the model and rest on the assumption that policy shocks have no contemporaneous impact on the economic variables. The dynamic effects of the orthogonalized shocks are analysed with the impulse response functions (IRFs) that represent the responses of the variables with respect to innovations in the errors of the system as one-step to multiple steps ahead forecast errors. The paper employs only relatively few restrictions on the model and will not use the two-pronged approach in Clarida and Gertler (1996) amid the lack of sufficient prior information.

The estimation comprises two models. The first model measures the monetary policy reaction function of the Reichsbank and includes in the following order: Log of tax and custom revenue, log of wholesale price index, Bank of England bank rate, Berlin market discount rate, Reichsbank interpolated gold stock, and reserve ratio. The ordering of the market discount rate before the Reichsbank's discount rate rests on the narrative account.[44] The model will also be estimated using the Reichsbank discount rate in lieu of the reserve ratio. The estimation with the Reichsbank discount rate is presented here amid more conclusive results. The second model measures the monetary policy reaction function of the Privatnotenbanken with the following order: Log of tax revenue Berlin market discount rate, Bank of England bank rate, Reichsbank discount rate, the reserve ratio of a Privatnotenbank to reflect the variables important for the formulation of the Reichsbank's policy stance. The wholesale price index was dropped from the second model amid its inclusive results in the first model. The data series used are not adjusted for seasonality to avoid the common seasonality pattern to influence the estimation. In general, the main results are robust to different orderings of the variables.

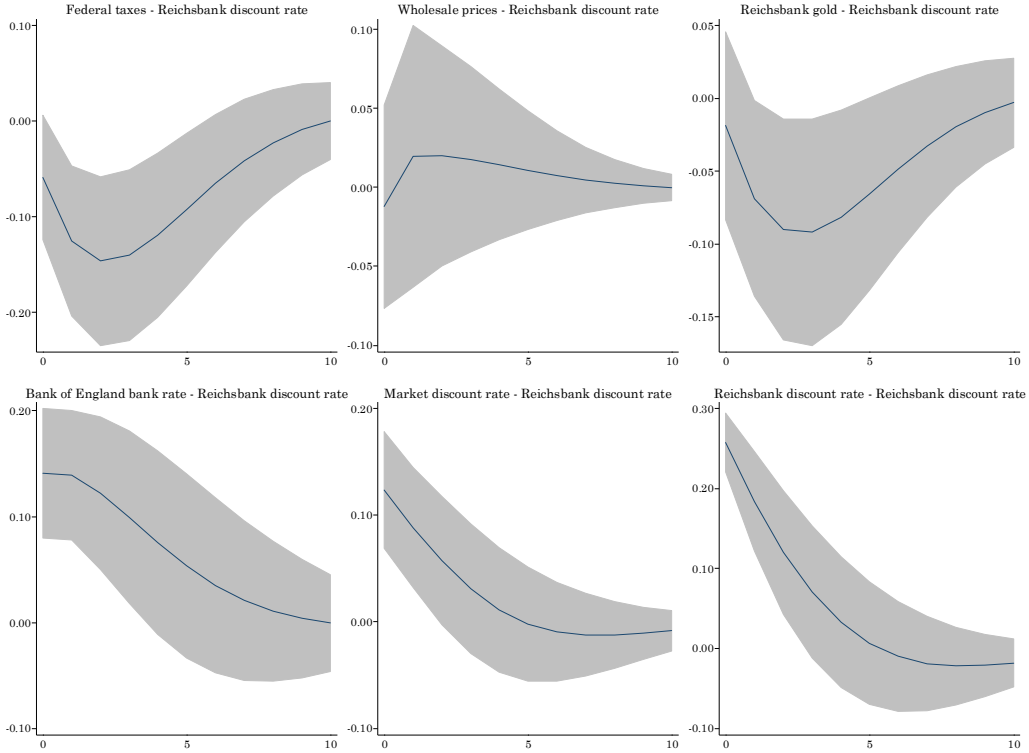
[44] See footnote 21 on the Reichsbank's view about the need to "be in constant touch with the money market."

The estimation of the Reichsbank policy reaction function distinguishes two period 1878 to 1886 and 1887 to 1890. For the Privatnotenbanken only the estimation for the first period is presented as, the distinction between the two periods has not returned significantly different results as for the entire period 1878-90.

The series are found to be stationary using an augmented Dicky-Fuller test except for the Reichsbank gold series and wholesale price index. The Reichsbank gold reserve and wholesale price index were made stationary by taking first differences of the logs of the series. The identification of the number of lags of y_t to include in the VAR is performed using the Hannan and Quinn's information criterion (HQIC) and the Schwarz Bayesian information criterion (SBIC). The appropriate lag length based on HQIC and SPIC is 1 and a 1 lag structure is chosen.

The estimation of the policy reaction of the Reichsbank for 1878-86 shows that the bank in 1878-86 was guided predominantly by external and market factors. The IRFs show that the Reichsbank's discount rate was adjusted upwards with a lag to declines in its gold reserve with the gold reserve reversing broadly to its pre-shock level within 10 months consistent with the notion that the Reichsbank adhered to the rules of the game. The Reichsbank discount rate also responded positively to an increase in the Bank of England bank rate and the impulse from the Bank of England lasted up to 10 months. The Reichsbank equally responded to promptly shocks in the market discount rate sufficient to cause a decline in the market discount to its level prior to the shock within 5 months. The Reichsbank discount rate responded pro-cyclically to shocks to tax revenue but not to shocks to wholesale prices (Figure 5).

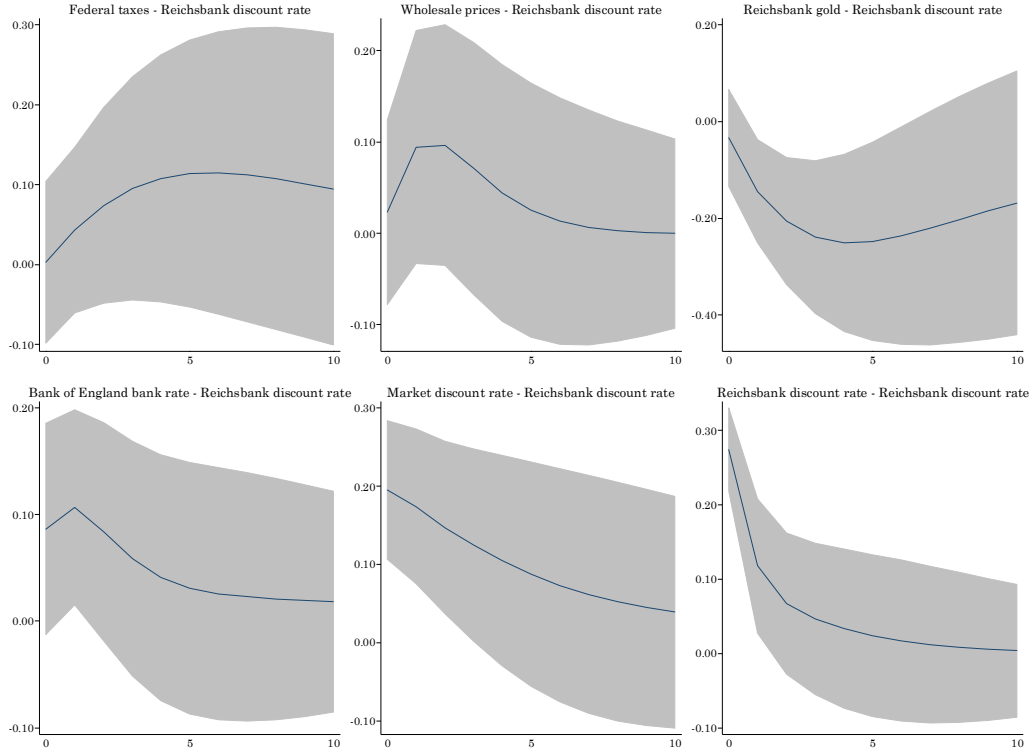
Figure 5. Reichsbank policy reaction function 1878-86



STATA 14.1 output. 95 percent confidence interval, 10 steps. SIRF, impulse variable - response variable. March 1878-December 1886.

The policy reaction function of the Reichsbank for the period 1887-90 indicates a shift towards domestic objectives. The Reichsbank responded contracyclically albeit not significantly to shocks to tax revenues. The response to wholesale price movement was also more pronounced though equally not statistically significant. Its discount rate responded significantly to shocks to the market discount rate and to shocks to its gold reserves. Shocks from the Bank of England bank rate played a significantly lesser role and for only a brief period. The discount rate adjustments was more abrupt than in the previous period as shown in the narrow confidence interval around the responses to shocks to the Reichsbank discount rate and to shocks to its gold reserves during the first few steps (Figure 6).

Figure 6. Reichsbank policy reaction function 1887-90



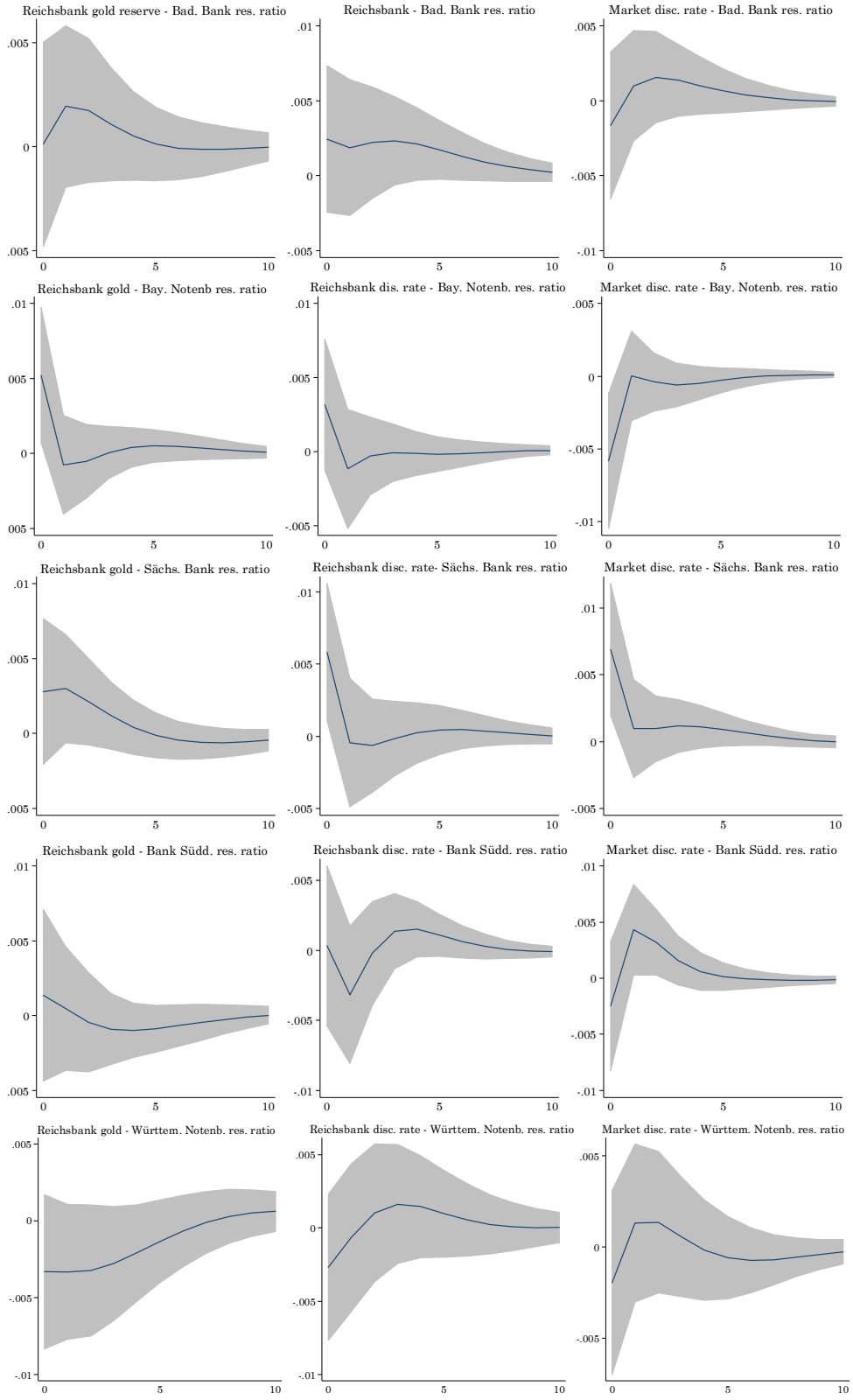
STATA 14.1 output. 95 percent confidence interval, 10 steps. SIRF, impulse variable - response variable. January 1887-December 1890.

The changes in the policy reaction function between 1879-86 and 1887-90 illustrate a shift towards domestic policy concerns while strengthening adjustment under the gold standard rule. In 1887-90, the Reichsbank responded more neutrally to counter-cyclically to adverse economic activity and price movements as shown in the two upper left charts of Figure 5 and Figure 6. The Reichsbank also responded less to shocks in the market discount rate as shown in the lower middle chart of Figure 5 and Figure 6 amid a wider confidence band compared with the period 1878-86. At the same time, shocks to the Bank of England bank rate in 1887-90 brought no longer a significant response from the Reichsbank as shown in the lower left chart of Figure 5 and Figure 6. The Reichsbank in 1887-90 maintained a significantly firmer response to shocks to its gold reserve as illustrated in the lower right chart of Figure 5 and Figure 6. The more assertive policy response of the

Reichsbank in 1878-86 is also illustrated by the more rapid adjustment of its discount rate as highlighted by the narrower confidence band during the first few steps in the lower right chart of Figure 5 and Figure 6.

The policy reaction functions of the Privatnotenbanken in support of the Reichsbank policy stance show no significant or very limited responses. The responses vary to similar shocks in the Reichsbank's gold reserve, discount rate and the market discount rate affirming the relative autonomy of the Privatnotenbanken. The absence of significant responses to variables important for the formulation of the Reichsbank's policy stance indicates that the Privatnotenbanken have not actively supported Reichsbank policy (Figure 7). The lack of response in the liquidity ratios of the Privatnotenbanken to shocks in the Reichsbank discount rate, as shown in the middle charts of Figure 7 is also consistent with the fact that the Privatnotenbanken conducted discount rate operations mostly at private discount rates below the official Reichsbank discount rate. The period 1887-90 shows a similar pattern.

Figure 7. Privatnotenbanken policy reaction function 1878-86



STATA 14.1 output. 95 percent confidence interval, 10 steps. SIRF, impulse variable - response variable. March 1878-December 1886.

4. Conclusions

The present paper shows that the Reichsbank in 1878-90 had followed the rules of the game of the classical gold standard. The findings demonstrate that for the sub-period 1887-90, the Reichsbank shifted emphasis to domestic policy concerns while strengthening its gold reserve adjustment. This suggests that the Reichsbank bolstered its commitment credibility to establish greater policy autonomy. The reduced role of external interest rate shocks in 1887-90 seems to indicate that the international interest rate transmission mechanism was less pronounced than conventionally assumed. The paper also shows that the dual accommodation of national and international objectives under the gold standard affirms doubts about the relevance of the classical exchange rate trilemma. The Privatnotenbanken maintained largely operational autonomy and had not supported the Reichsbank including in guarding against adverse shocks to its gold reserve.

The Reichsbank was able to address though only modestly domestic policy concerns while strengthening commitment credibility through adopting swifter adjustment to adverse gold reserve shocks. This seems to affirm that the gold standard offered a framework compatible with the ability to accommodate domestic shocks. The perceived commitment credibility of the Reichsbank appears to have provided adequate insulation from the exchange rate trilemma.

The constrained applicability of the trilemma under the classical gold standard seems relevant for fixed exchange rate regimes. While a fixed exchange rate regime, similar to the classical gold standard, requires a central bank to

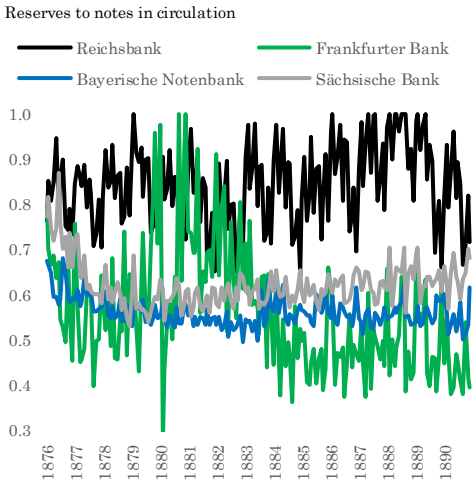
subordinate its domestic policy objectives to maintaining exchange rate parity, a credible fixed exchange rate commitment must not preclude the accommodation of domestic objectives.

Nineteenth century Germany supports the notion that the trilemma is only binding under insufficient perceived commitment credibility. For fixed exchange rates, this may suggest that the accommodation of domestic policy objectives can be achieved amid certainty that the exchange rate standard is sustained. For currency unions, it indicates that domestic policy objectives can be pursued if there is sufficient confidence that redenomination risk is small. In a broader context, nineteenth century Germany supports the view that the exchange rate is simply an outcome of economic policies. The trilemma seems more a function of policy credibility than of the incompatibility between fixed exchange rates, capital flows and monetary policy autonomy. Weak policy credibility can therefore reduce monetary policy autonomy even under flexible exchange rates.

Appendix

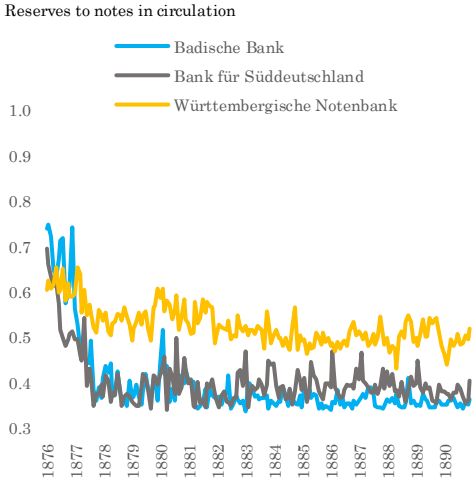
Reserve ratios

Appendix figure 1. Reserve ratios



Source: Central-Blatt für das Deutsche Reich.

Appendix figure 2. Reserve ratios (cont.)



Source: Central-Blatt für das Deutsche Reich.

Model specification

The short-run SVAR model used is specified on the basis of a structure matrix of the form AB.[45] The VAR specifies K variables as linear functions of p of their own lags and p lags of the other $K-1$ variables. A p-order VAR model $VAR(p)$ can be written as:

(1) $y_t = v + \Gamma_1 y_{t-1} + \cdots + \Gamma_p y_{t-p} + \epsilon_t$

where

$y_t = (y_{1t}, \ldots, y_{Kt})'$ is a $K \times 1$ random vector

Γ_1 through Γ_p are $K \times K$ matrices of parameters

ϵ_t is assumed to be the error term, that is,

$E(\epsilon_t) = 0$

$E(\epsilon_t \epsilon_t') = \Sigma$

Equation (1) can be rewritten after absorbing the constant v into the y_t vector and using the lag operator L and where I is the identify matrix:

(2) $y_t = \Gamma_1 L y_t + \cdots + \Gamma_p L^p y_t + \epsilon_t$

(3) $y_t = \left(I - \Gamma_1 L - \Gamma_p L^p\right)^{-1} \epsilon_t$

It can be shown that

(4) $y_t = I\epsilon_t + \Phi_1 \epsilon_{t-1} + \Phi_2 \epsilon_{t-2} \cdots = \sum_{i=0}^{\infty} \Phi_i \epsilon_{t-i}$

[45] See e.g. Amisano & Giannini, 1997. For the use of SVAR to analyse central bank behaviour and reaction to external shocks see e.g. Jeanne, 1995.

where $\Phi_0 = I$, which is the moving average representation and Φ are the IRFs.

The SVAR approach orthogonolises the error terms, i.e. finds new linear combinations of the error terms which are independent or orthogonal to each other. The SVAR is transformed to a new model such that the new errors e_t can be expressed as a function of the old errors ϵ_t where $A\epsilon_t = Be_t$ for some invertible matrices A and B and where A and B are chosen such that A and B are diagonal, then $\epsilon_t = A^{-1}Be_t$ and $e_t = B^{-1}A\epsilon_t$.

The identification is provided by placing restrictions on A and B where A is a lower triangular matrix with one on the diagonal and B a diagonal matrix and where A and B are nonsingular. The P matrix for the short run model is $P_{sr} = A^{-1}B$ obtained by imposing restrictions on A and B. Since Σ is symmetric, it has only $\{K(K+1)\}/2$ free parameters and so only $\{K(K+1)\}/2$ parameters may be estimated in an exactly identified P_{sr}. With $2K^2$ total parameters in A and B, the order condition for identification requires at least $2K^2 - K(K+1)/2$ restrictions be placed on those parameters.

The P matrix is constructed as the Cholesky decomposition of the error covariance matrix of the original VAR model with optional additional restrictions placed on the P matrix in terms of short-run restrictions on the contemporaneous covariances between shocks.[46] These restrictions are testable.

[46] The effect of the Cholesky decomposition can be replicated by defining A and B appropriately.

In the estimation of the model A and B are defined as matrices where a and b are freely estimated coefficients. The form of the A matrix imposes the recursive structure which orthogonolises the errors, while the diagonal B serves to scale the structural errors.

The estimation is performed with the lower triangular matrix A set such that all coefficients in the upper half are set to zero and all remaining coefficients in the lower half are freely estimated. The matrix is ordered based on conventional ordering provisions where the policy variable is ordered last as in Clarida and Gertler (1996).

The SVAR model on the basis of equation (1) is derived following equations (1) through (4) to rewrite the new model in its moving average representation as:

(5) $y_t = \sum_{j=0}^{\infty} \Theta_i e_{t-j}$

where $\Theta = \Phi_i P$ are the structural IRFs. The transformations of the errors allow to analyse the dynamics of the system in terms of a change to the structural errors e_t.

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