The Objectives of German Monetary Policy during the Classical Gold Standard, 1876-1913: an econometric analysis of the determinants of the Reichsbank's discount rate[1].

by

Giuseppe Tullio and Jürgen Wolters
(Luiss University Rome and Freie Universität Berlin)

The first author is professor of Economics at the Luiss University, Rome (Via Tolmino 12, 00198 Roma, Italy, e-mail: gt@giuseppetullio.com) and the second at the Freie Universität Berlin (Boltzmannstrasse 20, 14195 Berlin, Germany, e-mail: wolters@wiwsiss.fu-berlin.de).

Introduction

This paper analyses by means of econometric analysis the factors which influenced the Reichsbank's decisions to change the official discount rate from January 1 1876, the day the Reichsbank started operations, to the end of 1913. The discount rate was the most important instrument of monetary policy during the classical gold standard. A second instrument was the changes in the criteria for admission to rediscounting by commercial banks and of borrowing by the non-banking private sector which at that time had also access to Reichsbank credit. The third instrument was the use of so-called gold devices[2] which changed the conditions of gold shipments abroad and hence the width of the band around gold parity within which the market exchange rate fluctuated.

For the period from 1880 to 1913 Bloomfield (1959) showed graphically for a large number of gold standard Central Banks that there was an inverse correlation between annual

[1] This paper is based on a Laurea Dissertation presented on July 7 1997 by Cristina Francucci at the Università di Brescia entitled "Gli obiettivi della politica monetaria tedesca durante il tallone aureo: 1876-1914. Un'analisi econometrica delle determinanati del tasso di sconto della Reichsbank" and written under the supervision of the first author. We thank Hannah Nielsen for research assistance.

[2] Gold devices were used by Central Banks to avoid sales and exports of gold and/or to make these operations more costly to the private sector. They consisted in raising the sales price of gold, moving the delivery of gold to places distant from the border, delivering minted national coins instead of ingots and increase the interest rates on lending to gold exporters in order to increase transaction costs. The Bank of France is known to have simply refused the sale of gold in some periods.

discount rates and liquidity ratios defined as the ratio of gold holdings to the stock of banknotes issued. Goodhart (1972) used a more sophisticated approach to study the link between the official discount rate of the Bank of England and her liquidity ratio. Using monthly data from 1891 to 1914 he regressed the level of the discount rate of the Bank of England on her liquidity ratio, the lagged discount rate and seasonal dummy variables and found that the average speed of adjustment of the discount rate to the liquidity ratio was about four months. His explanation was that, as the liquidity ratio was falling, the Bank of England became more concerned about maintaining the convertibility of banknotes and would thus increase the discount rate to attract gold from internal circulation and from abroad. He also showed that the liquidity ratio moved anti-cyclically as the private sector's demand for gold and banknotes increased as the business cycle improved, and that an increase in the official discount rate would affect the whole structure of interest rates in London, so as to cause sufficient capital inflows from abroad.

Finally Sommariva and Tullio (1987) analysed the factors which influenced the Reichsbank's decisions to change the official discount rate from 1876 to 1913 using for their econometric analysis data which refer to each discount rate change enacted by the Reichsbank. These data are contained in a rather rare volume published in 1925 in Berlin by the German Imperial Printing Office and entitled "Vergleichende Notenbankstatistik" (1925) (henceforth: VN). They cover four gold standard countries (Germany, the United Kingdom, France and Austria-Hungary), using the same criteria for all four countries, and contain, besides discount rates and liquidity ratios, also data on exchange rates and private (commercial bank's) discount rates.

Sommariva and Tullio (1987), who were the first to use this data, found like Goodhart (1972) for the Bank of England that the Reichsbank reacted negatively, systematically and with a lag to changes in the liquidity ratio. This implies that the main objective of its actions was to maintain internal convertibility of banknotes issued into gold. Finally they show that there were significant differences in the effect of the liquidity ratio on the Reichsbank's discount rate between the sub-periods 1876-1895 and 1896-1913.

The findings of Bloomfield (1959), Goodhart (1972) and Sommariva and Tullio (1987), that the main objective of the Bank of England and the Reichsbank was to keep internal convertibility, should not come as a big surprise: if the Reichsbank managed to keep internal convertibility of her banknotes for over 38 years and the Bank of England for even longer it is rather obvious that the objective of keeping convertibility must have been very important for them.

In this paper we go several steps further with respect to the above mentioned literature. *First*, we estimate a more complete reaction function of the Reichsbank which includes in addition to the liquidity ratio also foreign discount rates and deviations of the market exchange rate from gold parity. This allows studying to what extent the Reichsbank and German financial markets were influenced by market exchange rates and foreign discount rates. Issues closely related are which were the most important gold standard countries influencing Germany, how high was the degree of international financial market integration at that time, whether it changed significantly from 1876 to 1913 and if there were periods during which the use of gold devices by the Reichsbank or other gold standard Central Banks significantly changed the coefficients of the estimated relationships.

Second, instead of using annual or monthly data we use the data from VN. The main advantages of this data are that they are available for the whole period from the day the Reichsbank started operations on January 1, 1876 to 1913, that the problems of reverse causation are avoided because of the way the data are constructed and that we have the same data set for four gold standard countries which makes meaningful international comparisons possible. *Third*, we study the stability of this function over time and this allows testing whether there were changes in the working of the gold standard during the period.

The paper is structured as follows: Section 1 presents the model explaining the Reichsbank's discount rate taking into account international influences. Section 2 describes the data used and how the variables have been constructed. Section 3 presents the estimates of the reaction function for the whole period and for the two sub-periods. Section 4 presents tests for asymmetric reaction on the part of the Reichsbank to changes in the explanatory variables in periods of stress and ease. Section 5 concludes.

1 The model

Following Sommariva and Tullio (1987), the changes in the Reichsbank's discount rate are assumed to depend in the first place on changes in its liquidity ratio. However, in order to investigate the hypothesis of bi-polarity or multi-polarity of the classical gold standard and to test how the degree of international financial market integration changed over time, a set of variables capturing international influences (market exchange rates and foreign official discount rates) was included among the explanatory variables.

The equation to be estimated is:

$$(1) \qquad \Delta i^D = a_1 + a_2 \Delta l_i + a_3 l_i + \sum\nolimits_j a_{4j} \Delta i^j + \sum\nolimits_j a_{5j} w^j + u$$

where

Δi^D denotes changes in the Reichsbank's discount rate; in this case Δ does not denote the usual difference operator, since in our data set the changes refer to differently spaced time points;

Δl_i denotes changes in the liquidity ratios of the Reichsbank and the subscript $i = 1$ stands for the narrow liquidity ratio defined as the ratio of the gold and silver stock to the banknotes issued by the Reichsbank (l_1), and $i = 2$ stands for the broad liquidity ratio which has the same numerator but includes in the denominator sight liabilities in addition to banknotes issued (l_2);

Δi^j denotes changes in the discount rate of foreign country j, where the superscript $j = E$ stands for Great Britain, F for France and A for Austria-Hungary;

$w^j = (e_j - e_j^*)/e_j^*$ denotes percentage deviation with respect to gold parity of the market exchange rate of the Reichsmark with the currency of country j; the asterisk indicates gold parity and the variable "e_j" the market exchange rate.

In equation (1) the changes in the Reichsbank's discount rate are assumed to depend on the level of the liquidity ratio and on its changes, on the changes in the official discount rates in Great Britain, France and Austria-Hungary and finally on the percentage deviations of the exchange rates of the Reichsmark with the Pound and the French Franc from their respective gold parity. The gold parity never changed during the whole period for Germany, France and Great Britain.

The expected signs of the coefficients of the exogenous variables in equation (1) are: negative for changes in the liquidity ratio, negative for the level of the liquidity ratio, positive for the changes in foreign official discount rates, and positive for the deviation of the Reichsmark from gold parity. The expected sign of the deviation is positive because the exchange rate of the Reichsmark is defined as the number of domestic currency units per foreign currency unit, such that an increase in e_j implies a depreciation of the Reichsmark (capital and gold outflows from Germany). The negative sign of changes in the liquidity ratio reflects the concern with convertibility of banknotes into gold. The level of the liquidity ratio has been introduced into the equation in order to verify whether at high levels of gold reserves the Reichsbank reacted less to a fall in the liquidity ratio and to changes in foreign explanatory

variables than at low levels. This is a first rudimentary test of the hypothesis of asymmetric behaviour.

Equation (1) can be considered a reaction function of the Reichsbank distinguishing between three objectives of monetary policy: the objective of keeping internal convertibility of banknotes issued into gold, the objective of keeping exchange rates within the gold points and a third objective, not completely independent of the other two, of acting defensively to changes in foreign discount rates in order not to loose too much short term capital (and hence gold). Concerning the latter objective one should keep in mind that coordinated movements in opposite directions of the official discount rates were extremely rare during the period. For the four countries considered there were just a few instances of such moves in opposite directions[3].

Reaction functions of Central Banks estimated for the post World-War II period usually include inflation, unemployment or deviations of real GDP from trend or from potential GDP and sometimes the changes in international reserves (to measure the degree of sterilization)[4]. However, the classical gold standard was a different period characterized by the absence of national accounts, by the fact that unemployment was not a major issue and by a predominance of concerns about financial stability over concerns about the business cycle. As a result this difference in specification of the reaction functions of Central Banks between then and now seems perfectly justified by the different historical background of the two periods.

For the exact definition of the variables and the time interval to which their changes refer see Section 2. Suffice to mention here that the series used refer to all episodes of official discount rate changes which were 136 for the Reichsbank.

2 Description of the data used for estimation

The VN data used in this paper are obtained from a 1925 volume entitled Vergleichende Notenbankstatistk: Organisation und Geschäftsverkehr Europäischer Notenbanken, 1876-1913. This two-volume publication contains monthly and annual financial data for seven European countries: Austria-Hungary, Belgium, France, Germany, Holland, the United Kingdom and Russia. For the four countries France, Germany, the United Kingdom and Austria-Hungary there are more detailed tables containing a wealth of data

[3]See Tullio and Wolters (1996).

[4]This approach has become popular as the so-called Taylor rule, especially since the work by Taylor (1993).

relating to each official discount rate change. For Germany the relevant table is Table 133 (pages 240 to 245 of Vol. 2). The columns of this table used in the empirical work are reproduced here as Table 1 to facilitate the description of the data. The numeration of the columns is retained from the original table of VN. We do not translate the headings from German because the explanation which follows should make the contents of the columns sufficiently clear.

The one and a half page long introduction to this set of tables contains the following sentence: "These tables represent an attempt to explain with a purely numerical methodology those factors taken into consideration in deciding changes in the discount rate at the time the changes were enacted. These factors were the balance sheet of the Central Bank on the days prior to the change, confronted with another balance sheet chosen on purpose *by the compilers of the table* (italic our addition), the foreign exchanges and some foreign discount rates" (VN, page 238). This sentence and the data description which follow go a long way in explaining what the German compilers were aiming at. They certainly knew very well, long before these concepts became current, what a reaction or an objective function of a Central Bank is.

The first four columns define each episode of change in the official discount rate:
Column 1 reports the year of the change,
column 2 reports the day and month of the change,
column 3 reports the discount rate before the change,
column 4 reports the discount rate after the change.

The official discount rates reported in column 4 minus the one reported in column 3 is the dependent variable of equation (1) (Δi^D).

Column 5 contains a date close to the discount rate change. It generally refers to one to five working days prior to the discount rate change[5],
column 6 contains a date preceding the discount rate change by two weeks to two months and on some occasions by substantially more. The compilers were interested in eliminating disturbances caused by seasonal factors or special events and sometimes they went back a full year. It is at these two dates that the items of the balance sheet of the Reichsbank are recorded in the succeeding columns. The choice of these two dates and hence of the interval between the two dates over which the changes in the liquidity ratios are measured was made by the

[5] In 7 out of 136 cases the data coincides with the day of the discount rate change and in 24 cases it lies one to three days after the discount rate change.

compilers of the tables and may have been based on the knowledge of the daily statements actually used by the Board of Directors to decide changes in the discount rate[6].

Table 1-Partial reproduction of Table 133 of VN.

Der Diskontsatz der Deutschen Reichsbank wurde verändert				A. Hauptposten des Status der Deutschen Reichsbank						B. Wechselkurse in Berlin am Tage vor der Diskontveränderung				C. Diskontsätze am Tage vor der Diskontveränderung				
am				Ausweise wurden herangezogen		Deckungsverhältnisse Deckung												
Jahr	Tag	von	auf	a. für die Beurteilung der Diskontveränderung maßgebend vom	b. zum Vergleich, um die Statusveränderung zu kennzeichnen vom	der Noten gegen Metall nach Spalte 5	der Noten gegen Metall + oder − gegen Spalte 6	Gold nach Spalte 5	der Noten und sonstigen täglich fälligen Verbindlichkeiten gegen Metall nach Spalte 5	der Noten und sonstigen täglich fälligen Verbindlichkeiten gegen Metall + oder − gegen Spalte 6	kurz London Mark für 1 £	kurz Paris Mark für 100 Fr.	kurz Amsterdam[7]) Mark für 100 hfl.	Vista New York Mark für 100 $	Bank von England	Bank von Frankreich	Österreichisch-ungarische Bank	Privatdiskont an der Berliner Börse	Spannung zwischen Spalte 32 und 34
		Prozent				Prozent												
1	2	3	4	5	6	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1876	3. Jan.	5	6	1. Jan. 76	23. Nov. 75	59,5	— 3,7	46,8	51,0	— 5,8	20,30	80,85	80,75	—	4	4	5	5½	+ ½
	19. Jan.	6	5	15. Jan. 76	1. Jan. 76	64,4	+ 4,9	49,8	51,7	+ 0,7	20,32	80,90	80,85	—	5	4	5	4½	— 1½
	4. Febr.	5	4	31. Jan. 76	15. Jan. 76	68,8	+ 9,1	51,9	54,3	+ 3,3	20,395	81,15	81,15	—	4	4	4½	3	—
	18. Mai	4	3½	15. Mai 76	31. Jan. 76	82,8	+ 14,2	48,1	61,1	+ 6,8	20,40	80,95	80,90	—	2	4	4½	3½	— 1½
	11. Juli	3½	4	7. Juli 76	31. Mai 76	70,8	— 14,7	38,1	53,7	— 7,7	20,51	80,95	80,95	—	2	3	4½	3	— ½
	25. Okt.	4	4½	23. Okt. 76	31. Mai 76	67,9	— 17,6	31,6	52,5	— 8,8	20,42	81,20	81,05	—	2	3	4½	3½	— ½
1877	5. Jan.	4½	4	7. Jan. 77	31. Dez. 76	66,4	+ 1,0	27,7	53,9	+ 1,1	20,40	81,15	81,05	—	2	3	4½	3½	—1½
	11. Mai	4	5	7. Mai 77	7. Febr. 77	77,1	— 1,2	30,8	60,8	— 0,2	20,47N	81,49	169,75	—	3	2	4½	3½	— ½
	16. Juni	5	4	15. Juni 77	15. Mai 77	82,7	+ 3,2	32,1	64,5	+ 2,4	20,475	81,15	169,00	—	3	2	4½	3½	— 1½
	12. Sept.	4	5	7. Sept. 77	23. Aug. 77	72,9	— 7,8	30,1	59,5	— 3,8	20,47	81,40	169,20	—	3	2	4½	3½	— ½
	3. Okt.	5	5½	30. Sept. 77	7. Sept. 77	64,1	— 8,8	26,8	53,9	— 5,6	20,43	81,25	169,00	—	3	2	4½	4½	— ½
	12. Nov.	5½	5	7. Nov. 77	7. Okt. 77	68,4	+ 4,7	29,1	56,7	+ 3,1	20,45	81,25	168,90	—	5	2	4½	4½	— 1½
	8. Dez.	5	4½	30. Nov. 77	7. Nov. 77	73,0	+ 4,6	30,8	57,5	+ 0,8	20,425	81,20	168,45	—	4	2	4½	3½	— 1½
1878	21. Jan.	4½	4	23. Jan. 78	31. Dez. 77	73,2	+ 10,0	29,8	56,5	+ 5,3	20,375	81,05	168,25	—	3	2	4½	2½	— 2½
	29. Aug.	4	5	31. Aug. 78	23. März 78	80,6	— 5,4	32,8	62,8	— 1,9	20,52	81,20	169,25	—	5	2	4½	2½	— 1½
	11. Dez.	5	4½	7. Dez. 78	31. Okt. 78	83,6	+ 12,4	32,6	61,5	+ 3,4	20,46	80,95	168,85	—	5	3	4½	3½	— 1½
1879	11. Jan.	4½	4	7. Jan. 79	31. Dez. 78	74,0	+ 2,9	28,2	58,5	+ 1,2	20,475	81,05	168,95	—	5	3	4½	3½	—1
	21. März	4	3	23. März 79	31. Dez. 78	96,3	+ 25,2	44,8	67,4	+ 10,2	20,495	80,95	169,25	—	2½	3	4½	2½	— 1½
	13. Aug.	3	4	7. Aug. 79	23. März 79	81,4	— 14,9	32,8	62,7	— 4,7	20,52	81,00	169,75	—	2	2	4	1½	— 1½
	11. Okt.	4	4½	7. Okt. 79	7. Aug. 79	65,6	— 15,8	22,5	56,4	— 7,4	20,35	80,45	168,50	—	2	2	4	3½	— ½
	10. Dez.	4½	4	7. Dez. 79	7. Okt. 79	78,5	+ 12,9	33,0	61,5	+ 6,1	20,335	80,55	168,35	—	3	3	4	3½	— 1½
1880	18. Aug.	4	5	15. Aug. 80	15. Juni 80	77,1	— 6,0	29,6	61,6	— 3,1	20,49	80,85	168,60	—	2½	2½	4	2½	— 1½
	4. Sept.	5	5½	31. Aug. 80	15. Aug. 80	74,0	— 3,1	26,9	60,1	— 1,5	20,48	80,90	168,60	—	2½	2½	4	3½	— 1½
	6. Okt.	5½	5	7. Okt. 80	7. Sept. 80	69,6	— 3,6	23,7	58,9	— 1,8	20,40	80,40	168,45	—	2½	2½	4	4½	—1
	18. Okt.	5	4½	15. Okt. 80	7. Okt. 80	71,6	+ 2,0	27,1	60,7	+ 1,8	20,39	80,50	168,20	—	2½	3½	4	4½	— ½
	9. Nov.	4½	4	7. Nov. 80	30. Sept. 80	73,8	+ 5,8	28,1	61,8	+ 5,4	20,365	80,60	168,35	—	2½	3½	4	3½	— 1
1881	26. Aug.	4	5	23. Aug. 81	23. März 81	79,1	— 8,7	28,8	64,0	— 1,9	20,49	81,00	168 40	—	4	4	4	3½	— ½
	5. Okt.	5	5½	7. Okt. 81	23. Aug. 81	61,8	— 17,3	13,7	51,9	— 12,1	20,415	80,70	168,30	—	4	4	4	4½	— ½
	20. Nov.	5½	5	23. Nov. 81	7. Okt. 81	71,8	+ 10,0	25,5	59,3	+ 7,4	20,38	80,75	167,95	—	5	5	4	4½	— ½
1882	1. Febr.	5	6	31. Jan. 82	31. Jan. 81	70,5	— 8,6	26,0	55,3	— 6,3	20,45	81,40	168,55	—	6	5	4	4½	— ½
	18. Febr.	6	5	15. Febr. 82	31. Jan. 82	79,2	+ 7,7	29,1	67,0	+ 7,7	20,46	81,10	168,60	—	6	5	4	3½	—2½
	3. März	5	4½	28. Febr. 82	31. Jan. 82	81,0	+ 10,5	30,9	64,8	+ 9,5	20,46	81,10	168,70	—	5	4	4	3½	— 1½
	10. März	4½	4	7. März 82	31. Jan. 82	82,7	+ 12,2	31,8	66,0	+ 10,7	20,46	81,05	168,85	—	4	4	4	3½	—1½
	8. Sept.	4	5	7. Sept. 82	15. Juni 82	72,8	— 9,6	25,8	59,5	— 5,7	20,46	81,06	168,40	—	4	3½	4	3½	— ½
1883	18. Jan.	5	4	15. Jan. 83	31. Dez. 82	77,4	+ 10,2	36,1	61,9	+ 8,4	20,355	80,75	168,15	—	5	3½	5	3½	— 1½
1885	10. März	4	5	7. März 85	7. März 84	85,9	— 6,9	39,6	63,3	— 5,5	20,53	80,90	169,65	—	4	3	4	2½	— 1½
	4. April	5	4½	7. April 85	31. März 85	73,6	+ 1,3	32,5	58,9	+ 0,8	20,475	80,75	169,65	—	3½	3	4	3½	—1½
	11. Mai	4½	4	7. Mai 85	31. März 85	80,7	+ 8,4	36,1	61,5	+ 8,4	20,456	80,85	169,25	—	3	3	4	2½	—1½
1886	22. Jan.	4	3½	23. Jan. 86	31. Dez. 85	90,4	+ 18,4	49,2	64,8	+ 9,6	20,39	80,90	169,00	—	3	3	4	2	—2
	20. Febr.	3½	3	15. Febr. 86	31. Dez. 85	100,1	+ 28,1	55,6	68,1	+ 12,9	20,405	81,05	169,35	—	2	3	4	1½	—2
	18. Okt.	3	3½	15. Okt. 86	23. Aug. 86	71,1	— 20,4	41,3	58,1	— 10,8	20,40	80,50	168,60	—	3½	3	4	2½	— ½
	29. Nov.	3½	4	30. Nov. 86	23. Aug. 86	80,0	— 14,5	45,1	58,7	— 10,2	20,37	80,55	168,20	—	4	3	4	3	— ½
	18. Dez.	4	5	15. Dez. 86	23. Aug. 86	82,8	— 11,7	47,4	59,4	— 9,5	20,36	80,20	168,25	—	5	3	4	3½	— ½

For the whole period the average interval between the two statements was 70.8 days. It increased from 35.4 days in the period 1876-1895 to 118.5 days in the period 1896-1913. These two sub-periods are the same considered by Sommariva and Tullio (1987) in their study of the Reichsbank and as we shall demonstrate below they constitute an appropriate

[6]We hasten to add that this is our own supposition.

subdivision of the period[7]. The significant (about threefold) increase observed from the first to the second period in the reference interval may be an indication that the Reichsbank was taking a longer run view of economic developments and that it was more relaxed than before sitting on a higher and increasing gold stock. This large increase in the gold stock observed for the Reichsbank stands in sharp contrast with the significant reduction observed for the Bank of England relative to the other main gold standard countries[8].

The explanatory variables of equation (1) are obtained from Table 133 of VN as follows:

(a) Δl_1 is obtained from column 21. This liquidity ratio is defined as the ratio of the gold and silver stock to banknotes issued by the Reichsbank. The change refers to the interval between the dates shown in columns 5 and 6.

(b) Δl_2 is obtained from column 24. This ratio is defined as the ratio of the gold and silver stock to the Reichsbank's short term liabilities (banknotes issued plus sight liabilities). Again the change is measured between the two dates shown in columns 5 and 6.

(c) l_1 is obtained from column 20: it is the level of the first liquidity ratio with reference to the date reported in column 5.

(d) l_2 is obtained from column 23.

The percentage deviations of the market exchange rate of the Reichsmark from the British Pound and the French Franc with respect to gold parity (w^j) were obtained as follows: Table 133 in VN reports the market exchange rates of the Reichsmark with four currencies on the day preceding the change in the official discount rate:

(e) Column 25 shows the number of Reichsmarks per Pound in London (e^E),

(f) column 26 shows the number of Reichsmarks per 100 French Francs in Paris (e^F),

(g) column 27 shows the number of Reichsmarks per 100 Dutch Florins in Amsterdam (e^H),

(h) column 28 shows the number of Reichsmarks per 100 US Dollars in New York (e^U).

The exchange rates e^E und e^F have been introduced into the regressions as percentage deviations from gold parities, which have been obtained from Gallarotti (1995) as $w^j = (e_j - e_j^*)/e_j^*,\ j = E, F$ and the asterisk stands for the gold parity[9].

[7]Also in the paper on the Bank of England the year 1895 was found to be appropriate to divide the whole period 1876-1913 into two sub-periods (see Tullio and Wolters 2003).

[8]See Tullio and Wolters, (1997).

[9]The gold parities used are: Reichsmark per Pound = 20.430, Reichsmark per 100 French Franc = 80.99.

(i) Turning to the changes of the official discount rates in Great Britain (Δi^E), France (Δi^F), and Austria-Hungary (Δi^A), the information contained in Table 133 is not sufficient to construct these series. For its construction we used information contained in the other tables of VN. As for these three foreign countries VN contains daily figures of the official discount rate for the whole period 1876-1913, we calculated for each of the 136 episodes of changes in the Reichsbank's discount rate the corresponding changes in the three foreign official discount rates with reference to the interval between the date given in column 6 and the day before the discount rate changed (see columns 29 – 31 of Table 1). Thus same-day changes in foreign official discount rates are excluded by construction. In the case of same-day changes we do not know exactly which Central Bank made the first move. Only in some cases of same-day changes in official discount rates can the direction of causation be found by reading the minutes of the meeting of the Central Bank's Boards[10].

To summarize five observations are in order. *First*, the data presented in Table 133 in VN can be divided into three main categories: (A) Information on the balance sheet items of the Central Bank, in other words on its assets and liabilities. (B) The market exchange rates with reference to the main foreign currencies on the day preceding the change in the discount rate. (C) The official discount rates in Great Britain, Germany and Austria-Hungary on the day preceding the change in the official discount rate.

S*econd*, the series contained in each column are not equally spaced chronologically ordered data; hence the frequency of the data is variable depending on the time elapsed between one discount rate change and the next. *Third*, there is virtually no degree of discretion on our part in the way the series were constructed. How the variables are constructed follows logically from a careful analysis of Table 133 in VN. *Fourth*, the compilers of the table were not just statisticians, they were economic historians writing a history of the gold standard in numbers. We presume that they must have had substantial inside information on how decisions were taken and on how the system was actually working. They may have written the book with some degree of longing for stability in international monetary matters which in 1925 was nowhere near in sight. They may have written it with the same spirit which guided Egyptian scholars in the third and second centuries BC to write down as much as they could about a disappearing culture[11].

[10] For instance from the minutes of the meetings of the Board of the Banque de France we know that on 5 or 6 occasions the Governor read a telegram from London, usually at the very beginning of the meeting, announcing a change in the Bank of England's discount rate and that a (same-day) change in the Banque de France's discount rate was decided.

[11] Most of the written Egyptian documents concerning the Egyptian culture date from these last centuries.

Fifth, recalling that between 1876 and 1913 the Reichsbank changed the official discount rate 136 times[12], varying from a minimum of zero in 1884 to a maximum of 7 in 1877, 1899 and 1905, it is clear that the use of annual data, as for example in Bloomfield (1959), hides a substantial amount of information and certainly entails problems of reverse causation between changes in the discount rate and changes in the liquidity ratio. This may hold also for monthly data, albeit to a much smaller degree. The VN data are not subject to this criticism.

3 The determinants of the Reichsbank's official discount rate

In this section we present ordinary least squares (OLS) estimates of equation (1) using the data described in Section 2 and including exchange rates and foreign discount rates among the explanatory variables[13]. Since the Reichsbank changed the official discount rate 136 times between 1876 and 1913 our sample has 136 observations. We started out with all the explanatory variables and then eliminated successively all those which were not significant.

Our "not equally spaced chronologically ordered data" exclude by construction all episodes on which the balance sheet of the Bank, the situation of foreign exchanges and recent changes in foreign discount rates were analysed and the decision was taken *not to change* the discount rate. This exclusion may lead some people to believe that the coefficients we estimate are biased. The question is: biased with respect to what? For instance in equation (1) the estimated coefficient of changes in the liquidity ratio is certainly higher in absolute value than in the case we had used equally spaced data. However, we simply do not have such data. On the other hand comparing the alleged bias in the coefficients estimated by us with coefficients estimated using for example monthly data is wrong first because our data is of a different nature and second because the coefficient estimated with monthly data may be strongly biased towards zero, especially if a large proportion of the changes in the discount rate occurred at the beginning of the month and if the gold stock of the Central Bank changed significantly in the expected direction within the month as a result of the change in discount rate itself.

[12] The average number of changes per year was 3.6 for the Reichsbank as opposed to 5.8 for Great Britain and only 0.9 for France.
[13] Computations are done with Eviews 4.0.

Table 2: The determinants of the official discount rate, 1876 – 1913 (T = 136)

	(1) Δi^D	(2) Δi^D
c	0.039 (1.0)	0.052 (1.4)
Δl_1	-0.035 (13.0)	
Δl_2		-0.062 (12.5)
Δi^E	0.085 (1.8)	0.086 (1.8)
w^E	0.704 (4.6)	0.735 (4.7)
$\overline{R}^2$	0.696	0.680
DW	2.35	2.26
AIC	1.202	1.253
SC	1.288	1.338
Q(10)	13.05 [0.22]	12.26 [0.27]
HET	2.11 [0.06]	2.11 [0.06]
JB	0.26 [0.88]	1.39 [0.50]
RESET	3.91 [0.07]	2.41 [0.12]

Notes:
Absolute values of the t-statistics are given in parantheses, p-values in brackets. DW denotes the Durbin-Watson statistic. Q(10) denotes the Box-Pierce Portmanteau statistic with 10 lags to test for white noise in the residuals. HET is the White test for heteroskedasticity in the residuals. The RESET test tests against specification errors. The Akaike (Schwarz) information criterium is denoted as AIC (SC).

The estimates for the narrow as well as for the broad liquidity ratios as explanatory variables are shown in Table 2. Both liquidity ratios have a highly significant influence on discount rate changes. With respect to foreign influences only the Reichsmark's exchange rate with the Pound and changes in the Bank of England's discount rate turned out to have coefficients which were significantly different from zero. France and Austria-Hungary did not seem to influence Germany during the period 1876-1913. Also the level of the liquidity ratio never turned out to influence significantly the Reichsbank's discount rate, which implies that its behaviour was not influenced by whether liquidity ratios were high or low.

All coefficients have the expected sign and are significantly different from zero. The Reichsmark-British Pound exchange rate is much more significant than changes in the Bank of England's discount rate. An increase of 100 basis points in the Bank of England's discount

rate led on average to an increase of 9 basis points in the German official discount rate. A 1% deviation of the Reichsmark from gold parity led to a much stronger 70 to 74 basis points increase in the discount rate. A one percentage point increase in the narrow liquidity ratio led on average to a 3.5 basis point reduction in the discount rate and a one percentage point increase in the broad liquidity ratio led to a 6.2 basis point reduction.

The regressions of Table 2 explain about 70% of the variance of Δi^D. At the 5% confidence level the residuals of the regressions pass all the misspecification tests. The stability tests for regression (1) and (2) of Table 2 are presented in Figures 1 and 2. The Cusum of Squares tests show that the estimated relationships are stable. The recursive parameter estimates of the two regressions are also shown in Figures 1 and 2. The coefficients of changes in the liquidity ratios show a positive upward drift in both figures. The coefficients

Figure 1: Recursive coefficients and CUSUM of Squares test for regrission (1) of Table 2

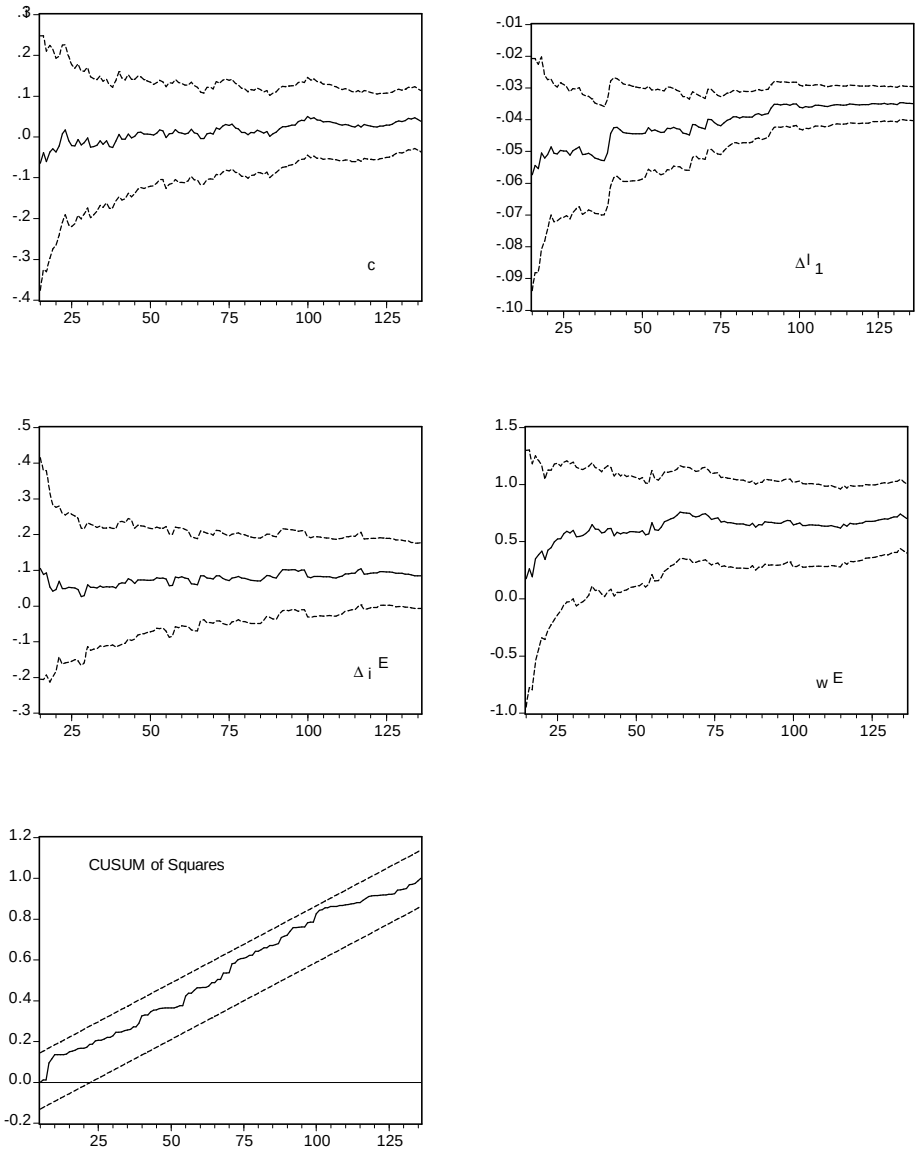
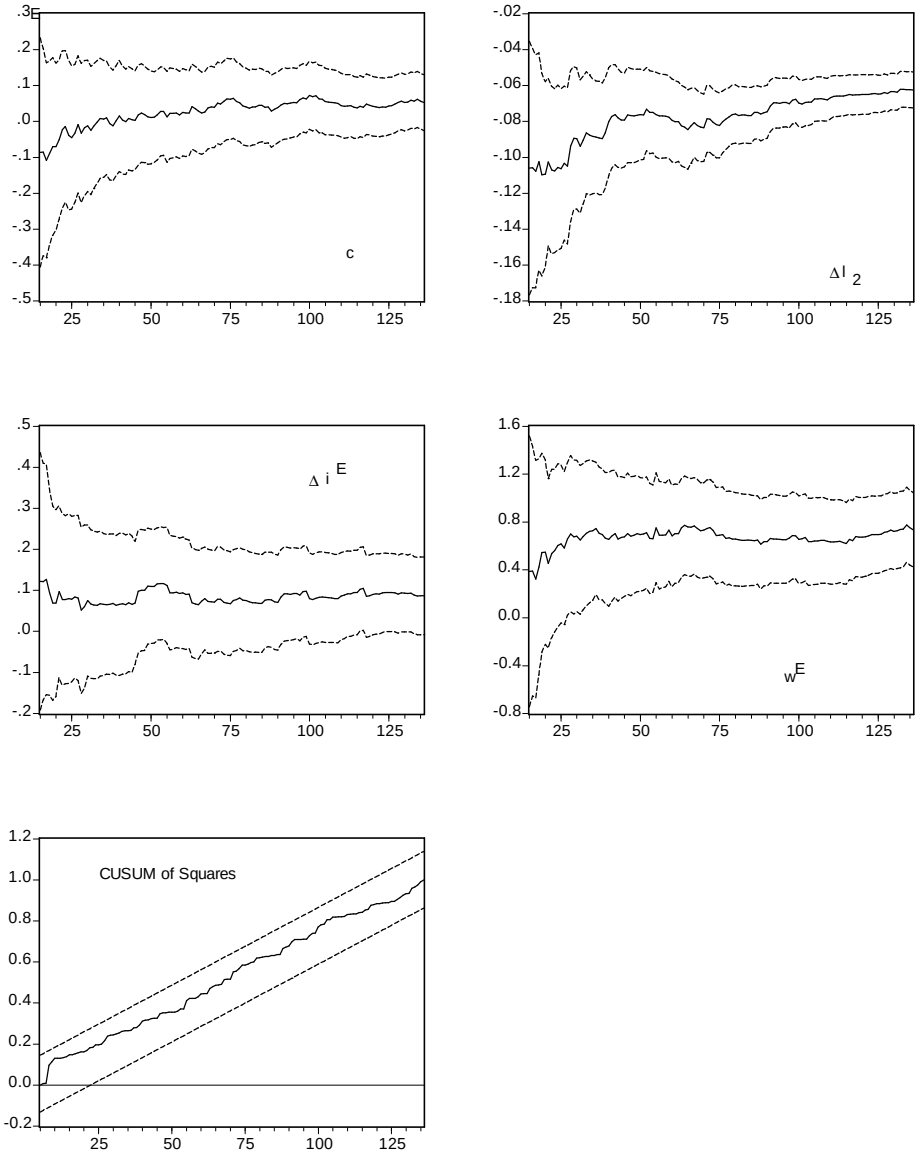


Figure 2: Recursive coefficients and CUSUM of Squares test for regression (2) of Table 2



of the British variables Δi^E and w^E show a remarkable degree of stability over the whole sample period. However, the coefficient of Δi^E becomes significantly different from zero only at the end of the sample period.

Table 3 contains the Chow-Break tests for regressions (1) and (2) of Table 2. In particular we are interested in knowing whether there was a significant break around 1895. The table shows that the lowest p-values for the Chow break test (0.048 and 0.026) are recorded in correspondence to observation number 66 or 67. These observations refer to the discount rate changes of November 11, 1895 and of February 12, 1896. Therefore, Table 4 shows the estimates of regressions (1) and (2) of Table 2 for the two sub-periods 1876-1895 (observations 1-66) and 1896-1913 (observations 67-136). This split is also justified by the

greater degree of international financial market integration after 1895 and by the beginning of a long period of rising prices after the gold discoveries of the previous years and the introduction of the cynide process in gold extraction. With the split changes in the British discount rate loose their significance in both periods and the Reichsmark-Pound exchange rate becomes less significant in the second period compared to the first.

Table 3: Chow-break tests for regressions of Table 2

Episodes	Equation (1) p-values	Equation (2) p-values
1 - 63	> 0.15	> 0.07
64	0.124	0.078
65	0.071	0.046
66	0.048	0.026
67	0.017	0.030
68 - 136	> 0.10	> 0.5

Table 4: The determinants of the official discount rate

Period	1876-1895 (T = 66) (1) Δi^D	1896-1913 (T = 70) (2) Δi^D	1876-1895 (T = 66) (3) Δi^D	1896-1913 (T = 70) (4) Δi^D
c	0.002	0.085	0.030	0.088
	(0.0)	(1.7)	(0.5)	(1.8)
Δl_1	-0.046	-0.034		
	(11.0)	(13.2)		
Δl_2			-0.090	-0.059
			(10.9)	(12.9)
w^E	0.745	0.456	0.750	0.496
	(3.7)	(1.9)	(3.7)	(2.0)
$\bar{R}^2$	0.695	0.714	0.692	0.706
DW	2.27	2.43	2.20	2.29
AIC	1.304	1.081	1.314	1.111
SC	1.404	1.177	1.413	1.207
Q(10)	19.58	10.71	25.84	7.65
	[0.03]	[0.38]	[0.00]	[0.66]
HET	0.70	1.66	0.78	2.82
	[0.59]	[0.17]	[0.55]	[0.03]
JB	0.28	1.26	1.74	1.66
	[0.87]	[0.53]	[0.42]	[0.44]
RESET	0.18	1.35	0.56	1.56
	[0.68]	[0.25]	[0.46]	[0.22]

Notes: see Table 2

Altogether, the evidence seems to indicate that in the second period Great Britain and the Bank of England had a smaller impact on decisions taken by the Reichsbank than in the first. This is obvious from the fact that, after splitting the period, Δi^E has no longer a significant influence for both periods and that in the second period the coefficients and the t-values of the Reichsmark-Pound exchange rate decreased. The gained independence of the Reichsbank in the second period was the result of the increased relative economic weight of Germany and of the growth of its gold stock which by 1895 had become sufficiently abundant to allow the Reichsbank to manage the domestic monetary system with more confidence. This conclusion is strengthened by the reduced absolute size of the coefficients of changes in the liquidity ratios and by the sharp (threefold) increase in the average reference interval between the two dates chosen by the compilers of Table 133 of VN[14].

The regressions estimated for the two sub-periods are stable and the residuals pass the specification tests with the exception of higher order autocorrelation in the regressions for the first period[15].

4 Tests for asymmetric behaviour of the Reichsbank

So far we only tried a very crude test of asymmetric behaviour on the part of the Reichsbank by introducing into equation (1) the level of the liquidity ratios. No evidence of asymmetric behaviour was found. A more formal test consists in splitting the observations of each explanatory variable into two groups: the observations referring to episodes of increases in the discount rate and those referring to decreases. For this purpose we defined the dummy variables DP and DN. DP is equal to one if Δi^D is positive and zero otherwise and DN is equal to 1-DP. Then we multiplied each explanatory variable with DP and with DN and ran the regressions of Tables 2 and 4 again with all new variables thus formed. The results are shown in Table 5 for the whole period.

Taking the regressions with the narrow liquidity ratio first, the Wald F tests shown at the bottom of each regression indicate that the Reichsbank reacted asymmetrically to changes in the British discount rate for the whole period. It reacted significantly to changes in Δi^E only in times of financial stress. It did not react to British discount rate changes in times of ease. As to the regressions using the broad liquidity ratio, the

[14] The changes in the average reference intervals are reported in Section 2.

[15] The Cusum of squares tests and the recursive parameter estimates do not indicate instability. They are available from the authors upon request.

Table 5: Determinants of the official discount rate: tests of asymmetry
Period 1876 – 1913 (T = 136)

	(1) Δi^D	(2) Δi^D	(3) Δi^D	(4) Δi^D
C	-0.111	-0.014	-0.068	-0.089
	(1.5)	(0.3)	(0.9)	(1.3)
$DP\Delta l_1$	-0.042			
	(8.4)			
$DN\Delta l_1$	0.028			
	(5.5)			
Δl_1		-0.035		
		(14.3)		
$DP\Delta l_2$			-0.076	-0.078
			(7.5)	(8.1)
$DN\Delta l_2$			-0.030	-0.051
			(5.7)	(6.4)
$DP\Delta i^E$	0.182	0.186	0.139	0.138
	(2.9)	(3.0)	(2.1)	(2.1)
$DN\Delta i^E$	0.003		0.004	
	(0.0)		(0.1)	
DPw^E	0.601		0.612	
	(2.9)		(2.8)	
DNw^E	0.714		0.750	
	(3.2)		(3.2)	
w^E		0.667		0.697
		(4.5)		(4.5)
$\overline{R}^2$	0.709	0.707	0.685	0.691
DW	2.24	2.24	2.29	2.21
AIC	1.180	1.163	1.260	1.226
SC	1.329	1.249	1.410	1.333
WALD (Δl_i)	2.81		2.01	
	[0.10]		[0.00]	
WALD (Δi^E)	3.79		1.92	
	[0.05]		[0.17]	
WALD (w^E)	0.13		0.18	
	[0.72]		[0.67]	
Q(10)	10.35	11.62	12.46	11.51
	[0.41]	[0.31]	[0.26]	[0.32]
HET	4.43	3.53	5.22	5.01
	[0.00]	[0.00]	[0.00]	[0.00]
JB	2.18	0.78	2.06	2.82
	[0.34]	[0.68]	[0.36]	[0.24]
RESET	21.12	0.97	15.72	13.57
	[0.00]	[0.33]	[0.00]	[0.00]

Notes: see Table 2

Table 6: Determinants of the official discount rate: tests of asymmetry

Period	1876-1895 (T = 66) (1) Δi^D	1896-1913 (T = 70) (2) Δi^D	1876-1895 (T =66) (3) Δi^D	1896-1913 (T = 70) (4) Δi^D
C	-0.188	-0.013	-0.091	-0.040
	(1.8)	(0.1)	(0.8)	(0.4)
$DP\Delta l_1$	-0.049	-0.038		
	(6.0)	(5.7)		
$DN\Delta l_1$	-0.036	-0.028		
	(3.3)	(4.7)		
$DP\Delta l_2$			-0.092	-0.071
			(4.8)	(5.8)
$DN\Delta l_2$			-0.072	-0.047
			(3.6)	(4.6)
$DP\Delta i^E$	0.246	0.072	0.163	0.047
	(3.0)	(0.7)	(1.8)	(0.4)
$DN\Delta i^E$	-0.069	0.005	-0.006	-0.014
	(0.7)	(0.0)	(0.1)	(0.1)
DPw^E	0.791	0.430	0.774	0.471
	(2.9)	(1.2)	(2.7)	(1.3)
DNw^E	0.589	0.376	0.692	0.437
	(1.9)	(1.0)	(2.2)	(1.1)
$\overline{R}^2$	0.728	0.703	0.693	0.698
DW	2.09	2.42	2.22	2.28
AIC	1.247	1.172	1.367	1.190
SC	1.479	1.397	1.599	1.415
WALD (Δl_i)	0.66	0.80	0.35	1.60
	[0.42]	[0.38]	[0.56]	[0.21]
WALD (Δi^E)	6.32	0.20	1.69	0.15
	[0.02]	[0.66]	[0.20]	[0.70]
WALD (w^E)	0.23	0.01	0.03	0.004
	[0.63]	[0.92]	[0.86]	[0.95]
Q(10)	15.39	9.73	24.06	6.85
	[0.12]	[0.46]	[0.01]	[0.74]
HET	2.21	3.51	1.85	4.45
	[0.02]	[0.00]	[0.06]	[0.00]
JB	1.83	1.61	1.01	2.76
	[0.40]	[0.45]	[0.60]	[0.25]
RESET	11.23	3.10	6.42	10.65
	[0.00]	[0.08]	[0.01]	[0.00]

Notes: see Table 2

Reichsbank reacted asymmetrically to changes in the liquidity ratio with a stronger reaction in times of financial stress. No evidence of asymmetric behaviour is found with respect to other explanatory variables.

Table 6 shows the asymmetry tests separately for the two sub-periods. In the period 1876-1895 there is evidence of asymmetric behaviour only with respect to changes in the Bank of England's discount rate in the regression using the narrow liquidity ratio. As for the whole period the Reichsbank reacted significantly to changes in the Bank of England's discount rate only in times of financial stress. As to the second period there is no evidence of asymmetric behaviour with respect to any explanatory variable.

Thus we can conclude that the Reichsbank reacted asymmetrically mainly to changes in the Bank of England's discount rate and only in the first period. This may be an indication that during the first period the Reichsbank was managing the monetary system on a narrow margin. Germany had decided in the early 1870's to join the gold standard and it accumulated gold on a massive scale for many years, contributing to the decline in world consumer and wholesale prices which lasted until 1895[16]. Instead in the second period the German gold stock was abundant and as a result Germany was no longer interested in further large-scale gold acquisitions. In addition the relative economic weight of Germany with respect to that of Great Britain had increased sharply.

5 Summary of main results and conclusions

In this paper we present estimates of a reaction function explaining changes in the Reichsbank's discount rate from 1876, when it started operations, to 1913. The changes in the discount rate are assumed to depend on changes in the liquidity ratio, on changes in foreign discount rates and on deviations of exchange rates from gold parity.

The main novelties of this paper are four. *First*, the data used. They refer to all episodes of discount rate changes enacted by the Reichsbank during the period. Since there were 136 such changes we have 136 observations. The use of these data avoids problems of reverse causation between exogenous and endogenous variables, contrary to annual or monthly data. In addition changes in discount rates and liquidity ratios were so frequent and large that the use of annual and even monthly data would hide a substantial amount of information. *Second,* we introduce international factors into the model: changes in foreign discount rates and

[16] Other European countries like Belgium and Sweden decided to move to the gold standard at about the same time (Hawtrey 1927) .

deviations of exchange rates from gold parity. The inclusion of foreign variables makes the analysis of mutual influences among countries possible. *Third*, we present stability tests and split the sample period in order to study changes in the degree of financial market integration over time and in the working of the gold standard in Germany. *Fourth*, we test whether the Reichsbank behaved asymmetrically in times of stress and ease.

The main findings of the paper are *first* that throughout the period the maintenance of internal convertibility of banknotes issued into gold was indeed the main concern of the Reichsbank, confirming the results of Bloomfield (1959) and Sommariva and Tullio (1987) for Germany and of Goodhart (1972) for Great Britain. The reaction of the Reichsbank to changes in the two liquidity ratios used in this paper, a narrow and a broad one, was particularly fast in the period 1876-1895 (about one month on average). The ratios were subject to large fluctuations.

Second, changes in the Bank of England's official discount rate and deviations of the Pound from parity cannot be neglected in estimating the reaction function of the Reichsbank. We were instead unable to find significant effects of changes in the French and Austro-Hungarian discount rates and the respective currency's exchange rates.

Third, by splitting the period we found that the influence of Great Britain on the Reichsbank was significantly stronger in the first period. This finding is in line with the results of Tullio and Wolters (2004) that the influence of Great Britain on the German liquidity ratios fell over time. *Fourth*, the tests for asymmetry show that the dependence of the Reichsbank from the Bank of England's discount rate was limited to those episodes of stress recorded in the first period. No evidence of asymmetry was found in the second period. *Fifth*, this significant reduction of London's influence on Berlin, coupled with the parallel finding by Tullio and Wolters that Berlin's influence on London increased significantly over time (2003b) imply that at least in the second period the classical gold standard was rather a decentralized multipolar system (or most likely a bi-polar one) as suggested by Eichengreen (1992) and Tullio and Wolters (1996, 1997, 2000) rather than the system which Keynes (1930) is alleged to have had in mind in his well known "conductor of the orchestra" view.

Recalling that the estimated relationship is a reaction function, which is usually considered quite unstable, the regressions presented in this paper can be considered as well behaved and relatively stable over time, even by the standard of today's industrial countries. Without any doubt, the behaviour of the Reichsbank was very consistent throughout the period from 1876 to 1913 despite the initial difficulties caused by the insufficient gold stock, the occurrence of financial crises, the change in the degree of international financial market

integration, the frequent use of gold devices by the Bank of England from about 1885 to about 1892/93 and the changing inflationary environment after 1895. The Reichsbank probably received a helping hand from the sharp increase in the economic weight of Germany, especially with respect to Great Britain, and from the increase in world gold production after 1890. It certainly knew exactly what it was doing.

References

Bloomfield, Arthur I., *Monetary Policy Under The International Gold Standard, 1880-1914.* Federal Reserve Bank, New York. 1959.

Eichengreen, Barry, *Golden Fetters,* Oxford University Press, Oxford and New York. 1992.

Gallarotti, Giulo, *The Anatomy of International Monetary Regime*, Oxford University Press, 1995.

Goodhart, Charles, *The Business of Banking,* Weidenfeld and Nicholson, London, 1972.

Hawtrey, Ralph G., *The Gold Standard in Theory and Paractice*, Longmans Green, London, 1927.

Keynes, John M., *A Treatise on Money*, MacMillan, London, 1930

Sommariva, Andrea and Tullio, Giuseppe, *German Macroeconomic History: a study of the effect of the monetary policy on inflation, currency depreciation and growth,* MacMillan, London and St. Martin Press, New York. 1987.

Taylor, John B., Discretion versus Policy Rules in Practice, *Carnegie Rochester Conference Series on Public Policy* 39, (1993), 195-214.

Tullio, Giuseppe and Wolters, Jürgen, Was London the conductor of the international orchestra or just the triangle player? An empirical analysis of asymmetries in interest rates behaviour during the classical gold standard, 1876-1913, in: *The Scottish Journal of Political Economy,* vol. 43, no. 3, September 1996, 419-443.

Tullio, Giuseppe and Wolters, Jürgen , Was London the Conductor of the International Orchestra, the Second Violinist or the Triangle Player? A Survey of the Literature on Asymmetries in Balance of Payments and Adjustment during the Classical Gold Standard, *Discussion Paper No. 9705*, Department of Economics, Università degli Studi di Brescia, July 1997.

Tullio, Giuseppe and Wolters, Jürgen , A Note on Interest Linkages between the US and the UK during the Gold Standard, *The Scottish Journal of Political Economy*, vol. 47, No. 1, February 2000, 61-71.

Tullio, Giuseppe and Wolters, Jürgen, The Objectives of British Monetary Policy during the Classical Gold Standard, 1876-1913: an econometric analysis of the determinants of the Bank of England's discount rate, *Diskussionsbeiträge des Fachbereichs Wirtschaftswissenschaft der Freien Universität Berlin* Nr. 2003/13 (2003).

Tullio, Giuseppe and Wolters, Jürgen, *Domestic and International Determinants of the Reichsbank's Liquidity Ratios during the Classical Gold Standard, 1876-1913: an Econometric Analysis, Diskussionsbeiträge des Fachbereichs Wirtschaftswissenschaft der Freien Universität Berlin* Nr. 2004/22 (2004).

Vergleichende Notenbankstatistik, Organisation und Geschäftsverkehr Europäischer Notenbanken, 1876-1913, Berlin, Reichsdruckerei, 1925.