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The Determinants of the German Official Discount Rate and of Liquidity Ratios during the classical gold standard : 1876-1913

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and
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Internal Paper

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CONTENTS

Introduction

This paper analyses the factors which influenced the Reichsbanks' decisions to change the official discount rate from 1876, the year during which it started operations, to 1913. The main hypothesis tested is that the Reichsbank reacted systematically to changes in the liquidity ratios, the ratios of gold or metal holdings to its short term liabilities. To this end reaction functions which use changes in the discount rate as the dependent variable are estimated.

The paper also goes one step further by investigating the factors affecting changes in the liquidity ratios. It shows that changes in the differential between the official discount rate and the private discount rate in Berlin played a crucial role in determining changes in the liquidity ratios. It also shows that the changes in the differential were in turn influenced by the business cycle and by foreign interest rates. Thus three links are isolated in the transmission of the business cycle and the foreign interest rate to the changes in the discount rate: a) the link from the business cycle and the foreign interest rate to the differential; b) the link from the differential to the liquidity ratios and c) the link from the liquidity ratios to the official discount rate.

The paper is structured as follows: Section 1 presents a model of the working of the domestic monetary system during the gold standard from which the hypotheses subsequently tested are derived. Section 2 contains tests of these hypotheses namely, that the business cycle and the foreign interest rate determine the differential (Section 2a), that the differential determines liquidity ratios (Section 2b) and that liquidity ratios in turn determine the official discount rate (Section 2c). The empirical analysis confirms the hypotheses that changes in liquidity ratios were the main determinants of the official discount rate and that changes in the differential were the main determinants of liquidity ratios. The implications of the analysis for the working of the gold standard in Germany are summarized in Section 3. In particular the nature of the automatic transmission of impulses from the business cycle and the foreign interest rate to the discount rate is analyzed.

1. The determinants of the official discount rate in Germany.

This Section focuses on the factors affecting changes in the official discount rate of the Reichsbank. Bloomfield (1959) and Goodhart (1972) advanced the hypothesis that during the gold standard changes in the official discount rate were determined by changes in the liquidity ratios of the Central Bank. Bloomfield showed graphically that there was a negative relationship between official discount rates and the liquidity ratios for most gold standard countries, while Goodhart regressed the discount rate of the Bank of England on its liquidity ratio using annual data.

This paper tries to carry the analysis of the factors affecting the official discount rate one step further by also analysing the determinants of changes in the liquidity ratios. A model is developed showing that changes in the liquidity ratios are determined by fluctuations of the differential between the more flexible market discount rate in Berlin and the official discount rate. The former is the interest rate at which commercial banks in Berlin discounted short term papers. The model also shows that changes in the differential are influenced by the foreign interest rates and the position of the economy in the cycle, both of which can be considered, for the purpose of the analysis of the short run discount rate policy of the Reichsbank, as exogenous variables or variables determined by past policies.

Let the symbol Δ indicate a first difference, BU currency in circulation, SL sight deposits of the public at the Reichsbank, p the price level, y real income, i the private short term discount rate in Berlin, G gold holdings, S silver and other metal holdings, and N notes issued by the Reichsbank. A superscript r stands for the Reichsbank and a superscript p for the public.

The demand function for currency in circulation and sight deposits at the Reichsbank is assumed to depend on the price level, real income and the private discount rate in Berlin (equation 1):

$$(1) \quad BU + SL = pf(y,i)$$

The supply of currency is defined as the sum of monetary gold, silver and other metals (GP) and currency issued by the Reichsbank and held by the public (N):[1]

$$(2) \quad BU = GP + N$$

In the model presented here the banking system and the nonbanking public have been consolidated. In principle it would be useful to keep them separate and to test whether the data justify the consolidation. The demand for gold, silver and Reichsbank notes by commercial banks may be influenced differently by interest rates and the business cycle than the demand by the non-banking public. Furthermore the demand for gold and silver by commercial banks was probably influenced by the amount of loans and discounts outstanding. However the existing data do not allow this disaggregation.

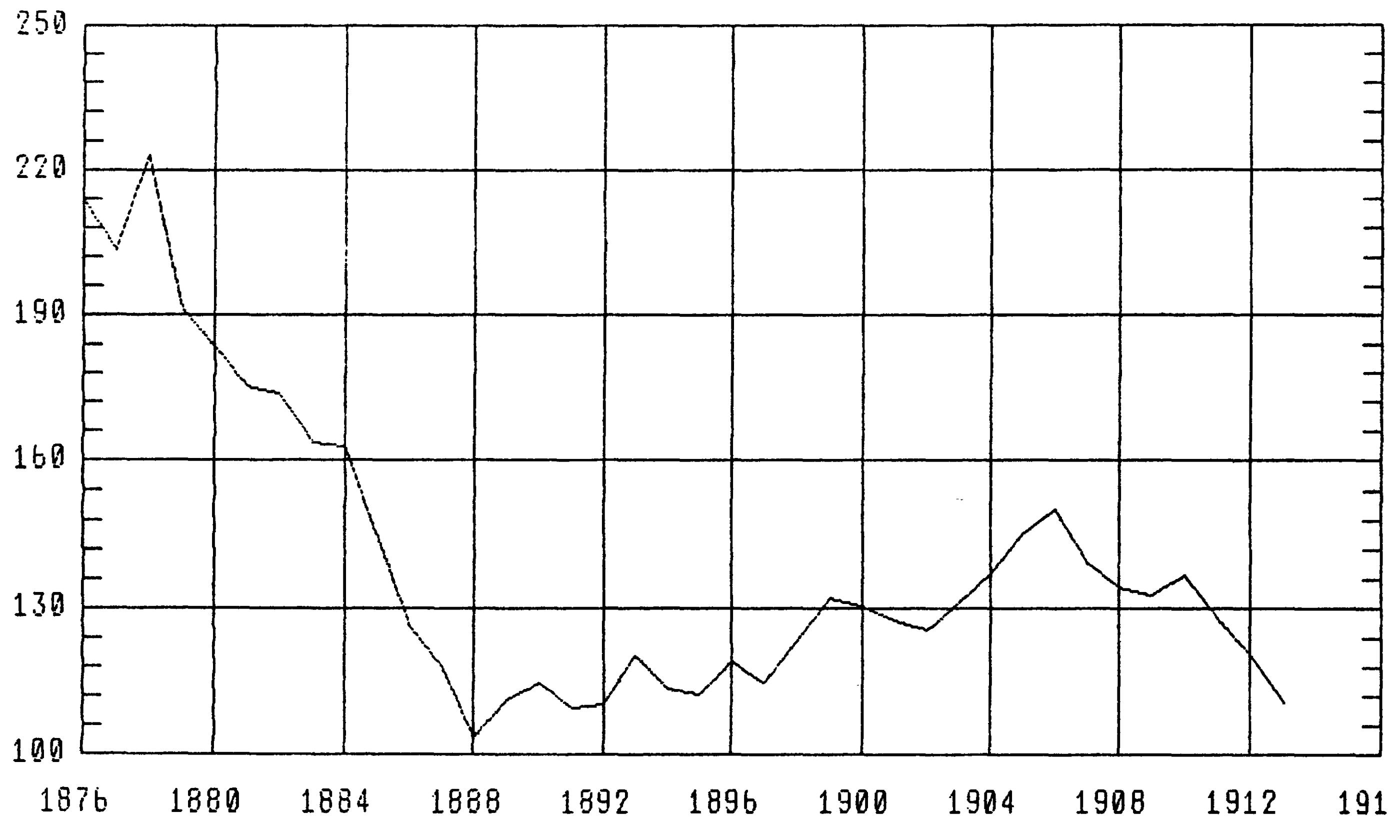
Equation (3) states that the proportion of metals that the public desires to hold is a constant fraction of its holdings of notes and sight deposits at the Reichsbank. Equation (3) implies that the public is not indifferent with respect to the composition of its currency and sight deposit holdings. Increased world production of gold changed however the desired ratio in the long run. The share of gold and silver holdings to currency issued by the Reichsbank and sight deposits at the Reichsbank fell from 214 per cent in 1876 to 103 per cent in 1888 during the period of gold scarcity. It reached a peak of 150 per cent in 1906, as world gold production was becoming more abundant (Chart 1). The changes in the ratio seemed relatively insensitive to the short run German business cycle and interest rate changes, except maybe in the period from 1888 to 1897. As this paper deals with short run fluctuations, equation (3) seems therefore a plausible simplifying assumption.

$$(3) \quad \frac{GP}{N + SL} = a_1$$

(1) Notes issued by other issuing banks are neglected here for simplicity.

CHART 1 : Ratio of gold and silver in private circulation to currency issued by the Reichsbank and sight deposits at the Reichsbank, 1876 - 1913 1).

(in per cent)



1) Using the symbols defined in the text the ratio is defined as: $\frac{G^P}{N + SL} \cdot 100$

Equation (4) states that German net foreign financial assets (K) depend on the difference between the foreign private interest rate and the private discount rate in Berlin.

$$(4) \quad K = a_2 + a_3(i^f - i) \qquad a_2 > 0$$

where i^f stands for the foreign interest rate. Equation (5) states that the cumulated current account surpluses are equal to the sum of gold and silver holdings of the Reichsbank (G^r) and the public plus net foreign financial assets of Germany. The cumulated current account surplus is assumed to be exogenous to keep the model as simple as possible.

$$(5) \quad \int C = G^r + G^p + K$$

An additional behavioural equation of the privàte sector explains the discounting of bills at the Reichsbank:

$$(6) \quad DA = a_4 + a_5(i - i^d) \qquad a_5 > 0$$

Where DA is the stock of bills discounted by the Reichsbank and i^d the official discount rate of the Reichsbank. The Reichsbank's balance sheet is given by:

$$(7) \quad DA + G^r = N + SL$$

Finally, equation (8) defines the liquidity ratio of the Reichsbank as the ratio of metal holdings to total short term liabilities:

$$(8) \quad l = \frac{G^r}{N + SL}$$

and equation (9) states that the official discount rate of the Reichsbank depends on the liquidity ratios:

(9) $i^d = a_6 - a_7 l$ $\qquad a_7 > 0$

The system of 9 equations contains 9 endogenous variables: BU, (SL + N), i, GP, DA, G^r, l, K, i^d where the division of gold and silver holdings of the Reichsbank and the private sector, as well as of N + SL is not determined by the model. The exogenous variables are p, y, i^f, $\int C$. The above system can be solved as follows.

Consider first the block of equations (1) - (5). By successive substitutions the 5 equations can be reduced to 2 equations. Assuming for the moment that (G^r) is fixed, the 2 equations can be solved for i and (N + SL) :

(10) $i = g_1 (\overset{+}{p}, \overset{+}{y}, \overset{+}{i^f}; G^r, \int C)$

(11) $(N + SL) = g_2(\overset{+}{p}, \overset{+}{y}, \overset{-}{i^f}; G^r, \int C)$

where the signs of the partial derivatives are indicated above the variables. Equation (10) states that an increase in the price level, real output and the foreign interest rate lead to an increase in the private discount rate in Berlin, for given G^r. An increase in p or y leads to an increase in N + SL, while an increase in the foreign interest rate leads to a fall.

Consider next the second block of equations in the model, equations (6) - (8). Substituting equations (6) and (7) into (8) one obtains that the liquidity ratio depends negatively on the differential between the private and the official discount rates:

(12) $l = l_4 - \dfrac{1}{N + SL} a_4 + a_5(i - i^d)$

The equations which will be subject to empirical tests in the next section are equations (9), (10), and (12').

(2)

Summarizing the three hypothesis advanced and tested are:

a) the business cycle and foreign interest rates determine the differential between the private short term discount rate in Berlin and the official discount rate of the Reichsbank;

b) the differential determines the liquidity ratios of the Reichsbank;

c) changes in the liquidity ratios determine changes in the official discount rate.

2. Empirical tests

Equation (10) can be linearized in the following way:

$$(10') \quad i = \alpha_0 + \alpha_1 p + \alpha_2 y + \alpha_3 i^f \qquad \alpha_1, \alpha_2, \alpha_3 > 0$$

where the coefficients of the variables G^r and $\int C$ have been set for simplicity equal to zero.

Equation (12) can be expressed in first differences as follows for a given value of (N + SL):

$$(12') \Delta l = -\alpha_4 \Delta (i - i^d) \qquad \alpha_4 > 0$$

where the coefficient of the variable (N + SL) has been arbitrarily set equal to zero, and Equation (9) can be rewritten in first differences as follows:

$$(9') \quad \Delta i^d = - a_6 \Delta l \qquad a_6 > 0$$

These three equations represent each one of the channels that will be investigated econometrically by using annual data and, whenever possible, data collected for each discount rate change. The use of the latter set of data allows tests of these hypotheses which are more reliable than those performed before by other authors. Annual data hide a substantial amount of information. Changes in the discount rate in Germany were rather frequent during the gold standard period, amounting to 136 from 1876 to 1913. There were 38 changes in the 20 years from 1876 to 1895 corresponding to 1.9 changes per year on average, as opposed to 98 changes in the 18 years from 1896 to 1913, corresponding to 5.4 changes per year on average. Fluctuations in the liquidity ratios within the year were also extremely high.[2] In addition the use of annual data could probably entail problems of reverse causation. For these reasons, whenever the availability of data allowed it, regressions using annual data have been supplemented by regressions using data available for each discount rate change and drawn upon two statements of the Reichsbank. The first one dated two to four days prior to the discount rate change and the second one generally preceding it by two weeks to two months. The choice of the lags was made by the compilers of a table contained in one volume published by the German Imperial Printing Office in 1925 (Vergleichende Notenbankstatistik, 1925).

The choice of the lags was based presumably on the knowledge of the statements which the Reichsbank actually compared prior to deciding changes in the discount rate. The table also contains information about the short term market interest rates and exchange rates on the day just preceding the discount rate change. Exactly the same table is available for other gold standard countries, possibly suggesting that the type of comparisons of statements done by the officials of the Reichsbank was a usual practice among gold standard central bankers. A contribution of this paper lies also in bringing to the attention of the readers this remarkable set of data.

The tests have been performed separately for the periods 1876 or 1878 to 1895 and from 1896 to 1913. 1895 has been chosen as the end year for

(2) The difference between the highest and the lowest level of gold holdings as a ratio of average annual gold holdings reached a maximum of 50.6 percent in 1905 and a minimum of 22.9 in 1892. The difference between the highest and the lowest level of fiduciary notes outstanding as a fraction of average yearly total Reichsbank notes outstanding reached a maximum of 74.6 percent in 1912 and a minimum of 23.8 percent in 1877. Variability within the year of notes outstanding increased substantially in the second part of the gold standard period. It goes without saying that part of the variability of both assets and liabilities was caused by seasonal factors. A similar variability is observed for the gold holdings and fiduciary notes outstanding of the Bank of England, while it was substantially lower for the other central banks for which comparable data are available.

the first period because the phase of declining prices in Germany and abroad came to an end in that year after the discoveries of new gold mines and of new processes to extract gold. Moreover, the degree of commercial and financial integration with the other gold standard countries had increased substantially since 1876 justifying the split into subperiods. For the first period the London private interest rate was used as the representative foreign interest rate. For the second period the Paris rate was used, because the degree of financial market integration between Germany and France had by then become higher than that between Germany and the United Kingdom[3]). Several liquidity ratios were used. In regressions using annual data the ratios of gold and of all metal holdings to notes outstanding were used. Annual regressions shown in Table 2 and 5 include only the former ratio, because it yielded better results. In the regressions using data relating to each discount rate change, the ratios of all metals to banknotes outstanding and of all metals to total short term liabilities outstanding (banknotes and sight deposits) are used because they are the only ones available.

The estimates of equation (10') are presented in Table 1. Estimates of equation (12') using annual data are presented in Table 2 while those using data relating to each discount rate change are presented in Table 3. Estimates of equation (9') using data relating to each discount change are presented in Table 4 while those using annual data are presented in Table 5.

2.1. The determinants of the private interest rate in Berlin.

Estimates of equation (10') are presented in Table 1. The price level and the level of income as expressed are deviations from trend. Measures of the business cycle could only be constructed on an annual basis.[4]) Therefore the empirical tests of equation (10') could only be performed using annual data. Regressions of the official discount rate and the differential between the private and the official discount rates are also presented in the lower part of the table. In the block of equations

(3) Regressions of German interest rates on foreign interest rates show that in the second period the Paris rate had a higher explanatory power than the London rate. See Sommariva and Tullio (1987).
(4) The measures used were deviations from trend of both income and prices. Trends were calculated separately for the two subperiods. For the estimated trends see Sommariva and Tullio (1987).

Table 1
Domestic and foreign factors affecting the private short term interest rate in Berlin, the official discount rate and their differential,

$$i = \alpha_0 + \alpha_1 p + \alpha_2 y + \alpha_3 i^f$$

Period	Intercept	p	y	i^f	RMSE	R^2	ε
1878-1895[1)]	1.24 (4.60)	4.84 (2.30)	-	0.65 (5.94)	0.35	0.76	0.06 (0.24)
1896-1913[1)]	0.55 (1.44)	2.69 (0.66)	9.63 (2.88)	1.18[4)] (8.24)	0.30	0.87	- 0.44 (2.08)
1978-1895[2)]	2.61 (10.36)	2.86 (1.25)	-	0.52 (5.28)	0.28	0.70	- 0.32 (1.45)
1896-1913[2)]	1.61 (3.42)	1.04 (0.21)	6.96 (1.72)	1.12[4)] (6.46)	0.36	0.79	- 0.44 (2.12)
1878-1895[3)]	- 1.48 (15.56)	1.69 (2.52)	-	0.18 (4.54)	0.15	0.68	0.44 (2.12)
1896-1913[3)]	- 0.91 (4.76)	3.10 (1.71)	1.88 (1.18)	0.003[4)] (0.04)	0.16	0.39	- 0.07 (0.28)

Numbers in parenthesis are t-statistics. ε is the coefficient of autocorrelation. Correction for autocorrelation has been performed by using the Cochrane-Orcutt technique.

1) The dependent variable is the level of private short term interest rate in Berlin.
2) The dependent variable is the level of the official discount rate of the Reichsbank.
3) The dependent variable is the differential between the private short term interest rate in Berlin and the official discount rate of the Reichsbank.
4) Private short term interest rate in Paris.

Legend: p = deviation from trend of German consumer price index.
y = deviation from trend of German real NNP.
i^f = private short term interest rate in London or Paris.

Source: Deutsche Bundesbank (1976) and Vergleichende Notenbankstatistik (1925).

(3)

(1)-(5) from which equation (10') was derived, the official discount rate does not appear. However, the official discount rate could be substituted for the private discount rate in the demand for currency in circulation (eq.(1)) and the capital flow equation (eq.(4)). Hence an equation such as (10') can be estimated also for the official discount rate and a fortiori for the differential between the two rates.

The results confirm that in the first period the level of both interest rates was more affected by the deviations from trend of consumer prices, while in the second period it was more influenced by deviations from trend of real NNP. The private short term rate was always more responsive than the official discount rate. The estimated coefficients imply that in the second period the private short term interest rate in Berlin rose, other things being equal, by about 9.63 basis points for every 1 percent rise of real NNP above trend.[5]) The corresponding figure for the official rate was 6.96 basis points. This procyclical movement of the private short term interest rate confirms Morgenstern's results, that the specific interest rate cycle and the reference cycle were in the same phase in 81.9 percent of the months from February 1878 to August 1913.[6]) The interest elasticity of the demand for currency in circulation and sight deposit implicit in the second regression of Table 1 is -0.10, if one assumes an income elasticity of 1 and -0.04 if one assumes the more plausible income elasticity of 0.42 obtained by Sommariva and Tullio (1987). As to the interest elasticity of net capital flows in relation to the domestic-foreign interest rate differential, a coefficient of i^f equal to 1 in regressions 2 and 4 of Table 2 implies an infinite elasticity for a one year time horizon. A coefficient equal to zero would imply a zero elasticity.

The last regressions in the table explain the differential in terms of the exogenous variables. The differential between the private and the discount rate underwent large fluctuations during the gold standard.[7])

(5) This is slightly less than half of the size of the coefficients found by Tanzi (1980) for the short term US interst rates from 1959 to 1975.

(6) Morgenstern (1959, Table 14, p.93).

(7) The differential is always positive when annual averages are used, because the official rate was the rate charged on loans of varied quality, while the private rate refers to lower risk loans. However, during the period the official rate fell from time to time below the private rate.

The exogenous variables explain 68 percent of the variance of the differential in the first period and 39 per cent in the second period. The cycles of real NNP and/or prices exerted a positive effect on the differential, as already found by McGouldrick using the reference cycles of Burns and Mitchell.[8]) The loss of significance of the foreign short term interest rate in the second period occurs partly because of the more frequent changes in the discount rate which shortened the lags between changes in the foreign private short term rate and the official discount rate in Berlin. As a result the effects of the foreign interest rate on the Berlin differential does not show up in the annual averages.

2.2. The determinants of the liquidity ratios of the Reichsbank

Regressions explaining changes in the liquidity ratios of the Reichsbank in terms of the differential are shown in Tables 2 and 3 (equation 12'). Table 2 uses annual data and Table 3 data relating to each discount rate change.[9]) Table 2 also shows regressions of the liquidity ratios on the cyclical variables and the foreign interest rate. The regressions, using annual data, are less satisfactory than the others, because annual averages hide relevant information. In the first period the non adjusted R^2 in the regression explaining annual changes in the gold cover of notes outstanding is 0.28, while the adjusted R^2 varies from 0.37 to 0.38 in the regressions using data relating to each discount rate change. In the second period the results of Table 3 are again superior to those of Table 2. The tables also show that the explanatory power of the differential increased substantially during the second period, suggesting a more important role of the differential in the latter period. During the first period factors other than the differential were relatively more important in affecting the liquidity ratios, such as changes in the demand for notes and sight deposits at the Reichsbank whose coefficient was arbitrarily set equal to zero in equation (12'). This is suggested by the fact that the explanatory power of the cyclical variables in Table 2, the cycle being an

(8) He found that during the 6 business upswings the spread as defined here increased by 43 basis points on average. It fell by 42 basis points on average during the 5 downswings.

(9) The coefficients of Tables 2 and 3 have to be interpreted with caution because in equation (12') the coefficient of (N+SL) has been arbitrarily set equal to zero. However because changes in $i-i^d$ and (N+SL) are likely to be multicollinear, since both depend on the business cycle, it was preferred not to try to include them both as regressors.

Table 2

Effect of differential between the private short term rate in Berlin and the official discount rate $(i-i^d)$ on changes in the ratio of gold held by the Reichsbank to Reichsbank notes outstanding[1)]
(Annual Data)

$$\Delta l = -\alpha_4 \Delta(i - i^d)$$

Period	Intercept	$\Delta(i-i^d)$	p	y	Δi^f	RMSE	R^2	ε
1878-1895	0.02 (1.46)	- 0.11 (2.44)	-	-	-	0.05	0.28	- 0.02 (0.08)
	0.01 (0.93)	-	- 0.61 (2.22)	- 0.25 (1.00)	- 0.03 (2.00)	0.05	0.41	0.26 (1.15)
1896-1913	-0.00 (0.49)	-0.14 (3.40)	-	-	-	0.04	0.43	0.11 (0.49)
	0.06 (0.06)	-	-	-0.35 (0.96)	-0.05[2)] (2.51)	0.04	0.40	-0.03 (0.15)

Numbers in parenthesis are t-statistics.
1) The dependent variable is Δl_1, where l_1 is the ratio of gold holdings to banknotes outstanding, annual averages.
2) i^f = private short term interest rate in Paris.
Legend: p = deviation from trend of consumer price index;
y = deviation from trend of German real NNP.
i^f = private short term interest rate in London or Paris.
$i-i^d$ = difference between private short term rate in Berlin and official discount rate of the Reichsbank.
Source: Vergleichende Notenbankstatistik (1925) and Deutsche Bundesbank (1976).

Table 3
Effect of differential between private short term rate in Berlin and official discount rate before each discount rate change on changes in major balance sheet items of Reichsbank

Period	No. of observations	Dependent variable	Intercept	$i-i^d$	R^2adj	DW
1876-1895	38	Δl_2	-0.14 (3.96)	-0.12 (4.41)	0.37	2.15
		Δl_3	-0.07 (3.91)	-0.07 (4.50)	0.38	2.10
		ΔG^r	-44.50 (3.55)	-29.78 (3.09)	0.21	2.23
		ΔDA	96.34 (4.19)	87.16 (4.93)	0.42	1.98
1896-1913	98	Δl_2	-0.18 (7.26)	-0.18 (10.32)	0.55	1.70
		Δl_3	-0.10 (7.38)	-0.10 (10.71)	0.57	1.80
		ΔG^r	-96.13 (7.23)	-88.22 (9.50)	0.51	1.47
		ΔDA	240.32 (5.09)	277.33 (8.41)	0.45	1.95

Numbers in parenthesis are t-statistics.
Legend: l_2 = metal coverage of Reichsbank notes outstanding.
l_3 = metal coverage of notes and other short term liabilities
G^r = gold stock of Reichsbank, in millions of Marks
DA = earning assets of Reichsbank, in millions of Marks
Δ = first difference of a variable between two statements of Reichsbank preceeding discount rate change.
Source: Vergleichende Notenbankstatistik (1925).

important determinant of the demand for notes, is higher than the explanatory power of the differential in the first period, while this is no longer true in the second period. In the first period a 100 basis points higher differential implied a fall of 12 percentage points of the ratio of metal holdings to notes outstanding and of 7 percentage points of the ratio of metal holdings to total short term liabilities. During the second period, a 100 basis point higher differential implied a fall of 18 and 10 percentage points respectively. These fluctuations were quite sharp and occured within a relatively short period of time or less than two months on average.

Finally, Table 3 shows that the coefficient of the differential was highly significant in also explaining absolute gold holdings and earning assets (Equation 6) in addition to the liquidity ratios of the Reichsbank. Both the absolute gold stock of the Reichsbank and earning assets are expressed in millions of marks. During the first period a 100 basis point higher differential on the day prior to the discount rate change implied a 29.8 million mark fall in the gold stock of the Reichsbank. The corresponding figure in the second period was 88.2 million. The effect of the differential on the level of earning assets was even more pronounced in both sub periods. The threefold increase in these coefficients reflects in part the growth of the German economy and the rise in the price level between the two periods, and in part a genuine greater responsiveness of the balance sheet items to the differential. Changes in the differential must have influenced the liquidity ratios mainly via larger discounts of bills at the Reichsbank coupled with an initial phase of passive behaviour of the Reischbank during which the profit motive prevailed. The increase in earning assets of the Reichsbank must have led initially to a one to one increase in the sum of Reischbank notes and short term liabilities outstanding. The effects on the liquidity ratios was reinforced if some of the proceeds from the rediscounting were converted by the private sector into gold.

2.3. The determinants of the official discount rate of the Reichsbank.

Table 4 presents regressions of the changes in the discount rate on changes in the liquidity ratios (equation (9')). The data ùsed relate to

Table 4
Reaction function of the Reichsbank; Determinants of changes in the discount rate
(data referring to each discount rate change)

$$\Delta i^d = - a_6 \Delta l$$

Period	No. of observations = No. of discount rate changes in period	Intercept	Δl_2	Δl_3	RMSE	R^2	ε
1876-1895	38	0.01	-0.06	-	0.45	0.63	0.29
		(0.14)	(7.77)				(1.87)
	38	0.01	-	-0.10	0.49	0.57	0.19
		(0.19)		(6.82)			(1.21)
1896-1913	98	0.04	-0.03	-	0.44	0.70	0.20
		(1.16)	(15.02)				(2.06)
	98	0.06	-	-0.06	0.46	0.69	0.19
		(1.56)		(14.41)			(1.89)

Numbers in parenthesis are t-statistics; ε is the coefficient of autocorrelation. The correction for autocorrelation has been performed by using the Cochrane-Orcutt technique.

Legend : l_2 = metal coverage of Reichsbank notes outstanding.
l_3 = metal coverage of notes and other short term liabilities outstanding.
Δ = first difference between latest available statement, usually relating to 2 to 4 days before the discount rate change and a statement generally dated 2 weeks to 2 months prior to the former.

Source of data : Vergleichende Notenbankstatistik (1925). Table 133, p.240-245.

each discount rate change. Table 5 presents the same regressions using annual data. Changes in the liquidity ratios between the two Reichsbank statements explain 60 to 70 percent of the variability of the changes in the discount rate (Table 4). The coefficients of the liquidity ratios have the expected negative sign and are very significantly different from zero. They indicate that a fall of one percentage point in the ratio of metal to notes outstanding led to the decision to raise the discount rate by 6 basis points in the first priod and 3 basis points in the second. The Reichsbank was more responsive to changes in the ratio of metal holdings to all short term liabilities: a one percentage point fall in the latter led to a 10 basis point increase in the discount rate in the first period, and 6 basis points in the second. By multiplying the coefficients of the differential basis point increase in the discount rate in the first period, and 6 basis points in the second. By multiplying the coefficients of the differential in the equations explaining the liquidity ratios (Table 3) with the coefficients of the liquidity ratios in the equation explaining discount rate changes (Table 4), one obtains that a 100 basis point increase in the differential led in the first period to 63.7 - 65.2 basis points increase in the official discount rate, depending on the liquidity ratio used for the calculation.[10] In the second period, the response of the Reichsbank was also less than full being in the order of 61.2 to 62.0 basis points for every 100 basis points increase in the differential.

The same regressions using annual data (Table 5) support the empirical results of Table 4. In the second period the ratio of gold to notes outstanding explains a smaller fraction of the annual variance of changes in the discount rate due to the greater variability of the liquidity ratios and of the discount rate within the year. The R^2 of the regression using annual data is only 0.49 for the second period (Table 5) as opposed to an R^2 of about 0.70 in the regression of Table 4 relating to the corresponding period.

(10) The coefficients in the tables are rounded up and their multiplication does not give precisely the figures reported here.

Table 5

Reaction function of Reichsbank - Determinants of changes in the official discount rate[1])
(Annual Data)

$$\Delta i^d = - a_6 \Delta l$$

Period	Intercept	Δl_1	RMSE	R^2	ε
1878-1895	0.05 (0.59)	-0.06 (4.45)	0.36	0.57	0.18 (0.79)
1896-1913	0.11 (0.63)	-0.11 (3.79)	0.57	0.49	-0.24 (1.07)

Numbers in parenthesis are t-statistics. ε is the coefficient of autocorrelation, correction for autocorrelation has been performed by using the Cochrane-Orcutt technique.

1) The dependent variable is the first difference of the official discount rate, with respect to the previous year.

Legend: l_1 = ratio of Reichsbank's gold holdings to notes outstanding.
Source: Vergleichende Notenbankstatistik (1925).

3. Summary and Conclusions

This paper's first objective was to test the hypothesis that liquidity ratios of the Reichsbank were the main determinants of official discount rate changes. To this end an interesting data source, not yet exploited, was used. These data refer to each discount rate change and yield estimates which are free of problems of reverse causation. The empirical tests show that changes of the liquidity ratios explain a very high fraction of the variance of discount rate changes, a result which is very similar to Goodhart's (1972) finding about the determinants of the official discount rate in the United Kingdom.

Secondly, this paper has also investigated the factors affecting the liquidity ratios of the Reichsbank. Changes in the differential between the private discount rate in Berlin and the official discount rate were found to determine changes in the liquidity ratios. Thirdly the effects of the business cycle and the foreign interest rates on the level of the private discount rate and the differential has also been investigated.

The econometric investigation of the three links mentioned above provides interesting insights into the working of the domestic gold standard in Germany. First the tests suggest that liquidity ratios were an automatic signalling device for a central bank principally interested in keeping the notes in circulation convertible into gold and in making profits. The perfection of the working of the system lay in an automatic and prompt transmission of information about the position of the economy in the cycle and the inflation outlook through the behaviour of the liquidity ratios. In this connection the equation explaining the discount rate presented in Table 1 have to be interpreted with caution; they do not imply that the Reichsbank was directly reacting to the position of the economy in the cycle, to deviations of prices from their trend and to foreign interest rates, but rather that these variables were influencing the liquidity ratios through the widening and narrowing of the differential, and that the Reichsbank was reacting to changes in the liquidity ratios.[11]) Thus the

(11) Bloomfield held a similar view.

analysis presented in this paper suggests that it is incorrect to attribute to central banks of the gold standard years objectives of today's central banks, like the stabilization of economic activity or full employment. Their objectives were much narrower and more clearly defined. One important reason for this behaviour is that accurate statistics about business cycles and the balance of payments were not promptly available as they are today, although during the gold standard central banks had probably some knowledge of the state of the business cycle and the balance of payments.

Second, the split of the period allows to infer that the relevance of the differential in influencing discount rate changes was greater in the second period, probably because of the better knowledge of the Reischsbank about the working of the system, of the stronger links among the Berlin money market and the foreign ones and of the more frequent changes in the discount rate. This evidence suggests that the working of the system was more automatic on average in the second part of the gold standard. As a result, the role of discount rate changes and of German monetary policy as a tool for stabilization of economic activity and of the price level must have increased in the latter period.

The model presented in Section 1, contains 9 structural equations. Three reduced form equations have been derived from it and have been further simplified by setting equal to zero the coefficients of several explanatory variables which were thought likely to be multicollinear with the key explanatory variables. It maybe worthwhile to estimate simultaneously the 9-equation structural model by a full information maximum likelihood method. This is left, however, for further research.

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