Were there Anomalies in the Sterling-Franc Exchange Rate Regulation during the Mid-19th Century?

Claude Diebolt¹ & Antoine Parent²

Abstract: In this paper, we test whether French and British central banks discount rates were an efficient tool for currency stabilisation over the 1850-1870 period. Causality and impulse analysis as well as outlier methodology are carried out in order to test this proposition. We give strong evidence that the discount rate differential between France and England had a crucial corrective influence on the Sterling-Franc spot exchange rate. Regarding this exchange rate regulation hypothesis, we find only one single anomaly which occurred in February 1861. The assessment of the historical context helps to understand this peculiar event. We conclude to the absence of anomalies in the Sterling-Franc exchange rate regulation over the 1850-1870 period.

JEL Classification: N10, N23.

Keywords: Exchange rate, Discount rate, Regulation, Causality and impulse analysis, Outliers, Cliometrics.

¹Association Française de Cliométrie (AFC), BETA/CNRS, Université Louis Pasteur de Strasbourg & Humboldt-Universität zu Berlin. E-mail: cdiebolt@cournot.u-strasbg.fr, www.cliometrie.org.

²Corresponding author: Association Française de Cliométrie (AFC), BETA/CNRS, UMR 7522, Université Louis Pasteur de Strasbourg, 61 Avenue de la Forêt Noire, 67085 Strasbourg Cedex. E-mail: parent@cournot.u-strasbg.fr.
Introduction

Our approach of the exchange rate regulation over twenty years of the bimetallic regime stands in contrast to the existing literature which identifies this regime as a pure automatic system, constrained by specie points. The underlying principles of our arguments are that the role of French and British monetary authorities in the regulation of the currency have to be reconsidered. In the traditional view (see for instance Flandreau (1995)) the role played by the discount rate as a monetary policy tool for currency stabilisation is overlooked. Yet, this aspect was largely evoked in the internal debates of the Banque de France in the early 1850s (Diebolt and Parent, 2006a, 2006b).

As a matter of fact, on January the 14th of 1847, the legislature enacted a law putting an end to the fixity of the discount rate (which had remained at the fixed level of 4% for over 26 years, from 1820 to 1847). The 9th of June 1857 Law abrogated the limitation of the legal interest rate to a ceiling of 6%. The policy of moving the discount rate (politique de mobilité du taux d’escompte) actually started in 1852 and can be considered as a turning point (see Appendix). From this date, moving the discount rate became a useful and flexible regulatory tool for the Banque de France.

The controversies over central banks’ solidarity during the bimetallic period are another important issue in the literature. Whether solidarity means rivalry between central banks for the sharing of gold and silver is the heart of the debate. Does a concomitant increase of discount rate necessarily define a retaliatory measure against the adverse issuance institution? On the one side, Patterson (1867) denounced the “war between banks”, “this system of rivalry and antagonisms”; Viner (1937) considered that “Co-operation between central banks was during this period exceptional rather than an established policy”; Plessis (1998) stated that “The solidarity between banks meant in fact a hard competition for the sharing of the metallic stock”; finally, Flandreau (1997) argued that “central bank cooperation was probably not decisive in the operation of the gold standard” (p. 735) and that “Co-operation had been exceptional, never reciprocal, and always failed to institutionalize (p. 737)”.

On the other side, Eichengreen (1985, 1992) underlined that central bank co-operation had been the key to the exchange rate stability of the pre-1914 gold standard. In the same way, Cottrell (1982) noted that “Co-operation between Threadneedle Street and the Rue des Petits Champs was not a new development… By the early 1850s co-operation, at least of an
intermittent form, was a well established practice. The two banks exchanged information and by 1854 telegraphed each other news of changes in their discount rates on a regular basis (p. 132).”

We discussed in other papers the pros and the cons of this controversy. It is worth quoted that this controversy does not concern straight the discount rate regulation but mainly few episodes of swap arrangement between French and English central banks. Obviously, talking about the bimetallic period as one of co-operation in the sense of multilateralism between institutions is irrelevent. Nevertheless, the “solidarity” over the bimetallic period did not limit to some sporadic swap arrangements between the Banque de France and the Bank of England. We found in Bonnet (1866) and Juglar (1866) evidence of a united action on discount rate by the Banque de France and the Bank of England (Parent, 2006). These authors assessed in a very explicit way the use of the discount rate as a proof of central banks co-operation in order to stabilise currency. It is quite striking how their assessment remained forgotten or unrecognized. Yet, this reading from Bonnet (1866) and Juglar (1866) highlighted some key points: the role of the external economic imbalances in the triggering of crises’ episodes of the mid-19th century; the role of the discount rate policy to prevent from exchange rate variations under the bimetallic regime; the efficiency of central banks co-operation over the bimetallic period. Following Bonnet (1866) and Juglar (1866), the purpose of this paper is to test econometrically the influence of the discount rate regulation on the spot exchange rate.

In this paper, we test whether French and British central banks discount rates were an efficient tool for currency stabilisation over the 1850-1870 period. Our assessment of this “exchange rate regulation hypothesis” relies on two variables: the Sterling-Franc spot exchange rate and the discount rate differential between the Banque de France and the Bank of England. Causality tests, impulse analysis and outliers methodology are carried out in the first section in order to test the dynamic interactions between these two variables. Our results are presented in the second section: over the 1850-1870 period, we found that the “exchange rate regulation hypothesis” could not be rejected. Indeed, only one single anomaly occured in February 1861. The assessment of the historical context helps to understand this peculiar event. Globaly, we conclude to the absence of anomalies in the Sterling-Franc exchange rate regulation over the 1850-1870 period.

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3Interested readers should refer to Diebolt and Parent (2006a,b).
1. Data, variables and cliometric methodology

1.1. Data and variables

Two variables were chosen to test the “exchange rate regulation hypothesis”: the “spot Franc-Sterling pound exchange rate” noted LPV (where the Sterling Pound is quoted *au certain* against the Franc), and the “discount rate differential” between France and England (calculated as the difference between the French discount rate and the British discount rate), noted STA.

These monthly data for the period 1850-1869 are taken from Boyer-Deleplace-Gillard (1995) for LPV and from the Banque de France and the NBER for STA.

**Figure 1: Series**

1.2. Methodology

*Seasonality of the time series*

As the data are monthly, it is first necessary to analyse their seasonal features so as to be able to possibly isolate and analyse the other characteristics of the variables. Three detection tests—classic and complementary in the analysis of seasonality—are proposed for this: analysis of the autocorrelation function, analysis of the Buys-Ballot table and finally analysis of variance using the Fisher test⁴.

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⁴As these tests are fairly well known, we do not provide a detailed description of each of them.
**Unit root tests and order of integration**

It is also essential to analyse the stationarity properties of the series chosen before starting the analysis. Efficient unit root tests (Elliott, Rothenberg and Stock, 1996, Ng and Perron, 2001) and the KPSS stationarity test (Kwiatkowski, Phillips, Schmidt and Shin, 1992) were used to determine the order of integration of the variables, stationarise the series (interested readers should see, in particular, Darné and Diebolt, 2004, 2005, 2006) and to know whether there is a risk of cointegration\(^5\).

**Granger causality**

Analysis of the relations between the variable chosen is performed using causality methodology for several reasons. First, although regression studies can make significant contributions, their great weakness is that they tend to equate correlation and causality. However, correlations between the variables do not necessarily mean the existence of a causality relation. Secondly, the demonstration of causal relations allows better addressing and understanding of the phenomena and provides additional information about the sequence of the events. Finally, economic variables rarely have an instant effect; a lag is often observed for the necessary adjustments of systems and behaviour. Likewise, it is not unusual for a variable to be affected by its own past behaviour. Analysis must therefore be seen not only in a dynamic manner but also as an autoregressive process. Analysis of the bimetallic system must be placed in a VAR modelling and causality framework for these different reasons.

The method for testing Granger causality was chosen from a set of possible methods in the light of the favourable results reported by Guilkey and Salemi (1982) and by Geweke, Meese and Dent (1983) for small samples (fewer than 200 observations). Thus, according to Granger (1969), variable \(y_{1t}\) causes variable \(y_{2t}\) if the forecasting of the latter is enhanced by incorporating in the analysis information concerning \(y_{1t}\) and its past. The test can then be conducted using a classic Fisher test for the nullity of the coefficients in the estimated model (VAR or VECM), operating equation by equation.

\(^5\)Johansen’s test (1988) was chosen for analysis of possible cointegration relations between the variables. If such relations are found, the causality study is performed using a VECM (Vector Error Correction Model); if not, the analysis is continued using a VAR (Vector Auto Regressive) model.
Impulse response functions and outliers

Two econometric methodologies can be envisaged for the analysis of shocks. We can either study shocks in the form of impulse response functions as in the traditional approach. In this case, analysis of shocks is based on estimation of a VAR model and takes the form essentially of an analytical and forecasting approach as the shocks envisaged are simulated and hence fictitious. Or we can analyse shocks in the form of outliers. Here, analysis of the shocks is part of an analytical and historical procedure, with the shocks being real ones.

The impulse response functions are based on estimation of a VAR model. They make it possible to measure the impact of a shock on the variables and to trace the effect of an innovation on the current and future values of the variables. In this case, a procedure for the orthogonalisation of shocks and errors is necessary. Cholesky’s decomposition is used here to diagonalise the variance-covariance matrix of the innovations and thus identify the variance of each of the variables. The Cholesky order is then performed according to the rule that stipulates that the choice of order of the series must be made by classification from the most exogenous series to the most endogenous, that is to say with no economic preconceptions.

Outliers are addressed using a very different methodology. Outliers in time series are defined informally as unexpected or surprising values in relation to the trend of the series. In other words, they are sharp temporary or permanent changes in a time series (Darné and Diebolt, 2004). According to the more detailed definitions of Tsay (1986, 1988) and Chen and Liu (1993), three main types of outlier exist: (i) Additive Outliers (AO), that affect only a single observation, (ii) Temporary Changes (TC) that have a temporary effect on several observations and whose effect decreases exponentially, and (iii) Level Shifts (LS) that have a permanent effect on the observations. More generally, AO are considered as outliers which are related to an exogenous and endogenous change in the series, whereas TC and LS are structural changes. TC represent ephemeral shifts, while LS are more the reflection of permanent shocks.

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6As the impulse response functions are comparatively well known, here also we do not provide a detailed description of each of them. Interested readers should refer to Diebolt and Doliger (2006).

7Interested readers should see, in particular, Darné and Diebolt (2004).
2. Results

Causality analysis

This analysis was performed through study of the growth rates of the variables defined above by checking before any statistical processing that the variables verified the seasonality and stationarity properties. Analysis of the possible seasonality of the monthly data showed that they were not seasonal and that no correction of seasonal variations was necessary. With regard to stationarity, the three tests were unanimous at the 5% threshold and it was seen that the variables were stationary:

<table>
<thead>
<tr>
<th></th>
<th>ERS</th>
<th>Ng Perron</th>
<th>KPSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stat</td>
<td>VC</td>
<td>Stat</td>
</tr>
<tr>
<td>LPV</td>
<td>-13.51205</td>
<td>-1.942164</td>
<td>-9.09559</td>
</tr>
<tr>
<td>STA</td>
<td>-15.24007</td>
<td>-1.942159</td>
<td>-7.72913</td>
</tr>
</tbody>
</table>

As a necessary condition for cointegration is that the variables be integrated of the same order, the risk of cointegration between the series is avoided and analysis of causality can be performed on an optimum VAR model. Application of the Granger causality test gave the following results:

<table>
<thead>
<tr>
<th></th>
<th>Stat</th>
<th>VC</th>
</tr>
</thead>
<tbody>
<tr>
<td>STA does not Granger Cause LPV</td>
<td>0.07901</td>
<td></td>
</tr>
<tr>
<td>LPV does not Granger Cause STA</td>
<td>0.62549</td>
<td></td>
</tr>
</tbody>
</table>

The different values reported for the various causality relations tested represent the probability of acceptance or rejection of the hypothesis. Thus, when the calculated probability is less than the first-species risk (10%), the existence of a causality relation at the threshold 10% is accepted. As is frequent in the literature on causality, application of the test can be represented by a so-called causality channel:

![Causality Channel](image)

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8That minimises the entropy criteria, that is to say the criteria AIC and SBC.

9Analysis was performed here not by using the lag given by the optimum VAR model but simply by varying the lag.
In a general manner, this channel shows that the exchange rate is characterised by a direct, univocal relation. Indeed, STA causes LPV directly.

**Analysis of shocks**

Now that the mechanism of regulation of the exchange rate by the discount rate over the 1850-1870 period has been shown, the discussion is illustrated with regard to the reactions of the system in the face of simulated or actual shocks.

The impulse response functions provide the first information about the relative forces that may exist between the variables and how the variables can react and interact when one of them is the subject of a simulated shock.

**Figure 3: Impulse response functions**

This analysis leads to various conclusions. Firstly, the shock is found to be transitory. It is then seen that a positive shock to STA significantly influences LPV with damped waves alternating between positive and then negative influence before returning to its equilibrium level in less than 10 periods. Decomposition of the variance of the prediction error for each variable provides the second set of information about relative forces and the measuring of the forces that may exist between the variables and how the variables can react and interact when one is subjected to a simulated shock.

\[^{10}\text{Only the functions of impulsional responses of the previously determined causality pattern are reported here.}\]
TABLE 3: DECOMPOSITION OF VARIANCE

<table>
<thead>
<tr>
<th>Period</th>
<th>STA</th>
<th>LPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.902080</td>
<td>98.09792</td>
</tr>
<tr>
<td>10</td>
<td>4.720267</td>
<td>95.27973</td>
</tr>
</tbody>
</table>

Decomposition of STA:

<table>
<thead>
<tr>
<th>Period</th>
<th>STA</th>
<th>LPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>99.33638</td>
<td>0.663617</td>
</tr>
<tr>
<td>10</td>
<td>99.25296</td>
<td>0.747039</td>
</tr>
</tbody>
</table>

It is seen in this case that a limited but nonetheless significant proportion of the variance of LPV, 1.90%, is explained in the short term (2 months) and 4.72% in the long term (10 months) by a shock to STA. Similarly, but less significantly, a shock to LPV accounts for approximately 0.70% in the short term and the long term. STA thus has more impact in both the short and the long terms than LPV on STA. These results are in agreement with those above and confirm that the exchange rate was indeed regulated by means of the discount rate during the period in question.

The outliers are a second source of information about the force of the interactions that may exist between variables and how the variables reacted and interacted when one of them was subjected to an actual shock. As in the various analyses of this type, we summarise the results of the detection of outliers in the form of a chronological table. This shows the characteristics of the outliers identified in the series, that is to say their date, nature and amplitude.

TABLE 4: OUTLIERS

<table>
<thead>
<tr>
<th>Series</th>
<th>Date</th>
<th>Type</th>
<th>Value</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPV</td>
<td>9</td>
<td>AO</td>
<td>0.9157</td>
<td>5.14</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>AO</td>
<td>-0.7915</td>
<td>-4.44</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>AO</td>
<td>0.7103</td>
<td>3.99</td>
</tr>
<tr>
<td>STA</td>
<td>6</td>
<td>AO</td>
<td>-10.231</td>
<td>-19.5</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>AO</td>
<td>1.9594</td>
<td>3.73</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>TC</td>
<td>1.5584</td>
<td>4.11</td>
</tr>
</tbody>
</table>

11See Darné and Diebolt (2004).
Several general results can be set out initially. First, it is seen that a number of national and international political, economic and monetary events caused substantial permanent and/or temporary shocks to the differential between the discount rate and the exchange rate. It is then noted that the total quantity of outliers in the data forms some 2.5% and 7.12% of observations for LPV and STA respectively. The STA sphere is therefore more sensitive than the LPV sphere to infrequent external events. Nevertheless, these results need to be the subject of closer investigation to analyse the nature and amplitude of the respective shocks that are the consequence of shocks to the other variable.

It is remarkable that over this twenty years’ period no level shift (LS), indicating a structural change in the relationships between the two variables, can be found. This means that the relationship between the discount rate differential and the exchange rate is robust in time. We observe that non frequent negative (respectively positive) shocks hitting STA have a positive (respectively negative) impact on LPV, in the case of non structural and transitory shocks (AO, like in 1855 and 1857), whereas the temporary change in 1861 (TC) has a similar positive impact. This point needs to be discussed in light of the historical context because it seems apparently inconsistent with the “exchange rate regulation hypothesis”.

For two of the three items which directly entail the relationship between STA and LPV, the impact of a shock on STA implies an effect of opposite sign on LPV. This is the case in 1855/6, when the negative impact on the discount rate differential creates a positive feedback on the exchange rate three months later in 1855/9. All signs are correctly oriented and conform to the “exchange rate regulation hypothesis”: as the discount rate differential (calculated as the difference between the French discount rate and the British discount rate) deepens, this logically increases the Sterling pound (quoted *au certain* against the Franc); capital inflows move to England where the interest rate is more attractive than in France. The same sequence occurs in 1857/11 (with inversed signs): the discount rate differential becomes positive (the French discount rate is higher than the British one) and one month later (in 1857/12), as a consequence of capital movements that this differential triggers, the exchange rate of the Sterling pound decreases. These selective phenomena (AO) can largely be explained in light of the relationship that the discount rate differential rules the exchange rate variations.
Finally, only one point (over this twenty years’ period) illustrates an anomaly in the regulation of the exchange rate by the discount rate differential. In 1861/2, the shock on the discount rate differential produces a similar impact on the exchange rate, the discount rate differential deepening and the Sterling decreasing. Although this inversion in the relationship is transitory, it is necessary to try to explain it according to financial well known newspapers of the time.

We found in the issues of January, February and March of *Le Moniteur industriel*[^12], a financial newspaper edited in Brussels, some key features highlighting the specific international and economic context of 1861/2[^13]. The articles are all written by P. Darnis and two kinds of factors can be put forward to explain the peculiar context of 1861/2: on the one hand, some strictly metallic causes refering to the scarcity of specie holdings of the Bank of England, and on the other hand, several causes related to the British trade imbalance and to the unfavourable economic context.

[^12]: *Le Moniteur industriel* became in 1863 *Le Moniteur des intérêts financiers et industriels*. The most famous financial newspaper of the time, *Le moniteur des intérêts matériels*, often cited in the literature, could not be consulted since the first edition started in 1873. *Le Moniteur des tirages financiers* could neither be exploited since its first publication is in date of 1863.

[^13]: The American reader should obviously be amazed that we did not already mention the US civil war which began precisely in 1861. Indeed this event may have provoked an exogenous shock in the relation between the discount rate differential and the Sterling-Franc spot exchange rate. As a matter of fact, Goschen (1861, 1863) frequently mentioned the peculiar American circumstances of 1861, and noted that “English people kept watching on anxiously the gold shipments to the United States” (p. 224, of the French edition). Nevertheless the timing of the American civil war does not fit exactly with the temporary change observed in our series in February 1861. January and February 1861 were just the very beginning of the American civil war since along January most of southern states seceded from the Union and on February 8 the convention of seceded states adopted a provisional constitution forming the Confederate states of America. Were the forward consequences of these first steps of secession immediately anticipated by English and French markets? Did they have a straight impact on the discount rates on the two sides of the channel and on the Sterling – Franc spot exchange rate? The core features appeared later on: on March 9 when the first money ($ one million) for the confederate states was authorized, on May 6 when the confederate congress voted war with the US, on July 17 when the Treasury Department was allowed to print and circulate the “demand notes” well-known as “greenbacks”, on August 5 when the Congress approved the first federal income tax – 3% levy on incomes over $800 –, on December 30, when New-York banks suspended specie payments followed quickly by other cities, and finally on February 25, 1862, when the Legal Tender Act provided for issue of $ 150 millions in “greenbacks”. It is a well known fact that until December 31, 1861, the war had been carried on by placing of loans through the cooperation of the United States Treasury and the banks and by the issue of about 25 millions of US notes payable on demand without interest, all transactions being on a specie basis. But at the end of the year 1861 the loans had exhausted the resources of the banks and specie payments had to be suspended. The American civil war may explain partly our outlier in February 1861 at two conditions: that in England the popular sentiment and the market feeling were that US bankruptcy was threatening; second, since specie payments were still not suspended in February 1861, that a rush for converting American exchange bills on gold in London actually occurred. Goschen (1861, 1863) rather situated these panic episodes later on, mainly when the convertibility of banknotes was no longer guaranteed. Finally, the relevance of the American civil war context to highlight the peculiar outlier identified in February 1861 should not be overestimated.
These elements all put together obviously contributed to weaken the Sterling pound versus Franc and could have impeded for a moment the discount rate differential although favourable to England to be sufficient to thwart the Sterling pound decrease.

In the issue of February, the 21st, P. Darnis in an article entitled “The monetary crisis in Great-Britain” wrote: “The crisis is caused by the growing scarcity of precious metals during these last six months… Gold imports from California are less important… The Mexican crisis and the Australian crises penalize the Bank of England in terms of gold supplying… The sudden gold demand from the Banque de France to the Bank of England at the end of 1860 and the beginning of 1861, facilitated by the agreement between these two institutions, accentuated the phenomenon… It left the Bank of England obliged to increase its discount rate.” Indeed, the Bank of England reacted strongly when the Comptoir d’Escompte de Paris tried to use 25 millions of bills on London to take the counterpart in gold for the Banque de France. Moreover the speculation on silver in France in the beginning of 1861 incited the Banque de France to get gold from London. This may have created a context of gold growing scarcity propitious to tensions on the Sterling pound.

In the issue of the 10 March 1861 P. Darnis mentioned “an unexpected news of gold exports from England to the United States last month (in February). Three ships would have left a British harbour to honour a contract with the Bank of the United States of America”. Simple rumor which arrived late to the Belgian newspaper or very important piece of information? Anyway, whatever true or wrong, these rumors feed the existing risk of tension on the metallic holding of the Bank of England, which may have moved the sterling pound spot exchange rate in February 1861.

Towards these metallic factors linked to the growing scarcity of the metallic holdings of the Bank of England, another set of factors can be added, concerning the international context and the difficulties of the British international trade imbalance. P. Darnis devoted many articles to the “seriousness of the British crisis”, mentioned “the complication of the British crisis” and in the issue of the 31st of January 1861 evoked the importance of the British commercial trade imbalance to come. In the issue of February the 3rd, he tried to define the driving forces of the foreseeable deterioration of the British commercial trade imbalance: at first the author evoked the consequences for the British cotton and textile industry of the American crisis. The states of the “old south” no longer purchased English furniture, which
closed the door to British products. In the issue of February the 14\textsuperscript{th} and 17\textsuperscript{th}, P. Darnis came back to “The American crisis which increases the English stocks and force the managers of the textile industry to decrease by 10\% the wages of textile workers in England”. As the outcomes of the commercial trade with the United States were worse than in the past, it obviously had a negative impact on the spot Sterling pound exchange rate.

In the same issue, P. Darnis mentioned the fear of French textile managers to see, out of a substitution effect, their domestic market flooded by english products. Followed in the columns of this issue a debate on the consequences of the French-British free-trade treaty of 1860 and on “the opportunity to keep the date of October, the 1\textsuperscript{st}, to implement the treaty for cotton and wool industries”. French managers of textile, notably those from Nord and Picardie, claimed for it to be postponed. The newspaper echoed the opinions and fears that such a request triggers in England, the British textile managers dreading a limitation in their exports. This feature, added to the former ones, may have contributed to a decrease in the Sterling Pound spot exchange rate.

In sum, these combined unfavorable elements may explain that momentarily the level of the British discount rate, although superior to the French one, had been unsufficient to impede the decrease in the Sterling Pound spot exchange rate. As a matter of fact, the following month the discount rate differential with France deepened again and this outlier disappeared.

Finally, these results on shocks, whatever simulated or actual, confirm the robustness of the causality relationships highlighted previously and underline the regulated nature of the Sterling-Franc exchange rate over the period. Actually, as soon as the mid 19\textsuperscript{th} century, using the discount rate on the two sides of the channel appeared to be a useful and flexible regulatory tool of currency stabilisation.

**Conclusion**

We found that acting through the discount rate canal had as early as the mid 19\textsuperscript{th} century a crucial correcting influence by causing and stabilising the spot exchange rate. The impact of the discount rate differential between London and Paris on the spot exchange rate clearly proves that the “regulation” hypothesis cannot be rejected.
Two core features are worth quoted: It is remarkable that over this twenty years’ period no level shift indicating a structural change in the relationships between the two variables can be found; regarding the exchange rate regulation hypothesis, we found only one single anomaly, in the form of a temporary change, which occurred in February 1861. We manage to highlight this peculiar event out of the historical context. This lack of deep anomaly between discount rates and the spot exchange rate ultimately corroborates the thesis that over the bimetallic regime, using the discount rate on the two sides of the channel was already an efficient tool of currency stabilisation.

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Appendix

Banque de France discount rate

source: Banque de France and NBER