Domestic and International Determinants of the Reichsbank's Liquidity Ratios during the Classical Gold Standard, 1876-1913: an econometric analysis[1].

by

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Introduction

This paper analyses from January 1, 1876 to the end of 1913 the factors which influenced the Reichsbank's liquidity ratio, defined as the ratio of its gold and silver holdings to its banknotes outstanding. January 1, 1876 is the day the Reichsbank started operations. A key aspect of the gold standard, as this period came to be called, was the legal obligation on the part of Central Banks to convert on request banknotes into gold. From this obligation resulted the "discipline" imposed on governments and Central Banks at the time. The minimum gold cover of notes outstanding was established by law and varied from country to country. As Central Banks could not let the gold cover of notes issued fall below the legally established minimum, it is clear that the ratio of gold to notes was constantly monitored, leading to apprehension when they were falling rapidly and or approaching the legal minimum and to a relaxed attitude when they were increasing.

The Central Banks had a very powerful instrument at their disposal to stop the ratio from falling and invert its decline. This instrument was the discount rate, which was the interest rate they applied on their lending to commercial banks and to the public[2]. An increase in the discount rate attracted in the first place capital flows and gold from abroad, thus

[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] At that time the Reichsbank was also operating as a commercial bank.

contributing to increase the Central Bank's gold stock. It also reduced the demand for rediscounting at the Bank and the level of economic activity in the country, thus reducing the stock of banknotes outstanding. Hence both the numerator and the denominator of the ratio would move in the right direction. The analysis of the determinants of the liquidity ratio is therefore crucial to understand the objectives of monetary policy during the classical gold standard to the extent that its changes caused changes in the discount rate and changes in the discount rate were the main instrument to control the liquidity ratio.

The determinants of the Reichsbank's liquidity ratio have already been studied by Sommariva and Tullio (1987), using a data set consisting of 136 observations referring to the 136 discount rate changes enacted during the period. However, while their study included only one explanatory variable, the differential between the private discount rate in Berlin and the official discount rate of the Reichsbank (henceforth called "the differential"), we include in this paper also foreign discount rate changes and the deviations of the Reichsmark from gold parity recorded in the other main financial centres.

The inclusion of foreign variables into the model allows us to analyse to what extent German financial markets and the Reichsbank's liquidity ratio were influenced by financial conditions abroad, which were the most important gold standard countries influencing Germany, the degree of international financial market integration at that time and whether it changed significantly from 1876 to 1913. Finally, the inclusion of foreign variables allows us to test if there were periods during which the use of gold devices[3] by the Reichsbank and/or other gold standard Central Banks significantly changed the coefficients of the estimated relationships.

The study of the determinants of the Reichsbank's liquidity ratio with the inclusion of foreign explanatory variables is not only important for the reasons stated above, it is also crucial to understand the factors which led to discount rate changes and hence which were the main objectives of monetary policy.

Changes in the discount rate were 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 Central Bank credit. The third instrument was the

[3] 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.

so-called gold devices which changed the conditions of gold shipments abroad and hence the width of the band around the gold parity within which the market exchange fluctuated.

For the period from 1880 to 1913 Bloomfield (1959) showed graphically that there was an inverse correlation between annual discount rates and the liquidity ratio for a large number of gold standard Central Banks. 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. Finally Sommariva and Tullio (1987) analysed the factors which influenced the Reichsbanks' decisions to change the official discount rate from 1876 to 1913 using 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). The data cover four gold standard countries (Germany, the United Kingdom, France and Austria-Hungary), they are collected 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) concluded in their study that the differential, a measure of the "tension" on the Reichsbank's gold stock, is a very significant determinant of the liquidity ratio. They show that the effect is negative and offer explanations of why this should be so. Finally they show that there were significant differences in the effect of the liquidity ratio on the Reichsbank's discount rate and of the differential on the liquidity ratio between the sub-period 1876-1895 and the sub-period 1896-1913.

Following Sommariva and Tullio (1987) we use in this paper the data from VN. Their main advantages are that they are available for the whole period from the day the Reichsbank started operations on January 1st 1876 to 1913 and since we have the same data set for four gold standard countries meaningful international comparisons are possible. In this paper we also present stability tests of the estimated regressions to gain insights into how the working of the gold standard changed during this 38 year period.

The paper is structured as follows: Section 1 presents the model explaining the Reichsbank's liquidity ratio taking into account international influences. Section 2 describes in detail the data used and how the variables have been constructed. Section 3 presents the estimates of the model for the whole period and for the two sub-periods 1876-1895 and 1896-1913. Section 4 concludes.

1. The model

In this section we present an equation explaining the changes in the Reichsbank's liquidity ratio. Following Sommariva and Tullio (1987), it is assumed that changes in the liquidity ratio depend on the differential between the private and the official discount rate in Berlin. However, in order to test how the degree of international financial market integration changed through time and to verify the assumption of bi-polarity or multi-polarity of the classical gold standard, a set of variables capturing international influences, market exchange rates and foreign official discount rates, was included among the explanatory variables.

Thus the equation to be estimated is:

$$(1) \qquad \Delta l_i = a_1 + a_2(i_P - i^D) + \sum_j a_{3j}\Delta i^j + \sum_j a_{4j} w^j + u,$$

where Δl_i denotes a change in the liquidity ratio of the Reichsbank. We shall use a narrow $(i = 1)$ and a broad definition $(i = 2)$. The first is the ratio of the gold and silver stock to banknotes issued by the Reichsbank (l_1), and the second has the same numerator but includes in the denominator sight liabilities in addition to banknotes issued (l_2). Δ stands for a change of the variable. In this case Δ does not denote the usual difference operator, since in our data set the changes refer to differently spaced time points. The residuals are denoted by u.

$i_P - i^D$ denotes the differential between the average private discount rate in Berlin and the Reichsbank's discount rate. The superscript D stands for Germany.

Δi^j denotes changes in discount rate of 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 the percentage deviation of the market exchange rate of the Reichsmark with the currency of country j with respect to the gold parity; the asterisk indicates the gold parity and the variable "e_j" the market exchange rate. The gold parity never changed during the whole period for Germany, France and Great Britain.

Equation (1) states that the main domestic determinant of changes in the liquidity ratio is the differential which reflects the situation of the domestic business cycle and the liquidity position of the German and in particular the Berlin financial market. The differential must have had very high informative contents for the markets and the monetary authorities. An increase in the differential put the Reichsbank under strain as it increased the demand for

rediscounting on the part of commercial banks and it increased the demand for notes, gold and Central Bank credit by the private sector. The channels between the business cycle and the liquidity ratio or its components have been studied by Goodhart (1972) for the United Kingdom and McGouldrick (1984) and Sommariva and Tullio (1987) for Germany. Unfortunately we cannot introduce the business cycle into this model because we have no data on industrial production and GDP comparable to those of VN.

In addition to the differential, changes in the liquidity ratio are assumed to be influenced by foreign discount rate changes and deviations of market exchanges rates from the gold parity.

The expected signs of the coefficients of the explanatory variables are: negative for the differential, negative for changes in foreign official discount rates and negative for the deviation of the exchange rate from the gold parity. The exchange rate is defined as the number of domestic currency units for one unit of foreign currency (Pound, French Franc and Austrian Florin/Krone); hence an increase in e_j indicates a devaluation of the Reichsmark (capital and gold outflows from Germany).

For the exact definition of the variables and for the time span to which their changes refer see Section 2. Suffice to mention here that the series used are not equidistant time series but they refer to timely ordered episodes of all official discount rate changes which occurred during the period. From 1876 to 1913 the Reichsbank changed the official discount rate 136 times.

Changes in foreign discount rates are measured over an interval similar to the one chosen by the compilers of the tables of VN to measure changes in liquidity ratios. The exact definition of the intervals over which changes in the foreign discount rates are measured is also discussed in Section 2.

2. Description of the data used for estimation

The data from VN used in this paper are obtained from a 1925 volume, entitled "Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr Europäischer Noten-banken, 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 four countries: France, Germany, the United Kingdom and Austria-Hungary there are more detailed tables containing a wealth of data relating to each official discount rate change. For Germany the relevant table is Table 133 (pages 240 to

246 of Vol. 2). In order to facilitate the description of the data we reproduce in Table 1 below the columns of Table 133 used in the empirical work together with the data for a limited number of discount rate changes.

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 follows 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 column contains the month, day, and year of the official discount rate change. The second column contains the date of the closest statement of the Reichsbank used by the compilers of the table, and possibly also by the members of the Board at the meeting during which the discount rate change was decided[4], to analyse the factors which led to the decision to change the discount rate. The date of the closest statement generally precedes the day of the discount rate change by one to seven days. In 7 cases the date of the closest statement coincides with the day of the discount rate change and in 22 cases it follows it by 1 to 3 days. The third column contains the date of a more distant statement, preceding the date of the closest one by a minimum of 1 week to a maximum of 1 year. The interval between the two statements was chosen by the compilers of the table. In choosing these reference intervals the compilers were interested in eliminating disturbances to the balance sheet items of the Bank caused by seasonal factors or special events. For the whole period the average interval between the two statements was 70.8 days. The average interval increased from 35.4 days in

[4]This is our supposition.

Table 1: Discount rate changes of the Reichsbank, 1876 – 1913. Some representative data at the beginning of the period.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Date of discount rate change	Date of closest statement used	Date of statement used for comparison	Δl_1	Δl_2	$i_P - i^D$	e^E	e^F	Δi^E	Δi^F	Δi^A
1	1/3/1876	1/1/1876	11/23/1875	-8,7	-5,8	0,5	20,30	80,85	0,0	0,0	0,0
2	1/19/1876	1/15/1876	1/1/1876	4,9	0,5	-1,625	20,32	80,90	1,0	0,0	0,0
3	2/4/1876	1/31/1876	1/1/1876	9,1	3,3	-2,0	20,395	81,15	0,0	0,0	-0,5
4	5/18/1876	5/15/1876	1/31/1876	14,2	6,8	-1,125	20,40	80,95	-2,0	0,0	0,0
5	7/11/1876	7/7/1876	5/31/1876	-14,7	-7,7	-0,5	20,51	80,95	0,0	0,0	0,0
6	10/25/1876	10/23/1876	5/31/1876	-17,6	-8,8	-0,375	20,42	81,20	0,0	0,0	0,0
7	1/5/1877	1/7/1877	12/31/1876	1,0	1,1	-1,25	20,40	81,15	0,0	0,0	0,0
8	5/11/1877	5/7/1877	2/7/1877	-1,2	-0,2	-0,875	20,475	81,49	1,0	-1,0	0,0
9	6/16/1877	6/15/1877	5/15/1877	3,2	2,4	-1,75	20,475	81,15	0,0	0,0	0,0
10	9/12/1877	9/7/1877	8/23/1877	-7,8	-3,8	-0,75	20,47	81,40	1,0	0,0	0,0
11	10/3/1877	9/30/1877	9/7/1877	-8,8	-5,6	-0,375	20,43	81,25	0,0	0,0	0,0
12	11/12/1877	11/7/1877	10/7/1877	4,7	3,1	-1,125	20,45	81,25	1,0	0,0	0,0
13	12/3/1877	11/30/1877	11/7/1877	4,6	0,8	-1,125	20,425	81,20	-1,0	0,0	0,0

Source: Table 133 of VN

the sub-period 1876-1895 to 118.5 days in the sub-period 1896-1913[5].

Columns 4 and 5 contain the changes in the narrow and broad definition of the liquidity ratio between the two dates reported in columns 2 and 3 of Table 1. l_1 is defined as the ratio of the gold and silver stock of the Reichsbank to its banknotes outstanding. l_2 is defined as the ratio of the gold and silver stock of the Reichsbank and the sum of banknotes plus sight liabilities issued by the Reichsbank.

Column 6 contains the differential between the average private discount rate of major commercial banks in Berlin and the official discount rate of the Reichsbank on the day prior to the discount rate change. It is worth mentioning that in VN this differential is called "the tension" (*Spannung* in German).

Columns 7 and 8 contain exchange rates on the day before the discount rate change. Column 7 reports the number of Reichsmark per Pound in London and column 8 the number of Reichsmark per 100 French Francs in Paris. In order to obtain the percentage deviations of the market exchange rates from gold parity, we used the gold parities reported in Gallarotti (1995). They are: 20.430 Reichsmark per Pound and 80.99 Reichsmark per 100 French Franc. For Austria-Hungary the exchange rate of the Reichsmark in Vienna is not available for the whole period.

Changes in the official discount rates in Great Britain (Δi^E), France (Δi^F) and Austria-Hungary (Δi^A) are not reported in Table 133 of VN. For their construction we had to use information contained in the other tables of VN. As for these three foreign countries, VN contains daily figures of the official discount rates 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. The changes are calculated over the interval between the date reported in column 3 of Table 1 and the day before the discount rate change.

To summarize five observations are in order. *First*, the data presented in Table 1 and derived from Table 133 of VN can be divided into four main categories: A. For each discount rate change information on the balance sheet items of the Reichsbank, in other words on its assets and liabilities, on two reference days which usually both precede the discount rate change (only in 29 out of 136 cases the end date is later than the discount rate change). B. The

[5]The significant (about threefold) increase in the reference interval observed from the first to the second sub-period 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 observed for the Reichsbank stands in sharp contrast with the significant reduction observed for the Bank of England. See Tullio and Wolters (2003b).

differential between the private discount rate of major commercial banks in Berlin and the discount rate of the Reichsbank on the day prior to the discount rate change. C. The market exchange rates with reference to two main foreign currencies on the day preceding the change in the discount rate. D. The changes in the foreign discount rates measured over the interval between the date indicated in column 3 and the day prior to the discount rate change in Germany.

Second, 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[6]. *Fifth*, it is clear that the use of annual data, as for example in Bloomfield (1959), hides a substantial amount of information and therefore their use would bias all coefficients towards zero. This may hold also for monthly data, albeit to a much smaller degree.

By estimating equation (1) with the data presented in this section we make use of an incredible wealth of information which has been hardly exploited so far.[7]

3. The determinants of changes in the Reichsbank's liquidity ratios

In this section we present ordinary least squares (OLS) estimates of equation (1) which includes exchange rates and foreign discount rates among the explanatory variables. We started out with all explanatory variables in the regression and then eliminated successively all non significant ones. The program used was Eviews 4.0. Table 2 contains the estimates for the narrowly defined liquidity ratio (Δl_1) for the whole period and for the sub-periods 1876-1895 and 1896-1913. The estimates for the broadly defined liquidity ratio (Δl_2) are presented

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

[7] Exceptions are Sommaria and Tullio (1987) and Tullio and Wolters (2003°, 2003b and 2004)

in Table 3. The important role played by the differential has been already explained in Section 1. The key role played by this variable is strongly confirmed by the regression results. As to foreign variables, only the Bank of England's discount rate was significant.

Table 2: The determinants of the Reichsbank's liquidity ratio Δl_1

Period	1876-1913 (T = 136) (1) Δl_1	1876-1895 (T = 66) (2) Δl_1	1896-1913 (T = 70) (3) Δl_1
c	-13.578	-11.530	-14.944
	(7.3)	(5.3)	(5.4)
$i_p - i^D$	-13.561	-10.069	-16.648
	(9.5)	(6.2)	(7.5)
Δi^E	-4.264	-4.039	-4.811
	(3.8)	(3.6)	(2.3)
$\overline{R}^2$	0.575	0.590	0.610
DW	1.84	1.90	1.82
AIC	7.714	7.228	7.953
SC	7.778	7.328	8.050
Q(10)	7.61	11.17	7.70
	[0.67]	[0.34]	[0.66]
HET	0.42	0.42	0.12
	[0.79]	[0.79]	[0.98]
JB	2.80	1.61	0.56
	[0.25]	[0.45]	[0.76]
RESET	1.18	0.22	2.28
	[0.28]	[0.64]	[0.14]

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).

Starting with the results for the whole period, the coefficients of both explanatory variables have the expected signs and are significantly different from zero at the 1% confidence level. In particular an increase in the differential of 100 basis points led to a fall of 13.6 percentage points in the first liquidity ratio and 7.4 in the second, and an increase in the Bank of England's discount rate of 100 basis points led to a fall of 4.3 percentage points in the first liquidity ratio and of 2.4 in the second[8]. The fraction of the variance explained is 59% for

[8] A few words are in order concerning the days on which the compilers of VN reported the tension and the final day of the period over which the changes in the liquidity ratio are measured (reference period). In 98 out of 136 cases the tension is measured one to 6 days after the end of the reference period. For regressions with time series the explanatory variables should normally not be measured at a date later than the date of the dependent variable.

the second. Thus, while the influence of domestic factors, as reflected by the differential, dominates over foreign ones, foreign influences cannot be neglected: they are very significant and lead to a noticeable improvement in the explanatory power of the regressions[9].

Table 3: The determinants of the Reichsbank's liquidity ratio Δl_2

Period	1876-1913 (T = 136) (1) Δl_2	1876-1895 (T = 66) (2) Δl_2	1896-1913 (T = 70) (3) Δl_2
C	-7.185	-5.471	-8.287
	(7.2)	(5.0)	(5.6)
$i_p - i^D$	-7.444	-5.055	-9.430
	(9.7)	(6.2)	(7.9)
Δi^E	-2.405	-2.171	-3.001
	(4.0)	(3.9)	(2.7)
$\overline{R}^2$	0.589	0.606	0.645
DW	1.89	2.02	1.86
AIC	6.468	5.833	6.706
SC	6.532	5.933	6.803
Q(10)	4.34	17.63	5.91
	[0.93]	[0.06]	[0.82]
HET	0.61	1.10	0.10
	[0.66]	[0.36]	[0.98]
JB	2.03	1.63	0.32
	[0.36]	[0.44]	[0.85]
RESET	3.44	2.22	1.19
	[0.07]	[0.14]	[0.28]

Notes: see Table 2

The residuals are well behaved: they are not autocorrelated, not heteroskedastic, and normally distributed. The regressions do not present signs of functional form misspecification. However, according to the Cusum of Squares test none of the regressions is stable at the 5% confidence level (see Figures 1 and 2). The recursive parameter estimates, also shown in Figures 1 and 2, indicate that the main reason for the instability is the significant increase in the absolute value of the coefficient of the differential from the first to the second period. The coefficient of changes in the Bank of England's discount rate remains instead more stable.

We do not think that this constitutes a problem in our case mainly because the differential measures the accumulation of *tensions over a time span* which may be as long as or even longer than the reference interval. In addition if the reference period is on average over two months long, a few days' lead of the differential should not matter.

[9] See Sommariva and Tullio (1987) for comparisons.

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

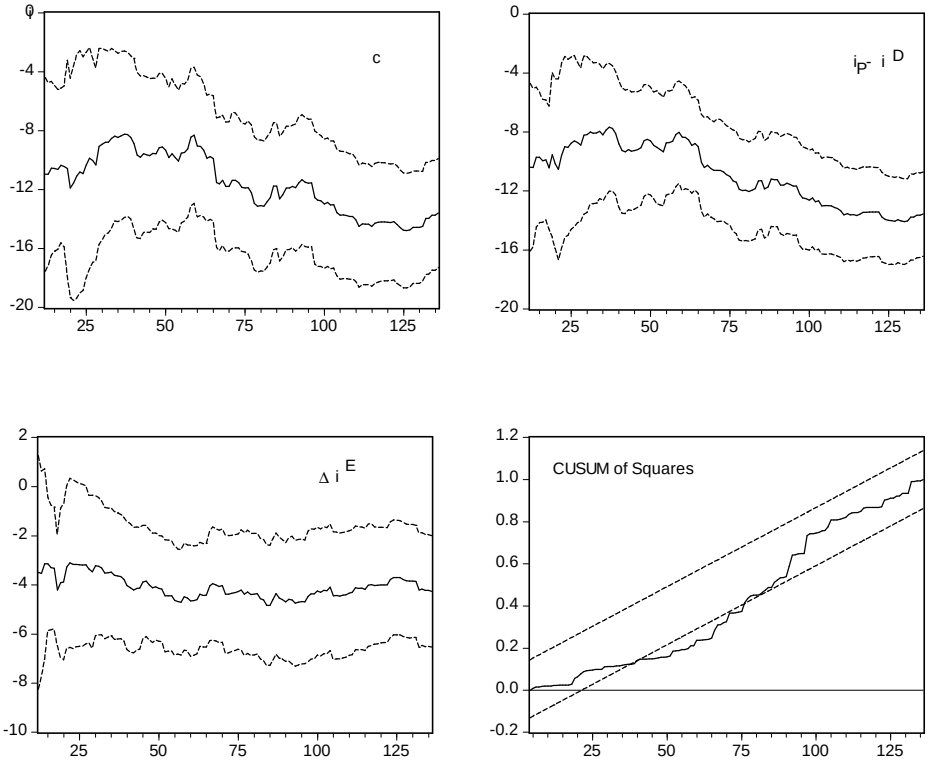
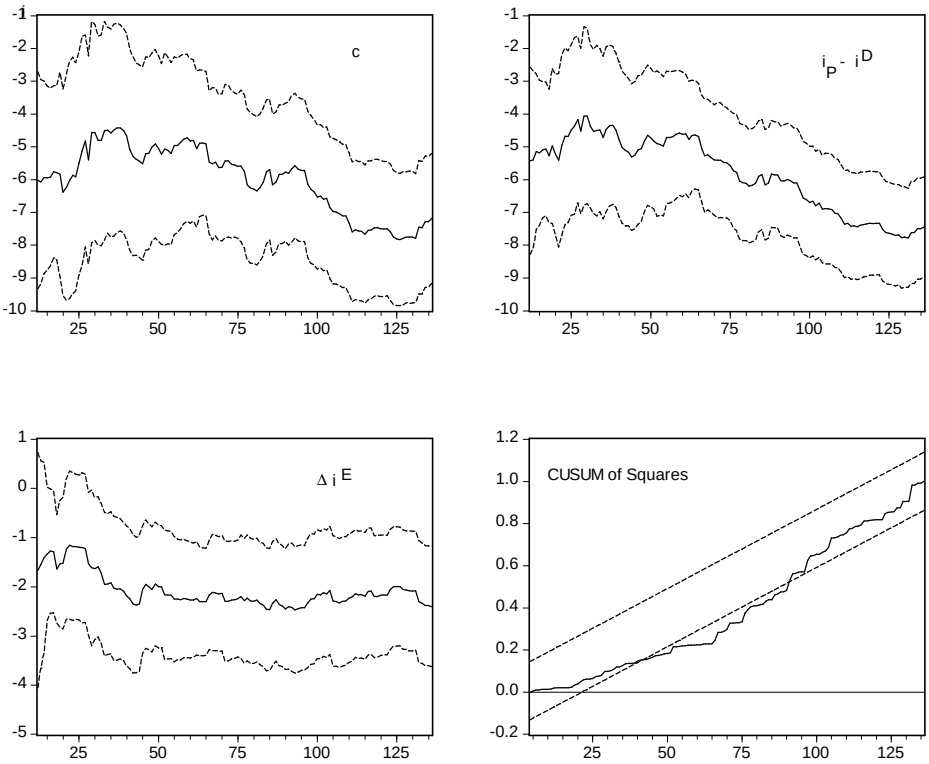


Figure 2: Recursive coefficients and CUSUM of Squares test for equation (1) of Table 3



In line with these findings, we performed Chow break F tests for both regressions in order to verify whether and when a structural break occurred. The lowest p-values of the statistic ($p = 0.002$) are observed at or just before observation 66, which corresponds to the

last discount rate change of 1895. After observation 66 the p-values increase sharply. Since the lowest p-values are associated with the highest probability of a structural break, we conclude that a break occurred at observation 66. As a result the period is split into two, the first period going from 1876 to 1895 (observations 1-66) and the second going from 1896 to 1913 (observations 67-136).

There are also many other reasons for choosing 1895 as a turning point in the history of the classical gold standard. Among them should be mentioned the end of the long period of declining prices in connection with the discovery of new gold mines and of a new process to extract gold. In addition in the second sub-period communication and transportation techniques were more developed, thus affecting the degree of international financial market integration. Furthermore in the early 1890s ended a period characterized by a more intensive use of gold devices on the part of most gold standard Central Banks, including the Bank of England, which was historically more averse to the use of such devices. The use of gold devices reduced the degree of international financial integration among countries[10]. Finally the relative economic and financial weight of Germany increased substantially and the Pound developed into an international reserve currency. Certainly, all these changes did not occur abruptly on December 31st, 1895. However, this date represents a justifiable dividing line between an earlier and a later phase of the classical gold standard.

The regressions for these two sub-periods are also presented in Table 2 for Δl_1 and in Table 3 for Δl_2. The coefficient of the differential shows a significant increase in absolute value for both liquidity ratios. This increase may simply be the result of the higher average gold stock in the second period and/or of the large increase from 35.4 days to 118.5 days in the average reference interval over which Δl_1 and Δl_2 are measured. More interesting is the reduction in the significance of the coefficient of Δi^E in the second period. This may be an indication of a somewhat reduced role of the London financial market in determining events in Germany and it may imply that the effect of increased economic weight of Germany and of its increased gold stock outweighed the effect of increased financial market integration. But it may also mean that in the second period London influenced Berlin more indirectly via the Berlin differential. The hypothesis that the effects of Δi^E on the Berlin differential became stronger in the second period could be tested with the data at our disposal but this is left for future work.

[10] For instance Tullio and Wolters (2004) find evidence of a signficantly reduced effect of the Berlin discount rate on London's narrow liquidity ratio from the end of 1885 to the end of 1893.

The residuals are well behaved and there is no indication of functional form misspecification. The stability tests for both periods are shown in Figure 3 for Δl_1 and in Figure 4 for Δl_2. The figures show that by splitting the period all regressions and coefficients become stable. The improvement seems more marked for Δl_2.

Figure 3: CUSUM of Squares test for regressions (2) and (3) of Table 2

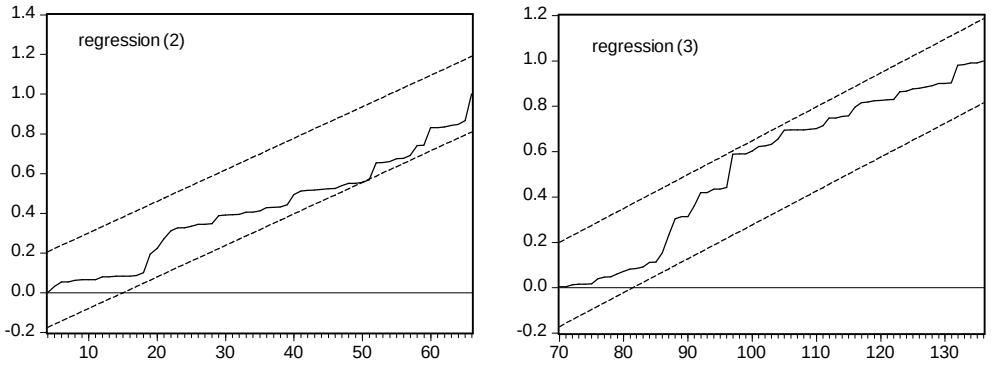
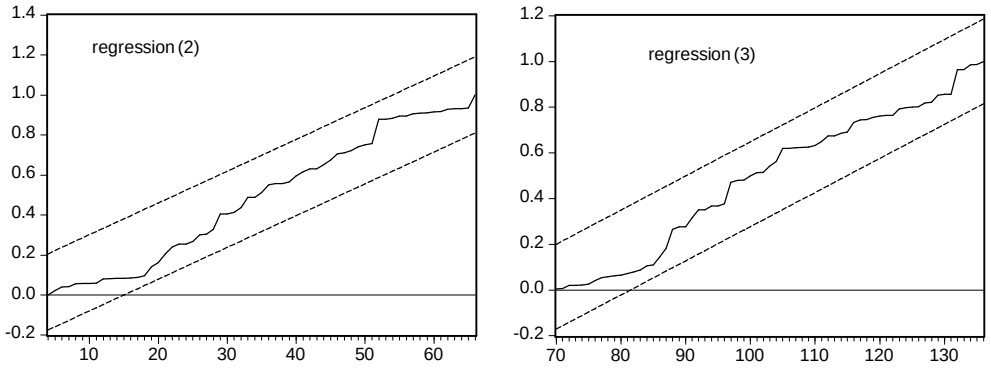


Figure 4: CUSUM of Squares test for regressions (2) and (3) of Table 3



4. Summary of main results and conclusions

In this paper we present OLS estimates of an equation explaining changes in the Reichsbank's liquidity ratios from 1876, when it started operations, to 1913. The changes in the liquidity ratios are assumed to depend on the differential between the private and the official discount rate in Berlin, on foreign discount rates and on deviations of exchange rates of the Reichsmark from gold parity. Two liquidity ratios are used in this paper, a narrow and a broad one. It does not make much difference in estimating the model whether the narrow or the broad definition of the liquidity ratio is used.

A number of observations are in order. We use data referring 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 reduces the problem of reverse causation between exogenous and endogenous variables, contrary to annual or monthly data which hide a substantial amount of information, given the frequent changes in the discount rate and the large and rapid changes in the liquidity ratios. We introduce international factors into the model: changes in foreign discount rates and deviations of exchange rates from gold parity. The introduction of foreign variables allows the study of mutual financial influences among countries. We present stability tests and split the sample period in order to analyse the changes in the role of the determinants of the liquidity ratios and in the working of the gold standard over time.

The main findings of the paper are *first* that throughout the period the differential between the private discount rate in Berlin and the official one played an important role in transmitting disturbances from the real economy, from the German financial market and from London to the Reichsbank's liquidity ratios.

Second, the only foreign country among the three considered in this paper (Great Britain, France and Austria-Hungary) which systematically and significantly influenced both liquidity ratios of the Reichsbank was Great Britain. In both periods the Bank of England's discount rate exerted a significant influence on the Reichsbank liquidity ratios. Instead the deviations of the Pound-Reichsmark exchange rate from parity were not significant. The effect of the Bank of England's discount rate on the Reichsbank's liquidity ratios became somewhat less significant in the second period.

Third, the finding of this paper that London significantly influenced Berlin coupled with the findings (Tullio and Wolters 2003b, 2004) that Berlin significantly influenced London, imply that the classical gold standard was a decentralized multi-polar system (or at least a bi-polar one) as suggested by Eichengreen (1992) and Tullio and Wolters (1996, 2000), rather than the system which Keynes(1930) is alleged to have had in mind in his well known "conductor of the orchestra" view.

Fourth, the relationships estimated for the whole period are unstable. The instability results mainly from a significant change in the coefficient of the differential from the first to the second period. This may be the result of a more important role played by the differential in the second period in transmitting financial market disturbances, including international ones, to the Reichsbank's balance sheet, but it may also much more simply be the result of the

increased average gold stock and/or of a large increase in the reference interval over which Δl_1 and Δl_2 are measured.

Fifth, even though the change in the coefficient of the differential does not occur abruptly, a Chow break test indicates that the most appropriate time to split the period in two is at the end of 1895. We then test all regressions separately for the sub-periods 1876-1895 and 1896-1913 and find that all regressions become stable. The improvement is more marked for the regressions explaining the broad liquidity ratios.

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.

McGouldrick, Paul, Operation of the German Central Bank and the Rules of the Game, 1879-1913, in: *A Retrospective on the Classical Gold Standard, 1821 1931,* edited by Bordo, Michael D. and Anna J. Schwartz, Chicago, University of Chicago Press, 1984.

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.

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, *The Scottish Journal of Political Economy*, vol. 43, no. 3, September 1996, 419-443.

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, n. 1, February 2000, 61-71.

Tullio, Giuseppe and Wolters, Jürgen, The Objectives of German Monetary Policy during the Classical Gold Standard, 1876-1913: an Econometric Analysis of the Determinants of the Reichsbank's Official Discount Rate, *Diskussionbeiträge des Fachbereichs Wirtschaftswissenschaft der Freien Universität Berlin*, Nr. 2003/14, 2003a.

Tullio, Giuseppe and Wolters, Jürgen, The Objectives of British Monetary Policy during the Classical Gold Standard, 1876-1913: an Econometric Analysis of Domestic and Foreign Determinats of Bank Rate, *Diskussionbeiträge des Fachbereichs Wirtschaftswissenschaft der Freien Universität Berlin,* Nr. 2003/13, (2003b).

Tullio, Giuseppe and Wolters, Jürgen, Domestic and International Determinants of the Bank of England's Liquidity Ratios during the Classical Gold Standard, 1876-1913, an Econometric Analysis, *Diskussionbeiträge des Fachbereichs Wirtschaftswissenschaft der Freien Universität Berlin*, Nr. 2004/27, 2004.

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