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Domestic and International Determinants of the Bank of England's Liquidity Ratios during the Classical Gold Standard, 1876-1913: an econometric analysis

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

by

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Introduction

This paper analyses the factors which influenced the Bank of England's liquidity ratio from January 1, 1876 to the end of 1913. The liquidity ratio is defined as the ratio of gold and silver holdings to banknotes issued by the Bank of England and it is also called the "Proportion". A key aspect of the gold standard, as this period is 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 it was falling rapidly and or approaching the legal minimum and to a relaxed attitude when it was 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 contributing to increase the Central Bank's gold stock. It also reduced the demand for

[1] This paper is based on a Laurea Dissertation presented on July 7, 1997 by Piera Bignetti at the Università di Brescia entitled "Le determinanti del tasso di sconto inglese durante il tallone aureo (1876-1913). Un'analisi econometrica" and written under the supervision of the first author. We thank Hannah Nielsen for research assistance.

[2] At that time the Bank of England was also operating as a commercial bank.

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 discount rate was the most important instrument of monetary policy during the classical gold standard. A second instrument were 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 use of so-called gold devices[3] which changed the conditions of gold shipments abroad and hence the width of the band around the gold parity within which the market exchange rates 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 the annual discount rate and the liquidity ratio. 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). 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 the data from VN, conclude that the differential between the private discount rate in Berlin and the official discount rate of the Reichsbank, a measure of "the tension" on the Bank's gold stock, is a very significant determinant of changes in the liquidity ratio. They show that the effect is negative and offer explanations of why this should be so. Finally they show that in Germany the effects of the liquidity ratio on the Reichsbank's discount rate and of the differential on the liquidity ratio were significantly different between the sub-period 1876-1895 and the sub-period 1896-1913.

[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.

In this paper on the Bank of England we also focus on the differential between the average discount rate on lending by major commercial banks in London and the official Bank of England's discount rate (henceforth called "the differential") as the main explanatory variable of the Proportion. However, we include among the explanatory variables also foreign discount rates and the deviations of the Pound from the gold parity recorded in the other main financial centres. The inclusion of foreign variables allows us to study the extent to which the London financial market and the Bank of England's liquidity ratio were influenced by financial conditions abroad and which were the most important gold standard countries influencing London. In addition we can study how the degree of international financial market integration changed from 1876 to 1913 and if there were periods during which the use of gold devices by the Bank of England and/or other gold standard Central Banks significantly changed the coefficients of the estimated relationships.

In this paper we use the data from VN. Their main advantages are that they are available for the whole period from January 1, 1876 to 1913 and that they provide the same data set for four gold standard countries and this makes meaningful international comparisons possible. In this paper we also present stability tests of the estimated regressions in order to gain insights into how the working of the gold standard changed during the 38 year period.

The paper is structured as follows: Section 1 presents the model explaining the changes in the Bank of England'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 Bank of England'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 London. 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:

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

where Δl_i denotes a change in the liquidity ratios of the Bank of England. 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 Bank of England (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.

$i_P - i^E$ denotes the differential between the private discount rate in London and the Bank of England's discount rate. The superscript E stands for England.

Δi^j denotes changes in the discount rate of country j, where the superscript $j = D$ stands for Germany, F for France and A for Austria-Hungary.

$w^j = (e_j - e_j^*)/e_j^*$ denotes percentage deviations of the market exchange rate of the British Pound 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 Great Britain, Germany and France.

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 British and in particular the London financial market. The differential must have had very high informative contents for the markets and the monetary authorities[4]. An increase in the differential put the Bank of England under strain as it led to an increased demand for rediscounting on the part of commercial banks and increased demand for banknotes, gold and Bank of England credit by the private sector and hence led to a fall in the liquidity ratio.

The channels between the business cycle and the liquidity ratio or its components have been studied by Goodhart (1972) for the United Kingdom, 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.

[4]At that time data on GDP and industrial production were not available.

In addition to the differential, changes in the liquidity ratio are assumed to be influenced by foreign discount rate changes and deviations of market exchange 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 positive for the deviation of the exchange rate from the gold parity. The exchange rate is defined as the number of foreign currency units (Reichsmark, French Franc and Austrian Florin/Krone) for one unit of domestic currency; hence an increase in e_j indicates an appreciation of the British Pound (capital and gold inflows from abroad).

For the exact definition of the variables and for the time intervals over which their changes are measured 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 Bank of England changed the official discount rate 221 times.

2. Description of the data used for estimation

The VN data used in this paper are obtained from a 1925 volume published by the German Imperial Printing Office entitled "Vergleichende Notenbankstatistik: 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 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 Great Britain the relevant table is Table 135 (pages 248 to 255 of Vol. 2). In order to facilitate the description of the data we reproduce in Table 1 the columns of Table 135 used in the empirical work together with the data for a limited number of episodes 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 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 column in Table 1 contains the month, day, and year of the official discount rate change. The second column contains the date of the closest statement of the Bank of England 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[5], 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 day. In 6 cases out of 221 the date of the closest statement follows the day of the discount rate change by one or two days. The third column contains the date of a more distant statement, generally preceding the day of the discount rate change by 2 weeks to 2 months and on some occasions by more. 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 50.0 days. The interval fell from 58.7 days in the period 1876-1895 to 36.9 days in the period 1896-1913[6].

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 between the gold and silver stock of the Bank of England to banknotes issued by her. l_2 is defined as the ratio of the gold and silver stock of the Bank of England to the sum of banknotes issued and sight liabilities.

[5]This is our supposition.

[6]The significant reduction observed from the first to the second period in the reference interval may be an indication that the Bank of England was operating the gold standard on a "thinner" gold stock and/or that it was managing the system in a more efficient way. This large reduction observed for the Bank of England stands in sharp contrast to the significant about threefold increase observed for the Reichsbank. See Tullio and Wolters (2003a).

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Date of discount rate change	Date of closest statement used	Date of statement used for comparison	Δl_1	Δl_2	$i_P - i^E$	e^D	e^F	e^A	Δi^D	Δi^F	Δi^A
1	1/6/1876	1/5/1876	12/29/1875	-3.2	-4.4	0.75	20.66	25.43	11.60	1.0	0.0	0.0
2	1/27/1876	1/26/1876	1/5/1876	7.5	14.3	-1.125	20.59	25.43	11.75	-1.0	0.0	0.0
3	3/23/1876	3/22/1876	1/5/1876	18.6	17.7	-0.625	20.70	25.50	11.83	-2.0	0.0	-0.5
4	4/6/1876	4/5/1876	1/5/1876	17.0	16.6	-0.625	20.71	25.48	11.94	-2.0	0.0	-0.5
5	4/20/1876	4/19/1876	1/5/1876	18.5	19.1	-1.125	20.68	25.48	12.30	-2.0	0.0	-0.5
6	5/3/1877	5/2/1877	3/14/1877	-11.9	-8.7	1.00	20.64	25.30	13.13	0.0	-1.0	0.0
7	7/5/1877	7/4/1877	5/2/1876	7.7	5.1	-1.00	20.66	25.35	12.81	1.0	0.0	0.0
8	7/12/1877	7/11/1877	7/4/1877	2.5	3.4	0.625	20.63	25.30	12.84	0.0	0.0	0.0
9	8/28/1877	8/29/1877	7/25/1877	-5.3	-3.1	1.00	20.64	25.30	12.25	0.0	0.0	0.0
10	10/4/1877	10/3/1877	8/29/1877	-8.1	-6.8	0.875	20.68	25.30	11.98	1.5	0.0	0.0
11	10/11/1877	10/10/1877	8/29/1877	-9.3	-8.4	0.75	20.70	25.40	12.18	1.5	0.0	0.0
12	11/29/1877	11/28/1877	10/10/1877	6.7	11.5	-1.375	20.70	25.35	12.16	-0.5	0.0	0.0
13	1/10/1878	1/9/1877	10/10/1877	8.4	4.1	-1.25	20.63	25.35	12.20	-1.0	0.0	0.0
14	1/31/1878	1/30/1978	1/9/1878	3.7	5.0	-1.00	20.57	25.33	12.50	-0.5	0.0	0.0

Source: Table 135 of VN

Column 6 contains the differential between the average private discount rate of major commercial banks in London and the official discount rate of the Bank of England 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 to 9 contain exchange rates on the day before the discount rate change. Column 7 reports the number of Reichsmark per Pound in Berlin, column 8 the number of French Francs per Pound in Paris and column 9 the number of Florins/Kronen per Pound in Vienna. 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 25.225 French Francs per Pound. For Austria-Hungary a gold parity of the Pound in Vienna was set only in 1892. It is 24.018 Kronen per Pound. However, because the Austro-Hungarian currency continued to fluctuate substantially until 1895, it makes sense to define a deviation of its market exchange rate from parity only starting in 1896[7].

Changes in the official discount rates in Germany (Δi^D), France (Δi^F) and Austria-Hungary (Δi^A) are not reported in Table 135 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 rate for the whole period 1876-1913, we calculated for each of the 221 episodes of changes in the Bank of England's discount rate the corresponding changes in the three foreign official discount rates over the interval between the date of column 3 of Table 1 and the day before the discount rate change.

To summarize four observations are in order. *First*, the data presented in Table 1 can be divided into four main categories: A. For each discount rate change information on the balance sheet items of the Bank of England, in other words on her assets and liabilities, on two reference days. B. The differential between the private discount rate of major commercial banks in London and the discount rate of the Bank of England 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 foreign official discount rates.

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.

[7] For an overwiew of the monetary developments in Austria-Hungary during this period see Flandreau (2003) and Tullio and Wolters (2004).

Third, there is virtually no degree of discretion on our part in the way the series were constructed. How they were constructed follows logically from a careful analysis of Table 135 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[8].

By estimating equation (1) with the data presented in this section we make use of an incredible wealth of information which has never been used before to study the determinants of the Bank of England's liquidity ratios.

3 The determinants of changes in the Bank of England'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 of equation (1) for the whole period and for both definitions of the liquidity ratio and Table 3 contains the estimates for the sub-periods 1876-1895 and 1896-1913.

The important role played by the differential between the London private discount rate and the official one has been explained in Section 1. The key role played by this variable is strongly confirmed by the regression results[9]. It is by far the most significant variable. Its negative sign indicates that the higher the differential (the higher the "tension" that was allowed to accumulate) the higher were the incentives for commercial banks to seek rediscounting at the Bank of England. Similarly, the higher was the differential, the higher were the incentives both for firms and individuals, which at that time had access to Bank of England credit, to borrow

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

[9] 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 2 out of 221 cases the tension is measured one day 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. 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 generally one to two months long, a one day lead of the differential do not matter. Finally this anomaly occurs only in two cases out of 221.

from her rather than from commercial banks. As a consequence the Bank of England experienced under such circumstances an increase of her banknotes outstanding and of her short term liabilities and a fall in her metal stock, all leading to a fall in the liquidity ratio. Furthermore it has been shown that in gold standard countries the demand for banknotes and gold coins by the private sector was moving pro-cyclically (McGouldrick, 1984, Sommariva and Tullio, 1987), that the liquidity ratio was moving anticyclically (Goodhart, 1972) and that the differential was moving pro-cyclically (Sommariva and Tullio, 1987). Hence it is plausible to assume that the high significance of the coefficient of the differential in the regressions of Table 2 catches also the effects of the business cycle on the items which appear in the numerator and the denominator of the liquidity ratio, besides substitution effects between the private sector's sources of borrowing (the Bank of England versus commercial banks). A one percentage point

Table 2: The determinants of the British liquidity ratios
Period 1876 – 1913 (T = 221)

	(1) Δl_1	(2) Δl_2
c	-6.415 (3.1)	-2.902 (2.2)
$i_p - i^E$	-10.083 (12.8)	-5.585 (11.2)
Δi^D	-2.295 (2.2)	-3.201 (4.9)
w^D	4.565 (2.5)	2.591 (2.2)
$\overline{R}^2$	0.492	0.488
DW	1.87	1.97
AIC	7.400	6.494
SC	7.462	6.556
Q(10)	12.94 [0.23]	17.27 [0.07]
HET	1.06 [0.39]	2.72 [0.01]
JB	1.03 [0.60]	3.12 [0.21]
RESET	1.27 [0.26]	1.43 [0.23]

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).

(100 basis points) higher differential led on average to a fall of about 10.1 percentage points in the narrowly defined liquidity ratio and of about 5.6 percentage points in the broadly defined one. These numbers are a clear indication of how sensitive the liquidity ratios were to the differential.

As to foreign variables, only changes in the Reichsbank's discount rate and deviations of the Reichsmark from gold parity are significant. No other country significantly influenced the Bank of England's liquidity ratios. However, when we split the period we find that Austria-Hungary significantly influenced both liquidity ratios in the first period. We shall discuss the influence of Austria-Hungary on British liquidity ratios in connection with Table 3 below.

The German official discount rate was exerting a significant and negative influence on both British liquidity ratios. However, its effect on the broadly defined liquidity ratio was much more significant. The fact that the significance of Δi^D on Δl_2 is much higher than on Δl_1 has a very interesting implication: the sight liabilities of the Bank of England, consisting mainly of deposits held probably by big investors, must have been much more sensitive to changes in Δi^D than her banknotes outstanding. Big investors are likely to pay greater attention than holders of banknotes to conditions prevailing in foreign markets.

The exchange rate of the Reichsmark has the expected positive sign. As it is defined as the number of foreign currency units per Pound, an increase in its value indicates an appreciation of the Pound, and hence presumably a balance of payments surplus, an inflow of gold into Great Britain and a rise in the liquidity ratios of the Bank of England. In other words, a strong Pound was associated with an improvement in the liquidity position of the Bank of England and symmetrically a weak one was worsening her liquidity position. A positive deviation of one percentage point from parity led to an increase in the narrowly defined liquidity ratio of 4.6 percentage points and of the broadly defined one by 2.6 percentage points. Overall the liquidity ratios were about half as sensitive to developments in the foreign exchange market as to developments of the differential.

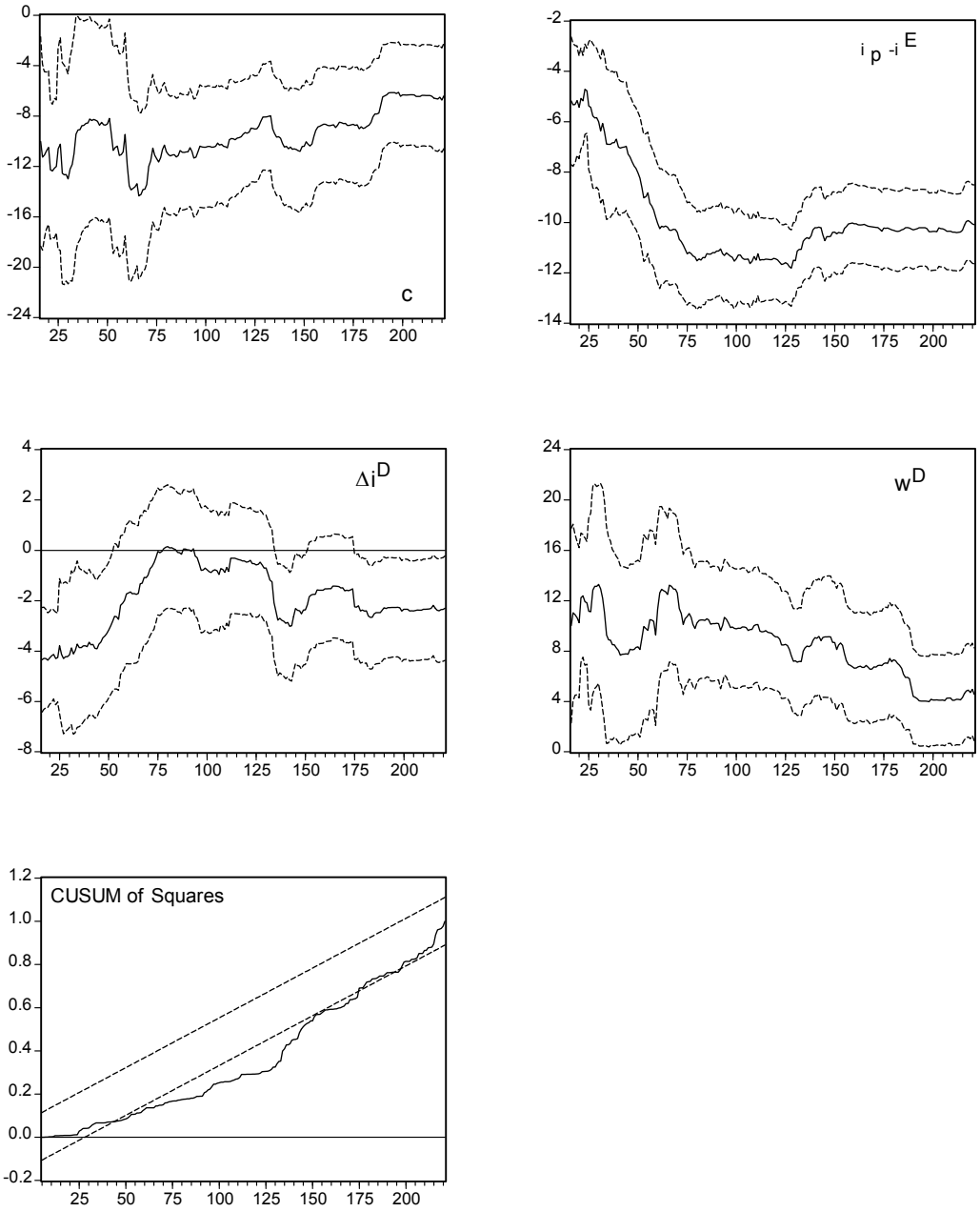
The significant effect of the exchange rate of the Reichsmark and of the German official discount rate on British liquidity ratios suggest that the classical gold standard was a bi-polar or multi-polar system with Berlin also playing an important role.

The Adjusted R^2s confirm the good descriptive capacity of the model which explains about 50% of the variability of changes in the liquidity ratios. This is quite high considering the high variability of the dependent variables and the fact that they are changes.

The residuals of the regression using the narrow definition are extremely well behaved. They pass all the standard tests reported at the bottom of Table 2. As to the residuals of the

regression using the broad definition they do not pass the test of absence of heteroskedasticity (White test) at the 5% confidence level and the Box-Pierce test of absence of autocorrelation at the 10% level. They pass the other tests. Thus judging from the behaviour of the residuals the regression which explains the broad definition is inferior to the one which explains the narrow one. This may imply that the stabilization of the narrow liquidity ratio was more important to the Bank of England, as implied by the laws on the gold coverage of banknotes issued.

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



The stability tests of the regression which uses the narrow definition as well as the recursive parameter estimates are presented in Figure 1. Those referring to the regression using the broad definition are shown in Figure 2. The Cusum of Squares test in Figure 1 shows that the

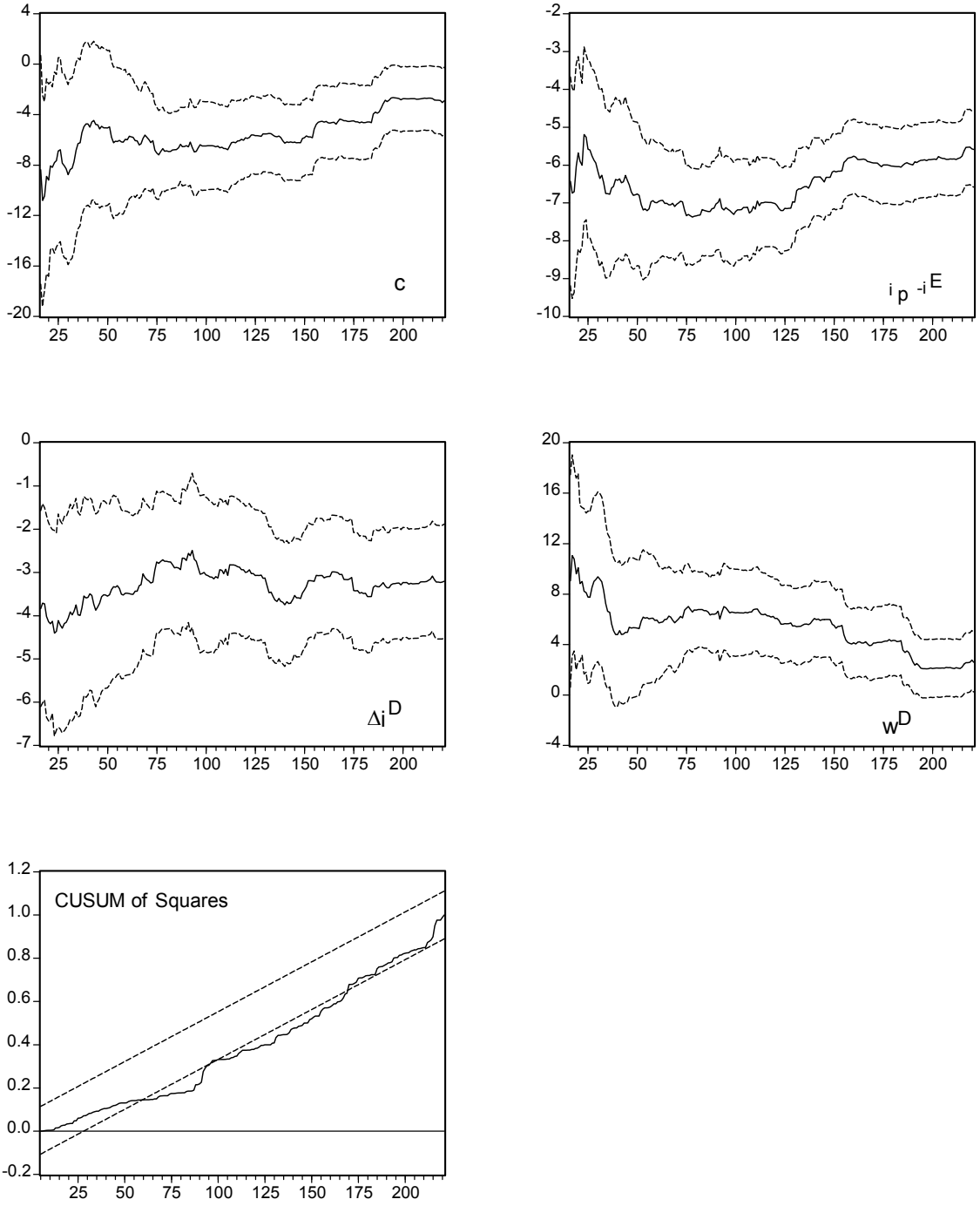
estimated regression is unstable at the 5% confidence level as the statistic moves quite early outside the 5% confidence interval and stays there for most of the sample period. The recursive parameter estimates confirm the instability of this regression and permit us to find its likely cause. Figure 1 shows that there is significant parameter instability for all three coefficients. Particularly the analysis of the dynamics of the coefficients of Δi^D and of $i_P - i^E$ allows us to isolate a period going from about the 60th observation to about the 130th observation during which (a) the coefficient of the German official discount rate is virtually zero, while before and after it is quite high in absolute value; (b) the effect of the differential is significantly higher in absolute value than before and after. Overall, during this period we observe a lower influence of Germany, and especially of the Reichsbank's discount rate, on the British liquidity ratio, while at the same time the influence of domestic factors is higher.

The interval between observations 60 and 130 corresponds to the period between November 12, 1885 and September 21, 1893. The observed behaviour of the parameters during those years may be explained by the frequent use of the so-called gold devices by the Bank of England. Their frequent use on the part of the Bank during this period, and especially in the late 1880s and in 1891-92, is reported by Sayers (1976) and Scammel (1965). A more intensive use of the devices in this period on the part of the Reichsbank could probably also contribute to explain the observed behaviour. However, we do not have sufficient evidence on a more intensive use of gold devices on the part of the Reichsbank during this period.

When sometimes in 1892-93 the Bank of England stopped using gold devices more intensively the effect of the German official discount rate on the Bank of England's liquidity ratio became again large and significant and there is correspondingly a significant reduction in the absolute value of the coefficient of the domestic explanatory variable (the differential in London). This change in roles between domestic and foreign explanatory variables was probably the consequence not only of the relaxation of capital controls on the part of the Bank of England but also of the greater financial integration between London and Berlin. The latter was also stimulated by the improvement in communication technology, a development which contributed to make Bank of England's sight liabilities particularly sensitive to Δi^D.

Figure 2 presents the stability tests and the recursive parameter estimates for the regression of Table 2 explaining the broad liquidity ratio. The Cusum of Squares test indicates that the estimated relationship is unstable and the estimated parameters present roughly similar problems

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



of instability as those of the regression explaining the narrow liquidity ratio. However, the instabilities are somewhat less pronounced and the effect of the use of gold devices on the parameters starts and ends earlier. In addition the coefficient of the German discount rate remains significantly different from zero also during the period of more intensive use of gold devices by

the Bank of England, probably because the latter's sight liabilities were more sensitive to foreign influences than the stock of her banknotes outstanding.

In the light of the observed instabilities we decided to split the sample period into two sub-periods. Following Sommariva and Tullio (1987) we split the period at the end of 1895. This is justified by several historical facts. Among them should be mentioned the end of the long period of declining prices in the gold standard world as a result of the discovery of new gold mines and of a new process to extract gold and the end, in the late 1880s and early 1890s, of a period characterized by the more intensive use of gold devices on the part of the Banque de France and the Bank of England. Furthermore, in analysing the coefficient of Δi^D in Figure 1, we saw that a break occurred around the 130th observation. This observation corresponds to the Bank Rate change of September 21st, 1893. Other important developments to justify the split were the improved communication and transportation techniques, the increased degree of integration of financial markets worldwide, the increased economic and financial weight of Germany and the development of the Pound as an international reserve currency. Certainly, all these changes did not occur abruptly on December 31st 1895. However, Chow Break tests performed on the Bank of England and Reichsbank's reaction functions show clearly that this is the most suitable date to split the gold standard period in two[10]. It is also worth noting that in 1895 there were no changes in Bank Rate, which contributes to make this year an appropriate dividing line.

Table 3 contains the estimates of equation (1) separately for the two sub-periods for both definitions of the liquidity ratio. The first period corresponds to observations 1 to 133 and the second to observations 134 to 221. This still leaves us with a comfortable number of observations in each sub-period (133 in the first and 88 in the second). Columns (1) and (2) show the estimates for the narrow definition of the liquidity ratio and columns (3) and (4) for the broad one. In both sub-periods and for both definitions of the Proportion the London differential is the most important explanatory variable, although its significance declines sharply in the second period. During the first period the discount rate in Vienna had a significant and negative effect on both liquidity ratios. This effect did not show up in the estimates for the whole period (cf. Table 2). Vienna was not really on the gold standard until 1902, although it had tried to "shadow" it since 1896 and although it had been struggling for decades to accumulate enough gold to allow it to establish convertibility of its banknotes. During the first period the Austro-Hungarian currency underwent large fluctuations. Its exchange rate with the Pound fluctuated within a range of about 15%. The Austro-Hungarian currency was "speculative" enough to influence the Proportion in

[10]See Tullio and Wolters 2003a and 2003b.

London. In the second period the currency of Austria-Hungary fluctuated much less and then eventually joined the gold standard in 1902. As a result the influence of the discount rate in Vienna on the London liquidity ratio fell more in line with the economic and financial weight of Austria-Hungary in the European context and vanished.

Table 3: The determinants of the liquidity ratios

Period	1876-1895 (T = 133) (1) Δl_1	1896-1913 (T = 88) (2) Δl_1	1876-1895 (T = 133) (3) Δl_2	1896-1913 (T = 88) (4) Δl_2
c	-8.652	-2.467	-5.854	0.815
	(4.2)	(1.5)	(3.9)	(0.9)
$i_p - i^E$	-10.749	-10.026	-6.475	-3.527
	(15.4)	(6.0)	(12.3)	(3.4)
Δi^D			-2.480	-3.240
			(3.0)	(2.7)
Δi^A	-7.240		-4.647	
	(3.4)		(2.8)	
w^D	7.416		5.527	
	(3.7)		(3.7)	
$\overline{R}^2$	0.690	0.284	0.666	0.257
DW	1.83	1.75	2.13	2.01
AIC	6.812	7.897	6.170	6.749
SC	6.899	7.953	6.279	6.834
Q(10)	5.89	9.46	14.88	17.65
	[0.83]	[0.49]	[0.14]	[0.06]
HET	0.48	0.43	1.41	1.90
	[0.83]	[0.65]	[0.20]	[0.12]
JB	1.63	1.18	8.53	6.97
	[0.44]	[0.55]	[0.01]	[0.03]
RESET	3.52	0.43	0.11	0.004
	[0.06]	[0.51]	[0.74]	[0.95]

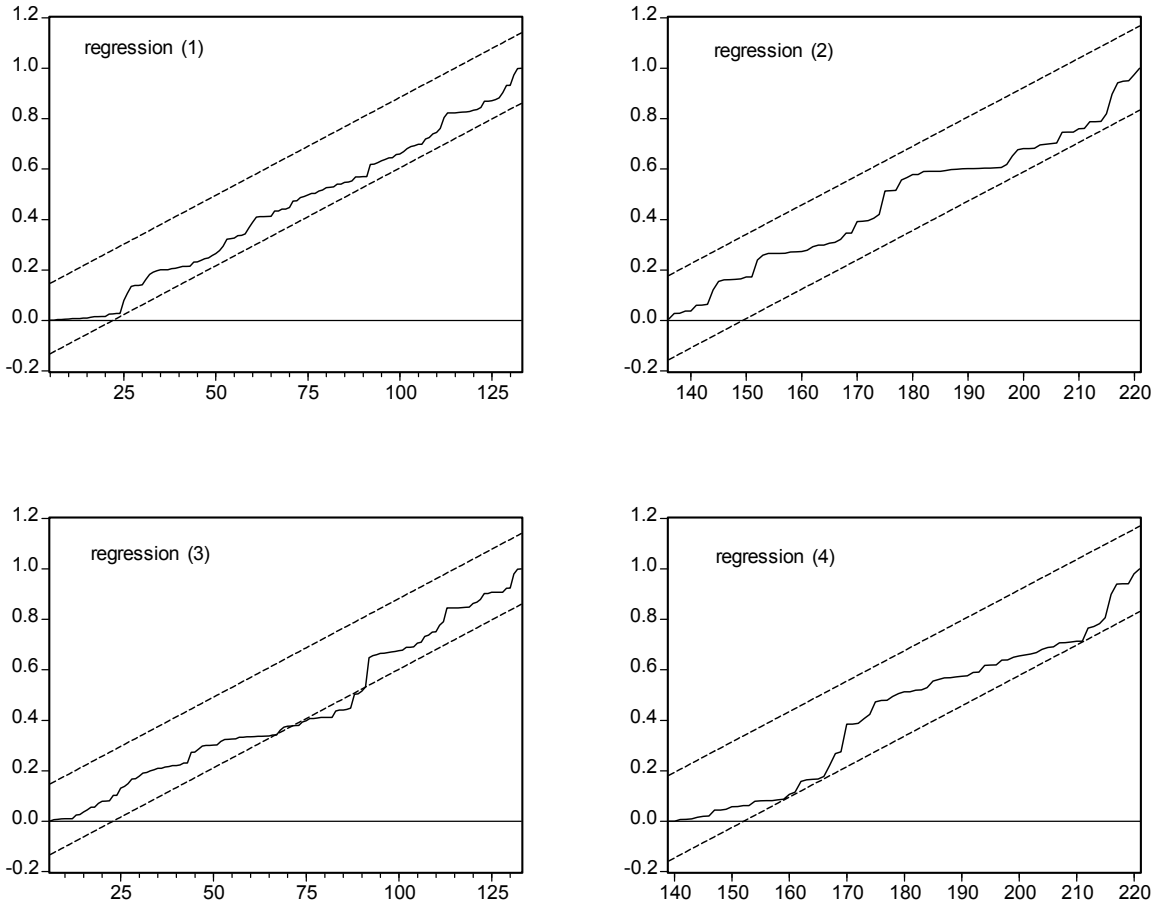
Notes: see Table 2

Germany had a significant influence on Δl_2 in both periods, whereas its influence on Δl_1 is restricted to the first period. Taking the narrow liquidity first, the influence of Germany worked principally via the deviations of the Reichsmark from parity (regression (1) of Table 3). As to the broad definition the effect worked both via the exchange rate and the German discount rate in the first period and only via the Reichsbank's discount rate in the second (regression (4) of Table 3). In the first period the economic and financial weight of Germany was still smaller than Great Britain's. However, the fact that Berlin had to consolidate its recent move to the gold standard caused relatively large disturbances to the world's gold and financial markets. In the second

period these shocks subsided. However, in the meantime the economic and financial weight of Germany had grown enormously with respect to Great Britain's. The likely cause of the greater influence of Berlin on London's broad liquidity ratio than on the narrow one has already been discussed in connection with Table 2.

The explanatory power of the regressions falls considerably from the first to the second period, suggesting that for the second period some important explanatory variables may be missing from our model, such as the increasing weight of the US in the world economy, the greater influence on London originating from colonies and developing countries and the development of the Pound as a reserve currency[11].

Figure 3: CUSUM of Squares test for regressions (1) - (4) of Table 3



[11] Using weekly data Tullio and Wolters (2000) show that the influence of financial conditions in the US on London were very significant, especially after 1897 when the debate about the adoption of a silver standard in the US had subsided.

The residuals of regressions (1) and (2) of Table 3, those explaining the narrow liquidity ratio, are well behaved and the estimated relationships are stable. At the 5% confidence level both regressions pass the Cusum of Squares stability test (see Figure 3). As to regressions (3) and (4), those explaining the broad liquidity ratio, the residuals do not pass the Jarque-Bera test of normality at the 5% level of significance. However the residuals of the regressions pass the other standard tests as shown at the bottom of Table 3 (autocorrelation, heteroskedasticity and functional form misspecification). In addition the Cusum of Squares test shows that regressions (3) and (4) are slightly unstable (Figure 3).

4 Summary of main results and conclusions

In this paper we present OLS estimates of an equation explaining changes in the Bank of England's liquidity ratios from 1876 to 1913. The changes in the liquidity ratios are assumed to depend on the differential between the private and the official discount rate in London, on foreign discount rate changes and on deviations of the exchange rates of the Pound from gold parity. Two liquidity ratios are used, a narrow and a broad one.

We use data referring to all episodes of discount rate changes enacted by the Bank of England during the period. Thus the data are "not equally spaced chronologically ordered". Since there were 221 such changes we have 221 observations. The use of these data reduces the problems of reverse causation between exogenous and endogenous variables, contrary to annual or monthly data which would hide a substantial amount of information. The changes in the discount rate within the year were namely frequent and the changes in the liquidity ratios large and rapid. We introduce international factors into the model in order to study mutual influences among countries and to check whether the classical gold standard was a bi-polar or multi-polar system. Finally we present stability tests and split the sample period in order to study 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 played an important role in transmitting disturbances from the real economy and from the London financial market to the Bank of England's liquidity ratios and ultimately to the official discount rate, confirming an hypothesis first advanced by Goodhart (1972) for Great Britain.

Second, of the three foreign countries considered in this paper, Germany, France and Austria-Hungary, only Germany and Austria-Hungary influenced both liquidity ratios of the Bank of England. However, the influence of Austria-Hungary was limited to the first period

and was mainly of a speculative nature, while the influence of Germany was significant in both periods. The German influence on the Bank of England's liquidity ratios operated both via the Reichsbank discount rate and via the exchange rate of the Reichsmark.

Third, the Reichsbank's discount rate exerted a more significant influence on the broad than on the narrow liquidity ratio. The explanation offered is that foreign banks, financial institutions and large investors, including German ones, held deposits in London and also at the Bank of England. They tended to react more promptly to changes in the German official discount rate than holders of Bank of England notes.

Fourth, the finding of this paper that Berlin significantly influenced London coupled with the findings of Tullio and Wolters that London significantly influenced the discount rate in Berlin (2003a), that Berlin influenced Paris almost as much as London (2003c) and that Berlin but not London influenced Vienna (2004) 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.

Fifth, the relationships estimated for the whole period are unstable. The instability results in the first place from significant changes in the coefficients of the differential and of the German discount rate. We put these significant changes in relation to a more intensive use of gold devices on the part of the Bank of England during the period from about 1885 to about 1892/93.

Sixth, even though the changes in the coefficients of the explanatory variables do not occur abruptly, we have argued in the paper that the most appropriate time to split the period in two is at the end of 1895. We then estimate all regressions separately for the sub-period 1876-1895 and for the sub-period 1896-1913 and find that the regressions explaining the narrow liquidity ratio, which was the most important for the Bank of England, become stable. The same cannot be said for the regressions explaining the broad liquidity ratio.

Seventh, by splitting the period, the explanatory power of the estimated equations falls significantly from the first to the second period for both definitions of the liquidity ratio. This implies that our model is less able to capture all the factors affecting changes in the Bank of England's liquidity ratios in the second period. We argue that this may have to do with the development of the Pound as a reserve currency, the increased role of Germany, the US and large countries of the British Empire in conditioning the financial market in London and the large relative decline of the British gold stock.

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