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Using ARIMA Forecasts to Explore the Efficiency of the Forward Reichsmark Market: Austria-Hungary, 1876-1914[1]

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Abstract: We explore the efficiency of the forward reichsmark market in Vienna between 1876 and 1914. We estimate ARIMA models of the spot exchange rate in order to forecast the one-month-ahead spot rate. In turn we compare these forecasts to the contemporaneous forward rate, i.e., the market's forecast of the future spot rate. We find that shortly after the introduction of a "shadow" gold standard in the mid-1890s the forward rate became a considerably better predictor of the future spot rate than during the prior flexible exchange rate regime. Between 1907 and 1914 forecast errors were between a half and one-fourth of their pre-1896 level. This implies that the Austro-Hungarian Bank's policy of defending the gold value of the currency was successful in improving the efficiency of the foreign exchange market.

JEL: F31, N32

Using ARIMA Forecasts to Explore the Efficiency of the Forward Reichsmark Market: Austria-Hungary, 1876-1914

Introduction

Austria-Hungary was on a flexible exchange-rate regime throughout most of the late 19th century, and the value of its currency, the florin, fluctuated markedly, - in a range of about ± 7 percent. In order to stabilize the florin, a gold standard was adopted in 1892 (de jure), though without an immediate effect, because convertibility was not introduced. However, in early 1896, the exact date remains unclear - , the Austro-Hungarian Bank began a policy of maintaining the new currency's legal parity with gold (Figure 1). We concluded in previous studies that the efficiency in the foreign exchange market increased markedly after the currency was stabilized in early 1896, and the Bank enforced a *de facto* target zone around parity of ± 0.4%. The forward premium became a much better predictor of future exchange rates (Flandreau and Komlos, 2001a; 2001b).

The present study explores the efficiency of the forward reichsmark market in Vienna from a different perspective. Insofar as the beginning of the month forward rate, f_t, was the market's forecast of the end of the month spot rate, y_{t+1}, our previous tests measured how effectively f_t predicted y_{t+1}. A limitation of these tests is, of course, that economic conditions could well change during the intervening one-month interval. Hence, the accuracy of the one-month-ahead market forecasts depended not only on the efficiency with which information was used at time (t), but also the degree to which economic fundamentals might have perturbed the money markets in the meanwhile. In order to attempt to circumvent this conceptual problem, we now turn to an alternative method to test the accuracy with which f_t predicted y_{t+1}. We use only information available to the market participants at time (t), the date at which f_t was determined, by estimating an ARIMA model for the spot rate up to and including y_t. Our goal is to ascertain the accuracy of the market forecasts over time, and how that accuracy changed after 1896. We then compare the ARIMA forecasts of y_{t+1} to the market's forecasts at t, f_t.

Before estimating an ARIMA model we test for stationarity of both (ask and bid) spot rate (y) series for 1870.1 to 1876.11, as well as for the two sub-periods 1870.1-1895.12 and 1896.1-1914.8. The augmented Dickey-Fuller test is:

(1.1) $$\Delta y_t = \alpha_0 + \alpha_2 t + \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t$$

Stationarity is rejected for the period 1870.01-1876.08, as well as for 1870.01-1895.12, but not for the subsequent period 1896.01-1914.08.[2] Hence, we proceed by differencing the series in the first period prior to estimating the ARIMA model for the spot rate series, but estimate an ARMA model for the second period. The partial autocorrelation function for 1870-1895 indicate that either an ARIMA (2,1,1) or an ARIMA ([1,12],1,0) model would be appropriate (see Appendix). We estimated both models, but inasmuch as the two results are virtually identical, only the latter is presented here in detail. The model estimated is:

(1.2) $$\Delta y_t = \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-12}$$

Because the forward rate was first published in 1876.11, the initial estimate of Eq. (1.2) is for the period 1870.1 to 1876.11. We then use $\hat{\beta}_i, \hat{\theta}$ to forecast the end of the month spot rate, $\hat{y}_{1876.12}$, and compare it with the market's forecast, $f_{1876.11}$. We thereby obtain a residual, an estimate of the market forecast error:

(1.3) $$\hat{e}_{1876.11} = (f_{1876.11} - \hat{y}_{1876.12})$$

which also includes a transaction cost. The information set is subsequently updated by one month, a new model is estimated, a new forecast is made, and a new forecast residual, $\hat{e}_{1876.12}$, is calculated. We thus obtain a forecast residual for each month of the period until the *de facto* end of the flexible exchange-rate regime in early 1896. We proceed similarly for the (shadow) gold-standard era (1896.1 to 1914.7), and subsequently compare the sum of the estimated forecast residuals $\sum_{t=0}^{t=N} \frac{|\hat{e}_t|}{N}$ under the flexible and the gold-standard exchange regimes in order to gauge the extent to which the forecast residuals changed during the two periods. We obtain thereby a measure of the accuracy of the forward rates using only information available to the market on the day the forward rate was determined.

<u>Results</u>

The estimated coefficients of the ARIMA ([1,12],1,0) model are small and unstable at the beginning of the period under consideration in 1876.11 (Figure 2). However, the coefficients settle down shortly, and within about 18 months become quite stable.[3] The short term memory, β_1, is both very close to zero and not statistically significant, implying that the spot rate series is practically a random walk in the first differences,[4] but the seasonal component, β_2, is statistically significant, implying that there was a seasonal component to the series. The ARIMA forecasts are virtually indistinguishable from the actual spot rates on the scale given in Figure 3. However, the residuals, $\hat{\varepsilon}$, do fluctuate quite a bit during the flexible-exchange-rate regime (Figure 4) and have a mean value of 0.035 fl (bid) and 0.051 fl (ask) (Table 3). This provides an estimate of the order of magnitude of the transaction costs as well as a standard to which the performance in the subsequent shadow-gold-standard period can be compared. (Note that the ask series began to be published in 1889; the results of the bid/ask series are virtually identical, and consequently we are not including the post-1896 ask forecast errors in Figure 4.)

During the gold standard period the best fit is provided by an AR(1) model with a highly significant coefficient close to 1 (not shown here). The forecast residuals do not improve at all immediately after 1896 (Figure 4); actually they do not do so until the end of 1898, implying that it took about two years for the policy of the Austro-Hungarian Bank to gain credibility, and for the market to learn to forecast the spot rates more accurately than during the prior regime. In fact, the previously used ARIMA ([1,12]1,0) model truly forecasts better during the transition period than does the AR(1) model. However, by 1899, the forward rates became a much better forecasts of the future spot rates than under the flexible exchange rate period (Figure 4). The range of the residuals using the AR(1) model is considerably smaller (0.20 bid and 0.25 ask) than under the previous exchange rate regime (0.71 bid and 0.37 ask). The mean of the residuals was about halved, and their standard deviation became about one-third of their previous values (Table 3). This suggests that the forward rates were a much more accurate predictors of the future spot rates under the shadow gold-standard period with smaller transaction costs than during the flexible exchange-rate regime.

In addition, it is noteworthy that the residuals were declining over time between 1899 and October of 1907 by about –0.00026 florin per month (bid), whereas during the flexible exchange rate period they either remained constant (ask) or even increased (bid) (Table 4). This implies that the market participants were able to improve their forecasts over time, while at the same time transaction costs were decreasing. The policy of the Austro-Hungarian Bank to support the florin must have been gaining in credibility. However, by October of 1907 the market's ability to improve its forecasts reached its limits: the forecast errors remained constant thereafter (Table 4) and remained at a very low level (Table 3). Forecast errors after October 1907 averaged about 0.015 florin – about half of the level between 1899 and 1907.

Conclusion

We estimated ARIMA models of the reichsmark/florin exchange rate for the period 1870-1914. In turn, these models were used to forecast the one-month-ahead spot rates, and subsequently compared to the forward rate of the reichsmark, the market's forecast of the future spot rate. We found that within about three years after the introduction of the shadow-gold standard the forward rate became a considerably better predictor of the future spot rate than during the prior flexible exchange rate regime. In addition, a certain learning took place on part of market participants in as much as the ability of the market to forecast the future rate improved over time. Although by 1907 the improvement came to an end, forecast errors stayed at a low level until 1914. Between 1907 and 1914 forecast errors were between a half and one-fourth of their pre-1896 level. This implies that the Austro-Hungarian Bank's policy of defending the gold value of the currency was quite successful in improving the efficiency of the foreign exchange market.

Figure 1. The Florin/Mark Exchange Rate. Florins / 100 Marks, 1870-1914

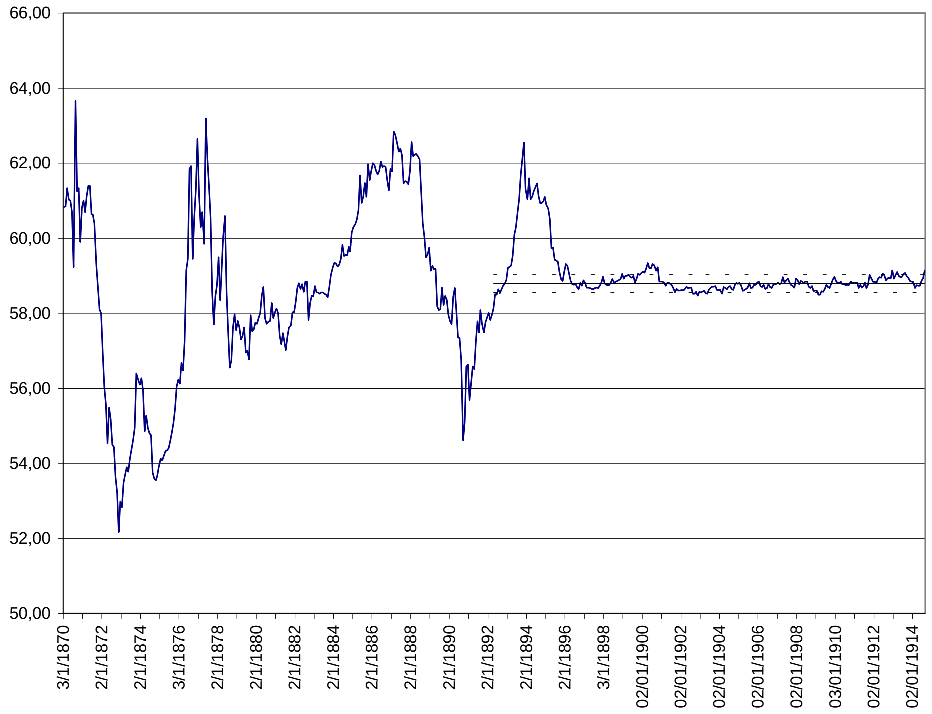
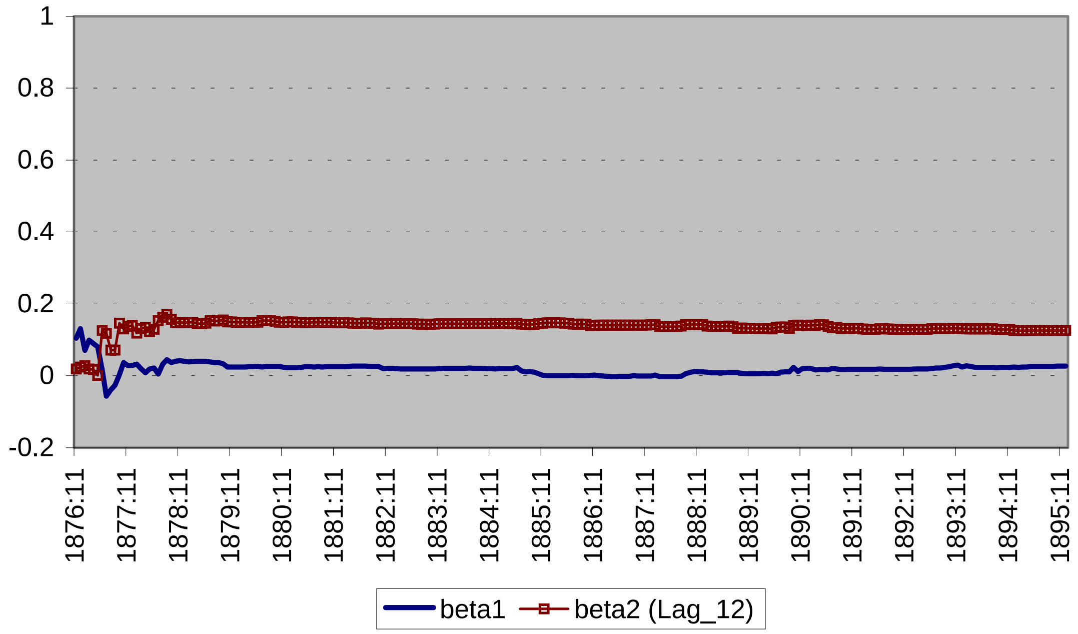


Figure 2. Estimated Coefficients of the ARIMA ([1,12]1,0) Model



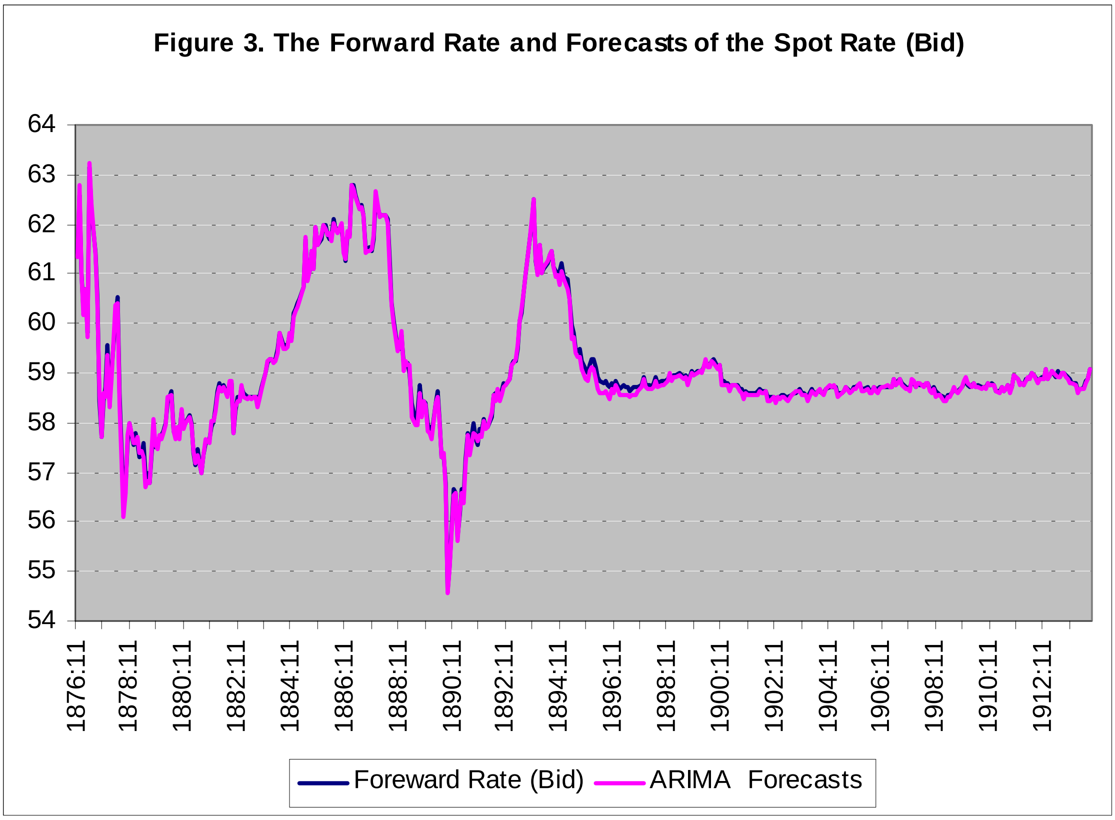


Figure 3. The Forward Rate and Forecasts of the Spot Rate (Bid)
64
63
62
61
60
59
58
57
56
55
54
1876:11
1878:11
1880:11
1882:11
1884:11
1886:11
1888:11
1890:11
1892:11
1894:11
1896:11
1898:11
1900:11
1902:11
1904:11
1906:11
1908:11
1910:11
1912:11
Foreward Rate (Bid)
ARIMA Forecasts

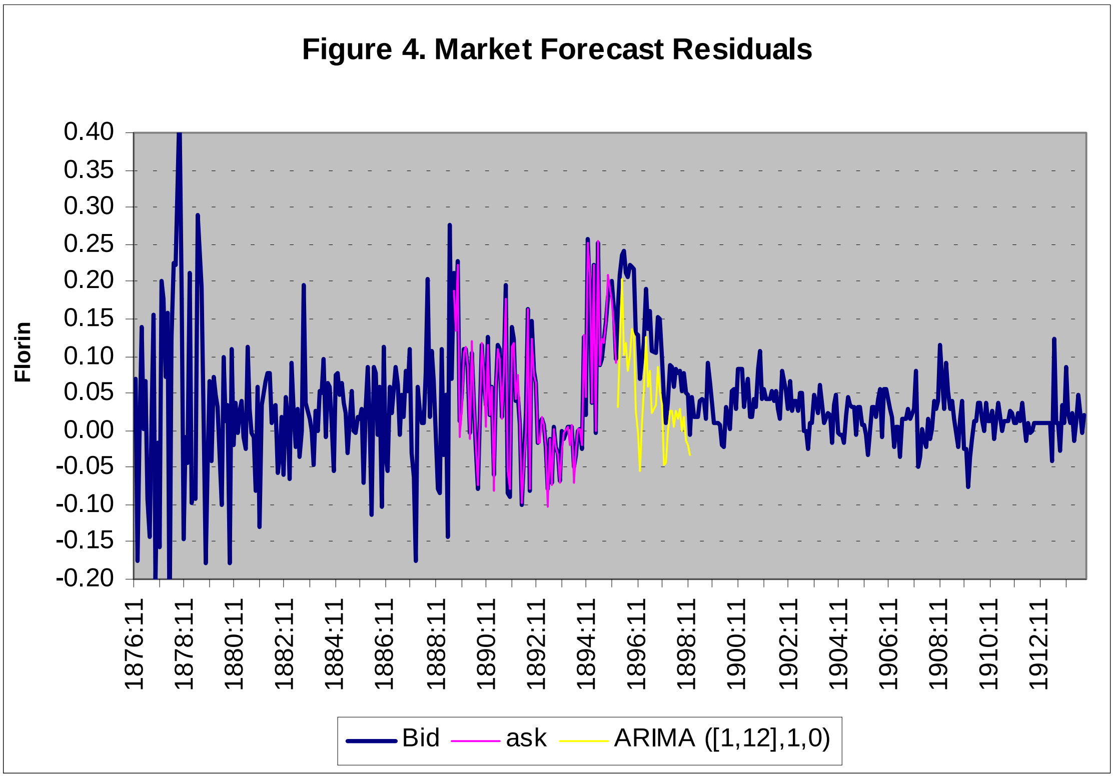


Figure 4. Market Forecast Residuals
Florin
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
1876:11
1878:11
1880:11
1882:11
1884:11
1886:11
1888:11
1890:11
1892:11
1894:11
1896:11
1898:11
1900:11
1902:11
1904:11
1906:11
1908:11
1910:11
1912:11
Bid
ask
ARIMA ([1,12],1,0)

Table 1. Augmented Dickey-Fuller-Tests for **Spot Rate bid series**

Period	α_0	α_2	γ		DW	N
1870.01-1876.10	-0.10 (-0.0429)	0.0087 (1.7762)	-0.0049 (-0.1306)		1.979	80
1870.01-1895.12	2.49** (2.6100)	0.0006 (1.4215)	-0.0443 (-2.6536)		1.996	310
1896.01-1914.08	7.33** (3.5526)	0.0001 (0.6472)	-0.1252** (-3.5695)		2.030	224

Level of significance: ** 5 percent, t-values in parenthesis.

Table 2. Augmented Dickey-Fuller-Tests for **Spot Rate Ask series**

Period	α_0	α_2	γ		DW	N
1870.01-1876.10	0.0890 (0.0373)	0.0086 (1.6733)	-0.0082 (-0.2044)		1.983	80
1870.01-1895.12	2.5793** (2.6261)	0.0006 (1.4151)	-0.0458 (-2.6695)		1.996	310
1896.01-1914.08	7.6353** (3.6463)	0.0001 (0.9371)	-0.1303** (-3.6628)		2.030	224

Level of significance: ** 5 percent; t-values in parenthesis.

Table 3. Performance of the Forward Market:
Descriptive Statistics of the Forecast Residuals

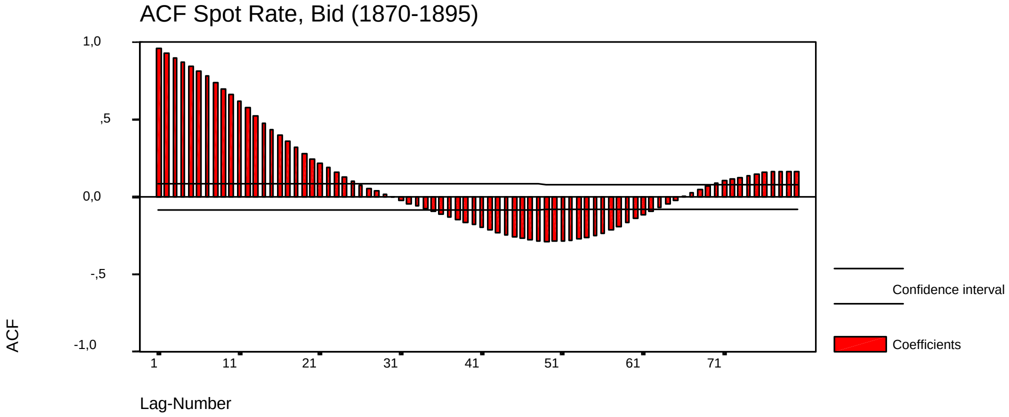
Period	Type of Rate	ARIMA Model	Miniumum Value	Maximum Value	Range	Mean Value	Standard Deviation	Number of Months
1876-1895	Bid	[1,12],1,0	-0.28	0.43	0.71	0.035	0.097	230
1889-1895	Ask	[1,12],1,0	-0.11	0.26	0.37	0.051	0.088	78
1876-1895	Bid	2,1,1	-0.48	0.79	1.27	0.035	0.102	230
1889-1895	Ask	2,1,1	-0.21	0.28	0.49	0.053	0.080	78
1876-1895	Bid	[1,12],1,1	-0.31	0.43	0.74	0.034	0.100	230
1889-1895	Ask	[1,12],1,1	-0.10	0.26	0.36	0.051	0.088	78
1899-1914	Bid	1,0,0	-0.08	0.12	0.20	0.022	0.031	188
1899-1914	Ask	1,0,0	-0.13	0.12	0.25	0.022	0.032	188
1899-1907.10	Bid	1,0,0	-0.03	0.11	0.14	0.028	0.027	106
1899-1907.10	Ask	1,0,0	-0.04	0.12	0.16	0.029	0.027	106
1907.11-1914	Bid	1,0,0	-0.08	0.12	0.20	0.015	0.032	82
1907.11-1914	Ask	1,0,0	-0.13	0.12	0.25	0.013	0.035	82

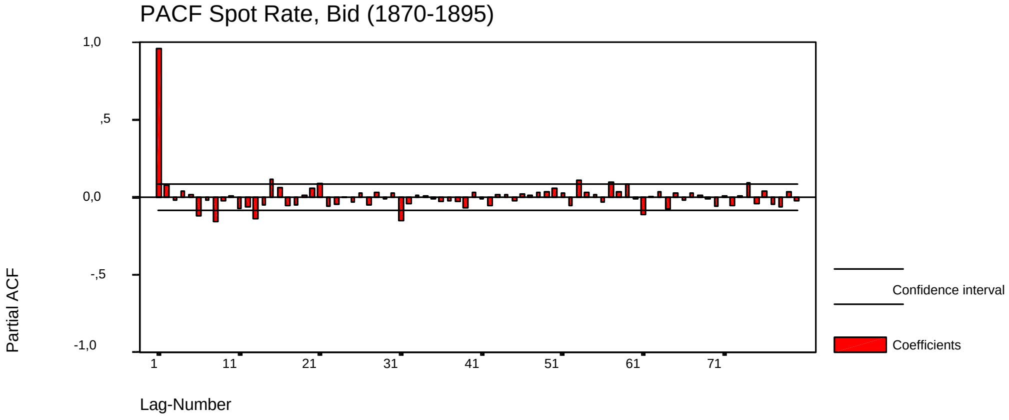
Table 4. Estimated Trend of the Residuals

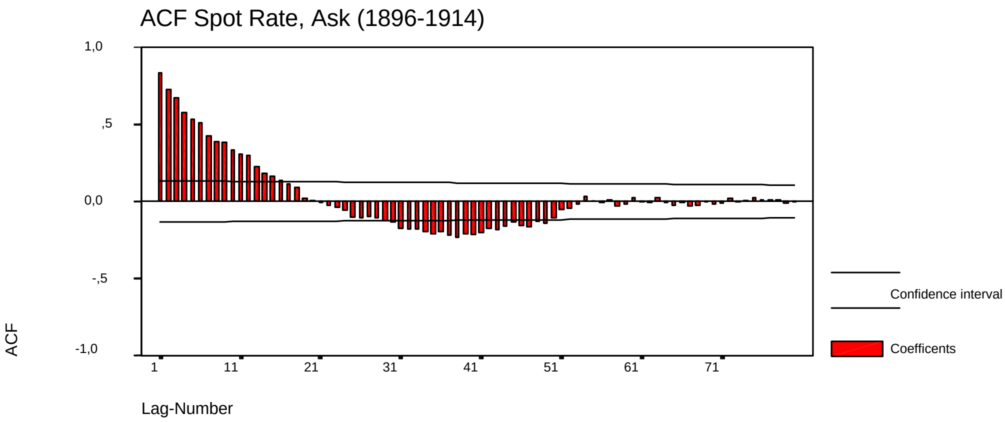
Period	Model	Type of Rate	Constant	Slope	F	
1876-1895	[1,12],1,0	Bid	0.016	0.00017*	3.084*	
			(1.22)	(1.76)		t-statistic
1889-1895	[1,12],1,0	Ask	*0.038**	0.00032	0.52	
			(1.9)	*(0.72)*		t-statistic
1899-1907.10	1,0,0	Bid	0.043***	-0.00026***	9.855***	
			(8.30)	*(-3.14)*		t-statistic
	1,0,0	Ask	0.044***	-0.00029***	12.17***	
			(8.64)	*(-4.28)*		t-statistic
1907.11-1914	1,0,0	Bid	0.012	0.00002	0.015	
			(0.55)	*(0.12)*		t-statistic
	1,0,0	Ask	0.017	-0.00003	0.25	
			(0.70)	*(-0.158)*		t-statistic

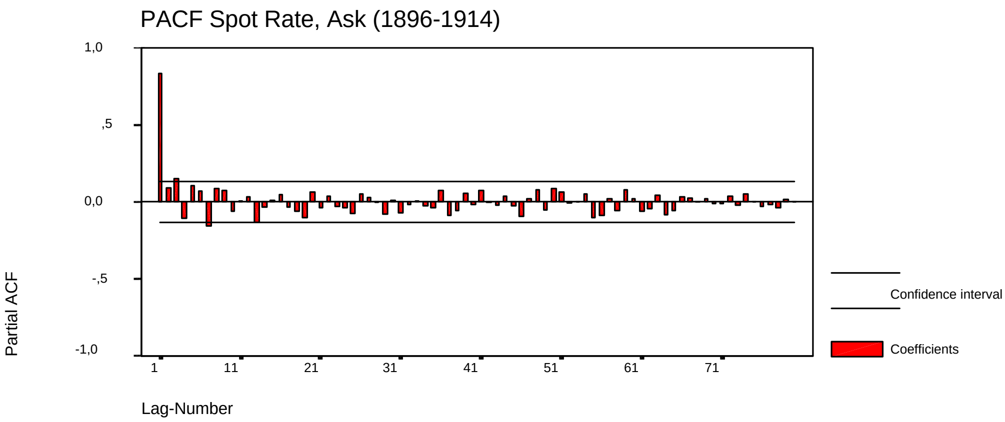
Significance level: *** 1 percent; ** 5 percent; * 10 percent.

Appendix


ACF Spot Rate, Bid (1870-1895)
1,0
,5
0,0
-,5
-1,0
ACF
1
11
21
31
41
51
61
71
Lag-Number
Confidence interval
Coefficients


PACF Spot Rate, Bid (1870-1895)
1,0
,5
0,0
-,5
-1,0
Partial ACF
1
11
21
31
41
51
61
71
Lag-Number
Confidence interval
Coefficients





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[1] We would like to thank the Ulf-Christian Ewert and Jörg Winne for their assistance with the computations.

[2] The critical values are -3.4 (at the 5% level), and -3.1 (at the 10% level).

[3] This points possibly to a learning process at the beginning of the period under consideration. It is not known when the forward market came into being, we only know that the forward rates were published beginning in 1876.11. The learning process leads to the inference that

the market might have been created at around that time so that agents first needed some time to learn to forecast the future spot rate, as after the introduction of the new regime after 1896.

[4] The coefficients of the (2,1,1) model are similarly insignificant.