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RESEARCH ARTICLE

Monetary Policy in Austria–Hungary, 1876–1913: An Econometric Analysis of the Determinants of the Central Bank's Discount Rate and the Liquidity Ratio

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Abstract This paper presents a model to explain the official discount rate of the Central Bank of Austria–Hungary from 1876 to 1913. The discount rate is assumed to depend on the liquidity ratio of the Bank, defined as the ratio of its stock of metals to banknotes issued, and on changes in foreign discount rates. The paper also presents an equation explaining the liquidity ratio. We use "not equally spaced chronologically ordered data" referring to the 50 discount rate changes enacted. The regressions confirm that the liquidity ratio was the main determinant of the discount rate and that Germany (and not Great Britain) played a significant role in determining the Austro–Hungarian discount rate and the liquidity ratios, supporting the view that the classical gold standard was a decentralized multipolar system rather than a system fully dominated by London as suggested by Keynes. The regressions also suggest that, although Austria–Hungary had an inconvertible paper currency (1879–1892) and fluctuating exchange rates (1876–1895) and formally joined the gold standard only in 1902, it "shadowed" the behaviour of gold standard Central Banks with such consistency that the stability of the estimated regressions was relatively unaffected by the frequent institutional changes.

Keywords Gold standard · Transmission process

JEL Classification N 23 · E58 · C22

This paper presents and estimates a model to explain the official discount rate of the Central Bank of Austria–Hungary from the beginning of 1876 to the end of 1913. Changes in the discount rate are assumed to depend on changes in the liquidity ratio

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of the Bank, defined as the ratio of banknotes issued to its stock of metals, and on changes in foreign discount rates. The equation estimated can be considered a reaction function of the Bank, taking into account the objectives of monetary policy. In order to gain a deeper insight into the factors which led to discount rate changes the paper also presents the estimates of an equation explaining the determinants of the liquidity ratio.

Changes in the discount rate were the most important instrument of monetary policy. There were 50 such changes during the period considered.[1] A second instrument was the changes in the criteria for admission to rediscounting by commercial banks and of borrowing by the non-bank private sector which at that time had also access to the Bank's credit. The Bank of Austria–Hungary also intervened in the foreign exchange market to avoid excessive fluctuations of the national currency. In addition it used the so-called gold devices which changed the conditions of imports and exports of gold.[2]

For the period 1880–1913 Bloomfield (1959) showed that there was an inverse relationship between annual discount rates and liquidity ratios 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. Using monthly data from 1891 to 1914 he regressed the level of the discount rate on her liquidity ratio, the lagged discount rate and seasonal dummy variables. He confirmed Bloomfield's result about the negative relationship. His explanation of this negative correlation was that since the liquidity ratio was falling, the Bank of England became more concerned about maintaining internal convertibility and would thus increase the discount rate to attract gold from internal circulation and from abroad.

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 and contained in a rather rare volume published in 1925 in Berlin by the German Imperial Printing Office and entitled "Vergleichende Notenbank-statistik" (henceforth VN). This data, which had never been used before, 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) found, like Goodhart (1972) for the Bank of England, that the Reichsbank reacted negatively and with a lag to changes in the liquidity ratio, which implies that its main objective was to maintain internal convertibility of notes issued into gold.[3]

[1] The discount rate changes were 221 in Great Britain, 136 in Germany and 35 in France.

[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.

[3] The conclusion that the main objective of the Bank of England and of the Reichsbank was to keep internal convertibility of banknotes outstanding should not come as a surprise: if the Reichsbank managed to keep internal convertibility of its banknotes for over 38 years, and the Bank of England for even longer, it is rather obvious that this objective must have been very important for them.

Before proceeding further it is important to spend a few words about the numerous and significant changes which occurred in the monetary system of Austria–Hungary during the period under analysis. While Great Britain, Germany and France maintained full convertibility of banknotes issued by their respective Central Banks into gold, the same is not true for Austria–Hungary. Austria–Hungary adopted internal convertibility of banknotes into gold only in 1902. It had struggled since the beginning of the period (1876) to accumulate enough gold and gain greater control over paper issues to enable it to formally join the gold standard. The 1902 adoption of convertibility was reached gradually in successive steps. This stands in sharp contrast with Germany's introduction of convertibility which was completed in just a few years (1871–1876), after massive purchases of gold in world markets.[4]

Austria–Hungary had a silver standard until March 1879 and an inconvertible paper currency until 1902. Other important dates in the monetary developments of the empire were:

- July 1, 1878, when the "Compromise" (statute of the Central Bank) of 1867 was renewed for another 10 years and the powers of Hungary on the management of the Bank were increased. The name of the Bank was changed from "Austrian National Bank" (*Oesterreichische Nationalbank*) to "Austro–Hungarian Bank" (*Oesterreichische–Ungarische Bank*), it became a bilingual institution with two main offices in Vienna and Budapest and the governor was to be appointed by the Emperor upon joint nomination of the Austrian and Hungarian finance ministers (Flandreau 2003).
- 1892, when a monetary reform was begun which introduced a new currency (the gold crown), fixed its value in terms of gold and took steps to stabilize the florin in terms of the crown (gold) by centralizing the issue of paper currency at the Bank.[5]
- 1896, when the Bank, feeling that its gold stock was sufficiently high, began to shadow the gold standard by intervening with foreign exchange in the foreign exchange market and by keeping the value of the national currency within the theoretical gold points, roughly corresponding to a band of +/−1%. Its value with respect to the main gold standard currencies, which had fluctuated within a range of about 15% from 1876 to 1891 and 8% between 1892 and 1895, began to fluctuate after 1896 within the much narrower band of about 2%. Only for the period 1896–1913 it makes sense to speak of a central gold parity of the Austrian Crown.
- September 21, 1899 when the charter of the Bank was renewed again, this time until 1910. Hungary was granted full parity with Austria in the management and control of the Bank and the quarrelling between the two sides of the empire, which had lasted for many years, finally came to an end. With the uncertainty regarding the future of monetary circulation within the empire thus removed, the 1892

[4] However, Germany's decision to adopt the gold standard in the early 1870s and its actual move in 1876 was faciliated by the requisitioning of part of the French gold stock after the victory over France in 1871 and by large reparation payments.

[5] Silver coinage on account of the two governments was discontinued and it was decided that the two governments would repurchase with gold the 312 million florins of government paper notes outstanding. Austria was to repurchase 70% and Hungary 30%.

monetary reform, setting the ground rules for the move to the gold standard, became credible at last. The boost in confidence which resulted from the September 21, 1899 renewal of the Bank charter was so high that large capital and gold inflows occurred from the main financial markets of Europe (London, Paris and Berlin). These centres all felt the strain and had to increase their discount rates several times between October 1899 and December 1900 (see Tullio and Wolters 2003). In addition in the first decade of the twentieth century the Austro–Hungarian currency was quoted above parity most of the time.

- 1902, when Austria–Hungary formally joined the gold standard by allowing full (unrestricted) convertibility of banknotes into gold. By now the gold stock and the reserves of foreign currencies of the Bank were so abundant and the credibility of the Bank so high that the gold crowns introduced into circulation returned to a very large extent to the Bank. From August 1901 to December 1907 the equivalent of 1616,4 million gold crowns were coined and put into circulation. On December 31, 1907 1381,7 million or 85,5% had returned to the Bank. The public preferred to use banknotes instead of gold coins because of a high confidence in the stability of the paper currency and because, during the years of inconvertibility, it had learned to appreciate its lower transaction costs. Among the factors that contributed to the high credibility of the Bank and to the strong confidence in the issued banknotes were the stabilization of the new currency in the foreign exchange markets from 1896 onwards and the abundant gold stock of the Central Bank. Another sign of the much higher gold stock and the return of confidence is given by the large increase in the ratio of metals to notes issued by the Central Bank. The ratio increased from 53.0% on average during the period 1876–1895 to 74.9% during 1896–1913. At the same time the ratio of gold to all metals in the coffers of the Central Bank increased from 36.4% to 78.1%.[6]

This brief historical overview of monetary developments in Austria–Hungary clarifies that the period under analysis was not homogenous from the point of view of the institutional (monetary and exchange rate) set-up. Its inclusion in this introduction is also important to understand possible breaks in the estimated equations. The historical overview may at first sight suggest that the institutional changes were so large to make it impossible and meaningless to estimate single equations explaining changes in the discount rate and changes in the liquidity ratio for the whole period under study. Yet, the overview should also make it clear that, despite these large institutional changes, there was one paramount concern on the part of the Bank of Austria–Hungary throughout the period, namely to defend and increase the stock of metals. In this respect the behaviour of the Bank was not much different from that of Central Banks which managed to keep full convertibility of their banknotes into gold for the whole period. This hypothesis is also confirmed by the fact that the compilers of VN (1925) put Austria–Hungary on exactly the same footing as Great Britain, Germany and France since the set-up of the table for Austria–Hungary does not differ from that of the other three countries; also the

[6] These averages are computed using the data from VN and they refer to the 50 episodes of changes in the discount rate enacted by the Bank of Austria–Hungary during the period. For more detail see Section 2.

sample period is exactly the same. In any case in estimating our two basic equations we always kept the institutional changes in mind and tried to model whenever possible potential structural changes.

The main novelties of the paper are *first*, that it is the first econometric study on the determinants of the official discount rate and of the liquidity ratio in Austria–Hungary covering the period of 1876–1913. *Second*, with respect to the previous literature on the other main gold standard countries, we go several steps further by estimating a more complete reaction function of the Bank of Austria–Hungary which includes, in addition to the liquidity ratio, also foreign discount rates and, for the period after 1895, deviations of the market exchange rates from gold parity. This will show to what extent monetary policy in Austria–Hungary was influenced by foreign discount rate changes, which were the foreign countries influencing the financial market of Austria–Hungary and how highly integrated was the financial market of Austria–Hungary with the rest of the world. *Third*, instead of using annual or monthly data, like in all previous studies, except Sommariva and Tullio (1987), we use the data published in VN. *Fourth*, we study the stability of the equations determining the discount rate and the liquidity ratio over time and this will give us interesting insights into the changes in the working of the monetary system in Austria–Hungary.

The paper is structured as follows: Section 1 presents the models explaining the changes of the Bank of Austria–Hungary's discount rate and liquidity ratio, taking into account international influences including the state of the foreign exchange market. Section 2 describes the data used and how the variables have been constructed. Section 3 presents the estimates and the stability tests of the reaction function of the Bank of Austria–Hungary Bank. Section 4 presents the estimates and the stability tests of the equation explaining changes in the liquidity ratio. Section 5 concludes.

1 The model

Following Bloomfield (1959), Goodhart (1972), Sommariva and Tullio (1987) and Contamin and Denise (1999) we present in this section two equations explaining changes in the Bank of Austria–Hungary's discount rate (the reaction function) and changes in its liquidity ratio. Like in the literature cited above, the changes in the official discount rate are assumed to depend on changes in the liquidity ratio. However, in order to check the assumption of multipolarity of the gold standard as suggested by Eichengreen (1992) and Tullio and Wolters (1996) and to measure the degree of financial openness of Austria–Hungary, a set of variables were included in the equation capturing international influences (exchange rates and foreign official discount rates).

The changes in the official discount rate of Austria–Hungary (Δi^{A}) are assumed to depend on the changes of the narrowly or broadly defined liquidity ratio ($\Delta \mathrm{l}_i$) (where i=1 stands for the narrow and i=2 stands for the broad one), on the changes in the official discount rates in Great Britain (Δi^{E}), Germany (Δi^{D}) and France (Δi^{F}) and finally, only from 1896 onwards, on the percentage deviation of the exchange rate of the Austro–Hungarian currency with the British pound from its gold parity $w^{E} = \left(e_E - e_E^*\right)/e_E^*$. The gold parity e_E^* became meaningful for Austria–Hungary from 1896 onwards for the reasons explained in the introduction.

The equation to be estimated is:

$$\Delta i^A = a_1 \Delta l_i + \Sigma_j a_{2,j} \Delta i^j + a_{3,E} w^E + u \quad (1)$$

where i=1,2; j=D,E,F and 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.

In estimating Eq. 1 two different definitions of the liquidity ratio have been used, the first is the ratio of the gold and silver stock of the Bank of Austria–Hungary to banknotes issued (1_1), and the second has the same numerator but includes in the denominator sight liabilities in addition to banknotes issued (1_2). By comparing the goodness of fit and the stability of the estimated regressions we will be able to make some inferences about which ratio may have been of greater importance to the Bank of Austria–Hungary.

The expected signs of the coefficients of the explanatory variables are: negative for the changes in the liquidity ratio, positive for the changes in foreign official discount rates, and positive for the deviation of the exchange rate from gold parity. The exchange rate is defined as the number of domestic currency units for one pound; hence an increase in e_E indicates a devaluation of the Austro–Hungarian currency (capital and gold outflows from Vienna).

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.

Equation 1 can be considered a reaction function of the Bank of Austria–Hungary distinguishing between three objectives of monetary policy: the objective of defending and increasing the gold stock before internal convertibility of outstanding banknotes into gold or silver was reached (1902) and defending the gold stock in order to keep convertibility after it was reached, the objective of keeping exchange rates within the gold points (only after 1895) and a third objective, not completely independent from the other two, of acting defensively to changes in foreign discount rates. Concerning the latter objective one should keep in mind that movements in opposite directions of the official discount rates within 1 month were rare during the period.

Reaction functions of Central Banks estimated for the post World-War II period usually include inflation, unemployment or deviation of real GDP from trend or from potential GDP.[7] However, the classical gold standard was a different time when national account data were not available, unemployment was not a major issue and concerns about financial stability probably prevailed over those about the business cycle. As a result this difference in the specification of the reaction functions of the Central Bank of Austria–Hungary between then and now seems perfectly justified by the different historical background of the two periods.

Turning to the second equation, the one explaining changes in the liquidity ratio, we follow Sommariva and Tullio (1987) in assuming that changes in the liquidity ratio depend on the differential between the private and the official discount rate in Vienna (henceforth called "the differential"). Changes in the liquidity ratio are also

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

assumed to depend on the same set of variables capturing international influences used in Eq. 1, namely market exchange rates and foreign official discount rates. The inclusion of foreign variables allows, like for Eq. 1 to test how the degree of Vienna's integration into international financial markets changed through time and to check the assumption of bi-polarity or multipolarity of the classical gold standard.

The equation to be estimated is:

$$\Delta l_i = a_1 + a_2 (i_p - i)^A + \Sigma_j a_{3j} \Delta i^j + a_{4E} w^E + u \quad (2)$$

where Δl_i denotes a change in the liquidity ratios of the Bank of Austria–Hungary. Like for Eq. 1 we shall use a narrow (i=1) and a broad (i=2) definition of the liquidity ratio. Like for Eq. 1 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. $(i_p - i)^A$ denotes the differential between the private discount rate in Vienna and the discount rate of the Bank of Austria–Hungary. All other variables have already been defined in connection with Eq. 1.

Equation 2 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 Austro–Hungarian financial market. Not surprisingly in VN the differential is called the "tension" (*Spannung* in German). The differential must have had very high informative contents for the markets and the monetary authorities. An increase in the differential put the Bank of Austria–Hungary under strain as it increased the demand for rediscounting on the part of commercial banks and the demand for notes, gold and Central Bank credit by the private sector.[8] 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.

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 gold parity.

2 Description of the data used

The data used in this paper are obtained from VN. 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 Austria–Hungary the relevant table is Table 136, pages 256–259 of Vol. 2.

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

[8] At that time the Bank of Austria–Hungary was also operating as a commercial bank.

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.

To facilitate the description of the data we have constructed Table 1, directly derived from Table 136 of VN, containing data of the variables we have used in the empirical work for the first 15 episodes of discount rate changes. Column 1 reports the date of the change in the official discount rate, which is given in column 2. This is the dependent variable of Eq. 1 (Δi^A). Column 3 contains a date close to the discount rate change. It generally refers to one to five working days prior to the discount rate change. In 5 cases the date is contemporaneous to the discount rate change and in 14 cases the date follows the day of the discount rate change by 1 to 4 days. Column 4 contains a date preceding the discount rate change by 1 week to 2 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 Bank of Austria–Hungary are recorded in Table 136. 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 compilers of the tables

Table 1 Discount rate changes of the Central Bank of Austria–Hungary, 1876–1913

(1) Date of discount rate change	(2) Discount rate change	(3) Date of closest statement used	(4) Date of statement used for comparison	(5) Δl_1	(6) Δl_2	(7) $(i_p - i)^A$	(8) e^E	(9) Δi^D	(10) Δi^E	(11) Δi^F
1 1/28/1876	−0.5	1/26/1876	1/5/1876	2.4	3.0	−0.250	114.40	−1.0	1.0	0.0
2 5/9/1879	−0.5	5/7/1879	1/7/1879	3.5	3.6	−0.500	117.40	−1.5	−3.0	0.0
3 10/20/1882	1.0	10/15/1882	8/31/1882	−0.2	0.1	1.000	119.50	1.0	1.0	0.0
4 2/3/1883	−0.5	1/31/1883	1/7/1883	2.0	2.3	−0.750	119.70	−1.0	−1.0	0.0
5 2/23/1883	−0.5	2/23/1883	1/7/1883	2.4	2.7	−0.875	119.75	−1.0	1.5	−0.5
6 10/7/1887	0.5	10/7/1887	9/7/1887	−4.6	−4.7	0.000	125.60	0.0	0.0	0.0
7 1/11/1888	−0.5	1/15/1888	1/1/1888	1.4	0.9	−0.625	126.80	0.0	−0.5	0.0
8 9/11/1888	0.5	9/7/1888	3/23/1888	−8.1	−7.8	0.500	122.00	0.0	1.0	0.0
9 1/25/1889	−0.5	1/23/1889	1/1/1889	5.6	5.6	−0.750	120.60	−1.5	−1.0	−0.5
10 11/6/1889	1.0	10/31/1889	3/23/1889	−9.5	−9.3	0.625	118.70	2.0	2.0	0.0
11 1/24/1890	−0.5	1/23/1890	1/1/1890	5.2	−5.8	−1.000	118.20	0.0	0.0	0.0
12 2/14/1890	−0.5	2/15/1890	1/23/1890	0.3	−1.0	−1.000	119.40	0.0	0.0	0.0
13 9/5/1890	0.5	9/7/1890	2/23/1890	−6.1	−5.8	0.250	111.80	0.0	−1.0	0.0
14 10/3/1890	0.5	9/30/1890	9/7/1890	−0.3	−0.1	0.000	112.80	1.0	1.0	0.0
15 10/17/1890	0.5	10/15/1890	9/7/1890	−1.4	−1.4	0.375	114.80	1.5	1.0	0.0

Some representative data at the beginning of the period
Table 136 of VN

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.[9]

Column 5 contains changes in the narrow liquidity ratio measured over the period between the dates reported in columns 3 and 4. This liquidity ratio is defined as the ratio of the gold and silver stock to banknotes issued by the Bank of Austria–Hungary. Column 6 contains changes in the broad liquidity ratio measured over the period between the dates reported in columns 3 and 4. This liquidity ratio is defined as the ratio of the gold and silver stock to banknotes issued and short term liabilities outstanding. Column 7 contains the differential between the private discount rate of major commercial banks in Vienna and the official discount rate of the Bank of Austria–Hungary on the day prior to the discount rate change. Column 8 shows the number of Florins/Crowns per 10 Pound in London (e^E).

Turning to the changes of the foreign official discount rates in Germany (Δi^D), Great Britain (Δi^E)and France (Δi^F) they are reported in columns 9–11. The information contained in Table 136 of VN is not sufficient to construct these series. For their construction we used information contained in 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 50 episodes of changes in the Austro–Hungarian official discount rate the corresponding changes in the three foreign ones with reference to the interval starting with the date given in column 4 of Table 1 and ending 1 day before the discount rate change. Thus same-day changes in foreign official discount rates are excluded by construction. In the case of same-day changes we do not know always which Central Bank made the first move. Only in some cases of same-day changes 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 1 can be divided into four 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 rate with reference to the British Pound on the day preceding the change in the discount rate. C. The changes in the official discount rates in Austria–Hungary, Great Britain, Germany and France. D. The differential between the private and the official discount rate in Vienna on the day prior to the change in the official discount rate.

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 were constructed follows logically from a careful analysis of Table 136 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

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

[10] For instance from the minutes of the meetings of the Board of the Banque de France we know that on five or six 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 (see Tullio and Wolters 2003).

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 B.C. to write down as much as they could about their disappearing culture.[11]

Fifth, recalling that between 1876 and 1913 the Bank of Austria–Hungary changed the official discount rate 50 times,[12] varying from a minimum of 0 in 1877–1878, 1880–1881, 1884–1886, 1897, 1903–1904, 1909 to a maximum of 5 in 1890, 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.

3 The determinants of the official discount rate

In this section we present ordinary least squares (OLS) estimates of Eq. 1 using the data described in Section 2 and including exchange rates and foreign discount rates among the explanatory variables.[13] Since the Bank of Austria–Hungary changed the official discount rate 50 times between 1876 and 1913 our sample includes 50 observations. We started out with all the explanatory variables including a constant and then eliminated successively all those which were not significantly different from zero at the 10% level.

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. These data deficiencies prevent us from using, for example, a probit analysis to assess the variables that would prompt the Bank to change rates.

Table 2 shows the estimates of Eq. 1 using the narrow and the broad definition of the liquidity ratio. Of all foreign explanatory variables, only the changes in the German official discount rate had a weakly significant influence. The coefficients of the changes in the liquidity ratios and of the German discount rate have the expected sign. A one percentage point increase in the narrow liquidity ratio led on average to a 4.9 basis point reduction in the discount rate and a one percentage point increase in the broad one led to a 5.7 basis point reduction. An increase of 100 basis points in the German discount rate led on average to an increase of 12 basis points in the Austro–Hungarian discount rate. The regressions of Table 2 explain about 67% of the variance of Δi^{A}. The fact that the explanatory power of the two regressions is the same indicates that for the Bank of Austria–Hungary the narrow and the broad

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

[12] The average number of changes per year was 1.3 for Austria–Hungary as opposed to 3.6 for Germany, 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 for the period 1876–1913 (T=50)

	(1) Δi^{A}	(2) Δi^{A}
Δl_1	−0.049 (5.6)	
Δl_2		−0.057 (5.5)
Δi^{D}	0.124 (1.8)	0.118 (1.7)
$\bar{R}^2$	0.672	0.667
DW	2.43	2.38
AIC	0.971	0.988
SC	1.047	1.064
$Q(10)$	17.24 [0.07]	14.14 [0.17]
HET	1.14 [0.35]	2.30 [0.07]
JB	0.39 [0.82]	0.90 [0.64]
RESET	1.15 [0.29]	0.02 [0.88]

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 ten 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)

liquidity ratio were equally important. At the 5% confidence level the residuals of the regressions pass all the misspecification tests.[14]

The Cusum of Squares test[15] for regression (1) shows that at the 5% confidence level the regression tends to become unstable at around observation 33 which corresponds to the discount rate reduction of February 6, 1900, the third of an uninterrupted string of 5 reductions over the period from December 7, 1899 to February 5, 1902. On September 21, 1899 the charter of the Bank was renewed and the dispute between the two sides of the empire about the division of power for the control of the Bank was finally settled, making the 1892 monetary reform at long last a credible step towards formal entry into the gold standard (Flandreau 2003). Formal entry occurred in 1902. As to regression (2), which uses the broad liquidity ratio, the Cusum of Squares test shows that at the 5% confidence level the regression tends to become unstable between observation 19 and 32. This period lasts from January 9, 1892 until January 22, 1900.

Recursive parameter estimates of regression (1) and (2) (also available on request) suggest a division of the period into two. Taking the beginning of the shadowing of the gold standard by Vienna as the dividing line, we decided to consider the sub-periods 1876–1895 and 1896–1913. The chosen subdivision of the period is also justified by several additional historical facts. Among them should be mentioned the end of the long period of declining prices in the gold standard world, in connection with the discovery of new gold mines and of a new process to extract gold, and, in

[14] We also tested whether there is evidence of asymmetric behaviour on the part of the Bank of Austria–Hungary by dividing the observations into two categories, those relating to periods of stress (characterized by increases in the discount rate) and those relating to periods of ease (characterized by reductions), then in multiplying all explanatory variables with two dummy variables, DP which is equal to 1 when Δi^{A} is positive and zero otherwise and DN=1-DP and finally in estimating equation (1) again. The tests clearly show that there is no asymmetric behaviour. To save space the results are not presented in this paper.

[15] Available from the authors on request.

Table 3 The determinants of the official discount rate for the period 1876–1913 (T=50)

	(1) $\Delta i^{\wedge}$	(2) $\Delta i^{\wedge}$	(3) $\Delta i^{\wedge}$	(4) $\Delta i^{\wedge}$
$D1\Delta l_1$	−0.087 (4.7)	−0.087 (4.7)		
$D2\Delta l_1$	−0.051 (5.3)	−0.052 (8.7)		
$D1\Delta l_2$			−0.069 (3.3)	
$D2\Delta l_2$			−0.063 (5.2)	
Δl_2				−0.063 (9.0)
$D1\Delta i^D$	0.160 (1.8)	0.160 (1.8)	0.215 (2.2)	0.234 (3.1)
$D2\Delta i^D$	0.014 (0.2)		−0.002 (0.0)	
$\bar{R}^2$	0.733	0.738	0.694	0.706
DW	2.23	2.23	2.11	2.14
AIC	0.806	0.766	0.941	0.863
SC	0.959	0.881	1.094	0.940
WALD(Δl_l)	3.07 [0.09]	3.35 [0.07]	0.07 [0.79]	–
WALD(Δi^D)	1.36 [0.25]	–	2.58 [0.12]	–
$Q(10)$	11.61 [0.31]	11.63 [0.31]	7.84 [0.65]	8.17 [0.61]
HET	1.06 [0.41]	1.28 [0.29]	1.74 [0.12]	3.51 [0.01]
JB	1.31 [0.52]	1.36 [0.51]	2.68 [0.26]	2.58 [0.28]
RESET	0.23 [0.63]	0.24 [0.63]	0.00 [0.96]	0.00 [0.98]

See Table 2

the late 1880s and early 1890s, the end of a period characterized by a more intensive use of gold devices on the part of the Banque de France and the Bank of England.[16] Other important developments to justify the split were the improved communication and transportation technology, the increased degree of financial market integration worldwide, the increased economic and financial weight of Germany in the world economy and the development of the pound as an international reserve currency.

Owing to the insufficient number of observations, we do not estimate Eq. 1 separately for these two sub-periods. Instead we defined a dummy variable D1 which is equal to one for observations 1 to 23 (1876–1895) and zero otherwise and a dummy variable D2 which is equal to 1-D1 (1 from 1896 to 1913 and zero otherwise). We then multiplied D1 and D2 with Δi^D and with Δl_l and ran the regressions again with the new explanatory variables thus defined. The results are presented in Table 3.

Wald-F tests applied to the coefficients of regressions (1) and (2) in Table 3, which use the narrow liquidity ratio, show that at the 10% level of significance the coefficients of changes in the liquidity ratio are different. Changes in the liquidity ratio have a smaller influence on the discount rate in the second period. This finding may be the result of more relaxed stance of the Bank in relation to the size of its stock of metals, after it had increased enough to allow the move to the gold standard. Germany's discount rate was weakly significant only in the first sub-period.

Regressions (3) and (4) in Table 3 using the broad liquidity ratio show that there is no significant difference between the coefficients of changes in the liquidity ratio in the two sub-periods. The German discount rate is significant at the 1% level only in the first sub-period. The residuals of all regressions in Table 3 are well behaved.

[16] See Scammel (1965), Sayers (1976) and Tullio and Wolters (2003).

By splitting the period, the explanatory power of all regressions, measured by the Adjusted R^2's, AIC and SC, shows a marked improvement with respect to the results of Table 2.

Since the foreign official discount rates could also extend their effects on Vienna's discount rate indirectly via changes in the liquidity ratios, we shall analyse in Section 4 the domestic and international determinants of the liquidity ratios of the Imperial Bank of Austria–Hungary (Eq. 2 of Section 1).

4 The determinants of the liquidity ratios

In this section we present ordinary least squares (OLS) estimates of Eq. 2 using the data described in Section 2 and including exchange rates and foreign discount rates among the explanatory variables.[17] We started out with all the explanatory variables and then eliminated successively all those which were not significantly different from zero at the 10% level.

Table 4 shows the estimates of Eq. 2 for the whole period. The most significant explanatory variable is always the differential between the private and the official discount rate in Vienna. The coefficient of this variable has the expected negative sign. A 100 basis points higher differential implies a reduction of 6.8–6.9 percentage points in the narrow liquidity ratio and of 5.6 in the broad one. The German official discount rate always has a highly significant and negative effect as expected. A 100 basis point increase in the German discount rate implies a reduction of 2.5–3.5 percentage points in the liquidity ratio, depending on the specification of the estimated equation. Changes in the discount rate of the Banque de France also have the expected negative influence on the Austro–Hungarian narrow liquidity ratio (see regression 1). However, since the changes in the French and German official discount rates are highly multicollinear, in the remainder of this section, we prefer the specification without the French discount rate.[18] The regressions presented in Table 4 explain from 64–66% of the variance of changes in the liquidity ratios. The residuals are well behaved.

According to the Cusum of Squares test (available on request), regression (3) is stable. The Cusum of Squares test of regression (2) shows that the estimated relationship is unstable at the 5% significance level. The Cusum of Squares test statistic moves outside the 5% confidence band from observation 17 to 32. These observations correspond to the period from February 5, 1891 to January 22, 1900. As explained in the introduction and in Section 3, during this period Austria–Hungary

[17] 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 25 out of 50 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. 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 two weeks to two months long, a few days' lead of the differential does not matter.

[18] The elimination of the French discount rate does not worsen the Schwarz (SC) criteria.

Table 4 The determinants of the liquidity ratios for the period 1876–1913 (T=50)

	(1) Δl_1	(2) Δl_1	(3) Δl_2
c	−2.745 (3.1)	−2.726 (3.0)	−2.770 (3.6)
$(i_p-i)^{\wedge}$	−6.834 (4.4)	−6.931 (4.3)	−5.552 (4.0)
Δi^D	−2.470 (2.7)	−3.521 (3.8)	−3.106 (4.2)
Δi^F	−4.869 (1.9)		
$\bar{R}^2$	0.661	0.641	0.652
DW	1.88	1.67	1.86
AIC	6.230	6.268	5.950
SC	6.383	6.383	6.064
$Q(10)$	2.83 [0.99]	8.16 [0.61]	5.61 [0.85]
HET	0.58 [0.75]	0.74 [0.57]	1.79 [0.15]
JB	0.46 [0.79]	0.80 [0.67]	0.32 [0.85]
RESET	1.08 [0.31]	4.04 [0.05]	2.89 [0.10]

See Table 2

implemented a monetary reform (1892), adopted the policy of shadowing the gold standard (1896), passed into law a new charter of the Imperial Bank of Austria–Hungary resolving the long dispute between the two sides of the empire for the control of the Bank (1899) and moved to formal adherence to the gold standard in 1902.

In order to investigate possible changes over time of the determinants of the liquidity ratio, we split the period into two sub-periods as in Section 3, and used the dummy variables D1 and D2 already defined, to reestimated regressions (2) and (3) of Table 4. The results are presented in Table 5. The Wald-F tests, shown in the lower part of the table, indicate that the coefficients of the differential are significantly different between the two periods. They increase in absolute value by roughly two times for the narrow liquidity ratio and three times for the broad one. This implies that in the second period the domestic financial market had become more efficient in transmitting information about the business cycle and the state of financial markets to the liquidity ratios of the Bank. The effect of the German discount rate is significant only in the second period for the narrow liquidity ratio, while for the broad one the effect remains strong and highly significant over the whole period. By allowing for differences in the coefficients between the two periods, the explanatory power of all regressions increases considerably.

5 Summary and conclusions

In this paper we presented estimates of two equations which jointly explain monetary policy in Austro–Hungary during the period from 1876 to 1913. The first equation explains the official discount rate of the Central Bank as a function of the liquidity ratio and the German official discount rate. This equation can be considered as a reaction function of the Bank of Austria–Hungary. The second equation explains changes in the liquidity ratio as a function of the differential between the private and the official discount rate in Vienna and of changes in the German official discount rate. Two liquidity ratios are used in this paper, a narrow and a broad one.

Table 5 The determinants of the liquidity ratios for the period 1876–1913 (T=50)

	(1) Δl_1	(2) Δl_1	(3) Δl_2	(4) Δl_2
c	−3.269 (4.3)	−3.366 (4.5)	−3.248 (4.9)	−3.263 (4.9)
$D1(i_p-i)^{\wedge}$	−5.510 (3.1)	−6.469 (4.9)	−3.662 (2.4)	−2.681 (2.0)
$D2(i_p-i)^{\wedge}$	−10.511 (5.9)	−10.625 (6.0)	−9.029 (5.8)	−9.609 (6.4)
$D1\Delta i^D$	−0.960 (0.8)		−1.843 (1.8)	
$D2\Delta i^D$	−4.067 (4.7)	−4.040 (4.7)	−3.437 (4.5)	
Δi^D				−2.889 (4.6)
$\bar{R}^2$	0.757	0.759	0.751	0.747
DW	1.61	1.62	1.73	1.78
AIC	5.915	5.890	5.653	5.648
SC	6.107	6.043	5.845	5.801
WALD$(i_p-i)^{\wedge}$	4.75 [0.03]	4.15 [0.05]	7.10 [0.01]	18.70 [0.00]
WALD(Δi^D)	4.69 [0.04]	–	1.60 [0.21]	–
$Q(10)$	6.36 [0.78]	10.45 [0.58]	3.13 [0.98]	2.34 [0.99]
HET	1.33 [0.26]	1.44 [0.22]	1.17 [0.34]	1.76 [0.13]
JB	0.63 [0.73]	0.70 [0.70]	0.36 [0.84]	0.09 [0.95]
RESET	0.20 [0.66]	0.19 [0.67]	0.02 [0.88]	0.02 [0.88]

See Table 2

The data used are from Vergleichende Notenbankstatistik (1925) referring to all episodes of discount rate changes enacted by the Bank during the period. Since there were 50 such changes we have 50 observations. The data used is "not equally spaced chronologically ordered." We present stability tests in order to study if and how institutional changes affected the determination of the official discount rate and the liquidity ratios.

Although the Austro–Hungarian Empire formally joined the gold standard only in 1902, it tried from the beginning of the period to approach the gold standard in steps, which meant in the first place accumulating sufficient gold to make the internal convertibility into gold viable. During the long period of convergence it shadowed the behaviour of gold standard Central Banks by increasing the official discount rate when metal reserves (consisting of silver and gold) were low and reducing it when they were high. This policy was pursued also in times of inconvertible paper currency (1879–1892) and fluctuating exchange rates (1876–1895).

The estimates presented in this paper suggest the following main conclusions. *First*, changes in the liquidity ratios were the main determinant of changes in the discount rate throughout the period, despite the lack of internal convertibility of outstanding banknotes into gold until 1902. *Second*, throughout the period the differential between the private and the official discount rate in Vienna played an important role in transmitting disturbances from the real economy and from domestic financial markets to the Bank's liquidity ratios, and hence ultimately to the official discount rate, confirming a hypothesis first advanced by Goodhart (1972) for Great Britain. *Third*, of the three main gold standard countries (Great Britain, Germany and France), only Germany played a significant role in determining the official Austro–Hungarian discount rate and the liquidity ratios. Changes in the German official discount rate were affecting the official discount rate in Vienna mainly directly in the first period and mainly indirectly in the second. *Fourth*, the fact that only Germany and not Great

Britain had significant effects on monetary policy in Austria–Hungary has an important implication for the role of London as the "conductor of the international orchestra" view suggested by Keynes (1930). Keynes thought that the classical gold standard was a system fully managed by London in which the impulses moved unidirectionally from London to the periphery of the system. Eichengreen (1992) suggested instead that the classical gold standard was rather a decentralized multipolar system or at least a bi-polar one.[19] The findings of this paper are in line with Eichengreen's view insofar as Great Britain played no role in explaining monetary policy in Austria–Hungary.

Fifth, we analyse the stability of all estimated regressions. In general we find evidence of instabilities during the period from about 1892 to 1900. This interval is characterized by important institutional changes in the Austro–Hungarian monetary system, which have been described in the introduction. Despite these instabilities in the estimated regressions, well justified by the institutional changes, the paper shows that the two equations presented can be estimated for the whole period 1876–1913 and that the objectives of the Bank of Austria–Hungary changed much less through time than the institutional framework it was confronted with. In this respect the superb economic historians and authors of VN (1925) who compiled the table also for Austria–Hungary were right to put the country on the same footing as Great Britain, France and Germany. *Sixth*, allowing for different coefficients of the explanatory variables before and after 1895, we find significant improvements in the explanatory power and in the stability of the regressions. *Seventh*, the estimates of Eq. 2 in Section 4 show that the model is able to explain changes in the broad liquidity ratio better than changes in the narrow one. In particular the estimated regression for Δl_2 is stable for the whole period while the one for Δl_1 is not. This may suggest that the broad liquidity ratio and its stabilization was more important for the Bank of Austria–Hungary than the narrow one, which may not be unrelated to the fact that the Austro–Hungarian monetary system was relying more on paper currency and bank liabilities and that it was in some sense a precursor of the monetary systems which emerged after World War II.

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References

Bloomfield AI (1959) Monetary policy under the International Gold Standard, 1880–1914. Federal Reserve Bank, New York
Contamin R, Denise C (1999) Quelle autonomie pour les politiques monetaires sous l'étalon d'or, 1880–1913? Economie Internationale 78:59–84
Eichengreen B (1992) Golden fetters. Oxford University Press, Oxford
Flandreau M (2003) The bank, the state, and the market: an Austro–Hungarian tale for Euroland 1867–1914. In: Capie F, Wood G (eds) Monetary unions: theory, history, public choice. Routledge, London
Goodhart C (1972) The business of banking. Weidenfeld and Nicholson, London
Keynes JM (1930) A treatise on money. MacMillan, London

[19] See also Tullio and Wolters (1996, 2000).

McGouldrick P (1984) Operation of the German Central Bank and the rules of the game, 1879–1913. In: Bordo MD, Schwartz AJ (eds) A retrospective on the classical gold standard, 1821–1931. University of Chicago Press, Chicago
Sayers RS (1976) The bank of England. Cambridge University Press, Cambridge
Scammel WM (1965) The working of the gold standard. Yorkshire bulletin of economic and social research 32–45; reprinted in Eichengreen, B. (1985) The gold standard in theory and history. Meuthuen, New York and London, pp 103–119
Sommariva A, Tullio G (1987) German macroeconomic history: a study of the effect of the monetary policy on inflation, currency depreciation and growth. St. Martin, New York
Taylor JB (1993) Discretion versus policy rules in practice. Carnegie-Rochester Conf Ser public policy 39:195–214
Tullio G, Wolters J (1996) 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. Scott J Polit Econ 43:419–443
Tullio G, Wolters J (2000) A note on interest linkages between the US and the UK during the gold standard. Scott J Polit Econ 47:61–71
Tullio G, Wolters J (2003) The objectives of French monetary policy during the classical gold standard, 1876–1919: an econometric analysis of the determinants of the Banque de France's official discount rate. Diskussionbeiträge des Fachbereichs Wirtschaftswissenschaft der Freien Universität Berlin 2003/12
Vergleichende Notenbankstatistik (1925) Organisation und Geschäftsverkehr Europäischer Notenbanken, 1876–1913. Berlin, Reichsdruckerei