Financial Market Integration in the Early Modern Period in Spain: Results from a Threshold Error Correction Model

Peter Bernholz

Peter Kugler

WWZ/Universität Basel

Abstract

This paper presents an empirical analysis of a dynamic adjustment of the exchange rate between the Spanish Ducado and the Dutch Groat in two different market places in Spain, namely Seville and Medina del Campo. We use annual data from 1564 to 1603 and a threshold vector error correction model. Our main finding is that deviations of up to 6 percent between the two market places were possible without leading to arbitrage operations. Larger deviations are disappearing within a year by a change of the exchange rate only in Medina del Campo. The asymmetric adjustment pattern is probably brought about by the fact that in Seville the silver market was very liquid given the large inflow from Latin America and that the costs of transportation on sea compared to those on land (as necessary to Medina del Campo) were lower.

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1. Introduction

Financial market integration in Europe and the European off-springs overseas since the late Middle Ages is receiving ever more attention by students of economic history. For data reasons most of the empirical work addressing this issue is done concerning exchange rates. In particular, there are studies considering the deviation of the exchange rate between two currencies from their par value defined by the relative silver or gold content. Prakash and Taylor (1997) and Canjels, Prakash and Taylor (2004) consider the classical gold standard period from 1879 to 1913, whereas Flandreau provides an analysis of the case of bimetallic currencies during the 19th century. Volckart and Wolf (2006) analyze the relationship between the silver currencies of Flanders, Lübeck and Prussia in the years from 1310 to 1490. All these studies use threshold autoregressive models (TAR) in order to account for transaction costs which were sometimes rather large and which prevented the removal by arbitrage of relatively small differences between the exchange rate and its par value. In general, taking into account this non-linearity improves the empirical models strongly.

In this paper we consider a slightly different issue: we analyze the dynamic adjustment of the exchange rate between the Spanish Ducado and the Dutch Groat in two different market places in Spain, namely Seville and Medina del Campo. We use annual data from 1564 to 1603 and we do not apply a TAR model but a threshold vector error correction model. This framework does not only allow to estimate how large deviations have to be in order to trigger arbitrage operations but which of the two market places adjusts to what extent. Our main finding is that deviations of up to 6 percent between the two market places were possible without leading to arbitrage operations. For larger deviations it takes a year for a full adjustment of the exchange rate in Medina del Campo to that of Seville. The paper is organized as follows: section 2 contains a brief account of the data used and its historical background. The econometric model is described in section 3. The results are reported in section 4, and section 5 concludes.

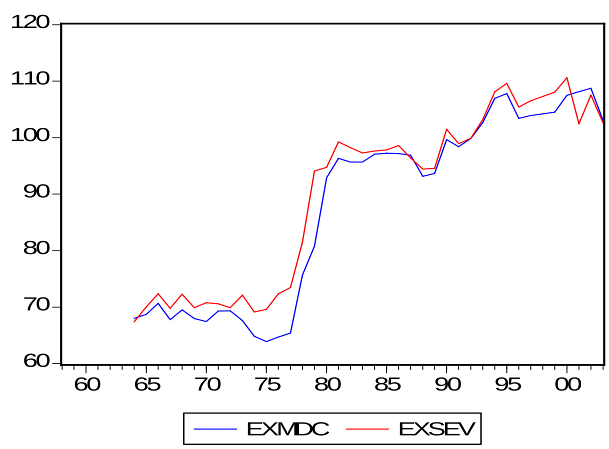
2. Historical Background and Data

We consider the exchange rate of the Dutch four pence silver coin Groat and the Spanish gold coin Ducado, which was issued by the Spanish kings since 1504 as a copy of the well established Venetian Ducat. It had a gold content of approximately 3.5 g. For the years 1565 to 1603 data are available for two exchange rates for theses two currency, one between Antwerp and Seville and the other between Antwerp and Medina del Campo.[1]

Arbitrage should lead a tendency to equalize the two rates, except that transaction costs, which were sizable at that time, should prevent a strict equalization. Given gold or silver currencies there are always transaction costs present in the form of transportation and insurance costs for the transportation of the metal. Since they would not be the same from Antwerp to Medina del Campo and Seville the exchange rates might diverge from each other. Or expressed differently, the distance between the upper and lower gold or silver points in the two places was presumably different. However, if the difference among the two exchange rates quoted in the two places gets "large", that is bigger than this difference, we would expect arbitrage operation equalizing the two rates.

The data plotted in Figure 1 show a rather persistent deviation between the two exchange rates. Moreover, we see a 50 percent depreciation of the Groat in the forty year period considered. In particular we note a very strong depreciation from 1575 to 1580.

Figure 1: Log of Exchange Rates in Seville (EXSEV) and Medina del Campo (EXMDC), Groat/Ducado 1565-1603



[1] The data source is Denzel (1995)

In order to understand these developments a brief account of the historical background is helpful[2]. At the end of the 1560ties the seven northern provinces of the seventeen that were under Spanish rule revolted against the oppressive rule of Philip II. The resistance against the king was on the one hand motivated economically because the booming economy of the Netherlands had to contribute very large amounts of taxes to the Spanish crown and thus to finance partly its attempt to obtain the hegemony and to restore the catholic religion in Europe. On the other hand many people in the Netherlands converted to Protestantism (Calvinism) and were not willing to return to the Catholic fold. In response to the union of Arras, which brought back the southern provinces under Spanish rule, they formed the Union of Utrecht in 1579 and declared independence of Spain in 1581. In 1585 the union of Utrecht lost Brabant and Flanders with Antwerp to Alexander Farnese, the representative of Philip II in the Netherlands. However, Farnese's military force had to intervene in the French religious war and the Northern provinces gained some territory back. Antwerp remained under Spanish control and lost its formerly paramount position as leading market place in Europe to Amsterdam since the river Scheldt was blocked by the Dutch. Moreover, many wealthy and skilled dissenters emigrated from the South to the North and thus weakened the economic base of the Southern Spanish Netherlands. The war was ended by an armistice in 1609 and the independence of the Netherlands was finally internationally accepted in the peace treaty of the thirty years war in 1648. In sum the Dutch clearly "won the war". They became the leading sea power and most prosperous trading nation in the 17th century and were able to replace the Portuguese who were under Spanish rule from 1580 to 1640. The Spanish attempt to obtain European hegemony and the catholic orthodoxy and religious intolerance of the crown ruined the economy and government finances in Spain which no longer played a dominating role in Europe.

Given this historical background is seems surprising to observe the strong depreciation of the Dutch against the Spanish currency. There are two main reasons: first, the Groat

[2] Compare Findlay and O'Rourke (2007, 175-187) for the political and economic developments in the Netherlands in the late 16th and early 17th century.

was strongly debased in several steps from 1575 to 1580 and lost 30 percent of its silver content. This was, of course, done for seigniorage reasons since the war against Spain had to be financed in a very difficult situation.[3] Second, the huge silver imports of Spain from its Latin American possessions with highly productive silver mines led to a marked rise in the price of gold relative to silver and to a quadrupling of the general price level in Europe where silver was the dominant monetary metal. This of course caused a general appreciation of all gold currencies like the Spanish Ducado.

[3] In the later years of the conflict the Dutch provinces managed to finance their high expenditures in the Amsterdam capital market at decreasing interest rates (from 10 % in 1600 to 4% in 1640) with funds provided by Dutch private savings.

3. Econometric Model

Now let us turn to the econometric model used in this study. Let *x* and *y* be the log of exchange rates in Seville and Medina del Campo, respectively, and define the log difference as $z = x - y$. Instead of considering a TAR model for *z* as in Canjels, Prakash and Taylor (2004) we apply the following threshold (vector) error correction model[4]:

$$
\begin{aligned}
\Delta x_t &= a_1 + \lambda_1 z_{t-1} + \varepsilon_{1t}, \ \ if\ abs(z_{t-1}) < \tau \\
\Delta x_t &= a_1 + \lambda_2 z_{t-1} + \varepsilon_{1t}, \ \ if\ abs(z_{t-1}) \geq \tau \\
\Delta y_t &= a_2 + \lambda_3 z_{t-1} + \varepsilon_{2t}, \ \ if\ abs(z_{t-1}) < \tau \\
\Delta y_t &= a_2 + \lambda_4 z_{t-1} + \varepsilon_{2t}, \ \ if\ abs(z_{t-1}) \geq \tau \\
&\lambda_1, \lambda_2 \leq 0; \ \ \lambda_3, \lambda_4 \geq 0
\end{aligned} \tag{1}
$$

If transaction costs are relevant we expect $\lambda_2 = \lambda_3 = 0$ and at least one of the two other error correction coefficients to be different from zero. Defining a dummy variable *d*, which is one when $abs(z_{t-1}) < \tau$ holds and otherwise 0, we can rewrite our model in two equations:

$$
\begin{aligned}
\Delta x_t &= a_1 + \lambda_1 z_{t-1} d_{t-1} + \lambda_2 z_{t-1}(1 - d_{t-1}) + \varepsilon_{1t} \\
\Delta y_t &= a_2 + \lambda_3 z_{t-1} d_{t-1} + \lambda_4 z_{t-1}(1 - d_{t-1}) + \varepsilon_{2t}
\end{aligned} \tag{2}
$$

These two equations can be estimated by OLS when τ is known. In order to determine this parameter we use a grid search over the possible interval (τ > min(z) and τ < max(*z*)) to get the value which minimizes the determinant of the residual covariance matrix of system (2). Of course the parameter τ is only identified if this nonlinearity is present. In order to test this we adopt the approach developed by Tsay (1989) for testing the appropriateness of a TAR specification based on "arranged" AR(1) models. This approach is applied twice, namely to both linear variants of the EC-model given in (1). In this framework the observations are ordered in ascending or descending order of the

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[4] This modeling framework was developed by Balke and Fomby (1997) for non-stationary but cointegrated series with nonlinear adjustment dynamics. It is applied to analyze commodity market integration in the 19th century by Ejrneas and Persson (2000) as well as Jacks (2005).

regressor (lagged z in our case) and then parameter stability is tested using the Chow or CUSUM test. The Chow test is applied with two breakpoints for absolutely large negative values and large positive values. The threshold structure implies that the model does not exhibit parameter stability. Moreover, Tsay suggested a test based on the recursive residuals of this arranged AR model: the recursive residual is regressed on the lagged regressor and the corresponding coefficient is tested to be zero as implied by linearity.

Compared to the univariate TAR-model for z this bivariate model provides more information on the adjustment process (x, y or both) and should give more powerful tests and accurate parameter estimates. Moreover, we would expect the model to be an improvement over the standard linear error correction model as the nonlinearity caused by transaction costs is accounted for.

4. Empirical Results

Before turning to the estimation results for the threshold EC-model we report some preliminary test results. Table 1 provides us with the findings of the Phillips-Perron unit root test and the Kwiatkowski-Phillips-Schmid-Shin stationarity test. The results of several stability tests applied to on the two arranged EC equations as well as the Tsay test applied to these equations are reported in Table 2.

Table 1: PP Unit Root Test and KPSS Stationarity Test Results, Log Exchange Rates in Seville and Medina del Campo, Groat/Ducado 1565-1603

	PP	KPSS
Δlog exchange rate Seville	-5.8219**	0.1409
Δlog exchange rate Medina del Campo	-4.0284**	0.0979
Log ratio exchange rate in Seville and Medina del Campo	-3.1634*	0.3127

Bartlett kernel, bandwith 4; * and ** denotes significance at the 5% and 1% level, respectively

Table 1 points clearly to stationarity of the three series involved in our model: the unit root hypothesis can be decisively rejected at the 5% or even 1% level whereas the stationarity hypothesis cannot be rejected at the 5% level. Although both the log exchange rates are indicated to be non-stationary they appear to be cointegrated leading to a stationary difference of the logs of the two exchange rates[5].

[5] The PP statistics for the level of the nominal exchange rates including a deterministic trend are -1.6303 and -1.8301, respectively. Thus the unit root hypothesis cannot be rejected against the alternative of trend stationarity.

Table 2: Nonlinearity Tests for Arranged Linear EC Equations for Log Exchange Rates in Seville (*x*) and Medina del Campo (*y*), Groat/Ducado 1565-1603

$$\Delta x_t = a_1 + \lambda_1 z_{t-1} + \varepsilon_{1t}$$
$$\Delta y_t = a_2 + \lambda_3 z_{t-1} + \varepsilon_{2t}$$
$$observations\ in\ ascending\ order\ of\ z_{t-1}$$

	Δx_t	Δy_t
Chow-Test F(4,33) break at 5th and 34th observation	1.6975 (0.1741)	3.9926 (0.00947)
CUSUM Test Significant at	-	-
Tsay-test (single equation) F(1,35)	0.3275 (0.5708)	4.0949 (0.0507)

Marginal significance in parentheses beneath test statistics

First the hypothesis of parameter stability is not rejected by the Chow and CUSUM test for first arranged linear error correction equation. Moreover the Tsay test statistic is insignificant, too, and there is no evidence in favor of non-linear adjustment of the exchange rate in Seville. Of course, this pattern of results could be caused by a weakly exogenous exchange rate in Seville and non-linear adjustment of the rate in Medina del Campo. This interpretation is supported by the results for the second equation: the stability hypothesis is clearly rejected by the Chow test for the second arranged error correction equation. This indicates that absolute large regressor values have different effects from small ones. Second, the Tsay test based on a regression of the arranged regression recursive residual on the regressor is marginally significant for the second equations leading to a rejection of the linearity hypothesis. In sum, the test results reported in Table 2 point to a non-linear error correction model for the exchange rate in Medina del Campo and thus support our threshold specification.

The estimation results we obtained for the optimal τ which was 0.064, that is approximately 6 percent, are as follows (standard errors below coefficient estimates in parentheses):

$$\Delta x_t = \underset{(0.00820)}{0.01203} + \underset{(0.2685)}{0.3412} z_{t-1} d_{t-1} + \underset{(0.1763)}{0.3753} z_{t-1}(1 - d_{t-1})$$

$$R^2 = 0.1817, \quad DW = 2.5242$$

$$\Delta y_t = \underset{(0.006359)}{0.001652} - \underset{(0.2082)}{0.04519} z_{t-1} d_{t-1} + \underset{(0.1367)}{0.8032} z_{t-1}(1 - d_{t-1})$$

$$R^2 = 0.5106, \quad DW = 2.2467$$

These estimates tell us that no adjustment of the exchange rates takes place if the deviation is smaller than 6 percent in absolute value. That is both error correction coefficients are low and statistically not different from zero at any reasonable significance level for the first regime. By contrast, for larger deviations we obtain an asymmetric adjustment with all the change taking place solely in the Medina del Campo rate within one year: The error correction coefficient for the Seville rate is wrongly signed and statistically not different from zero at the 10 percent level. However, the error correction coefficient of the Medina del Campo rate is positive (as it should), highly statistically different from zero and statistically not different from one. Thus, deviations of the two exchange rates larger than 6 % are fully corrected by a change in the Medina del Campo rate within a year.

The estimated threshold of 6 percent is rather large compared to the values estimated by Prakash and Taylor (1997) for the classical gold standard period: they report values between 0.15% and 0.46% for sub periods from 1880 to 1913. However, this much bigger difference for the 16th century is not implausible given the dramatic reduction of transportation cost and increased transport security standards in the 19th century.

Moreover, this interpretation is supported because the application of the same methodology to the exchange rate of the Basle pound and the Rhinegulden in the 14th and 15th century led to a similar threshold estimate, namely approximately 7 percent (Kugler, 2008)

It is interesting to compare the TEC results with those of a usual linear EC model. These results are given by

$$\Delta x_t = 0.00885 + 0.1412 z_{t-1}$$
$$(0.007004) \; (0.1740)$$
$$R^2 = 0.01661, \quad DW = 2.1260$$

$$\Delta y_t = 0.004653 + 0.4420 z_{t-1}$$
$$(0.006491) \; (0.1666)$$
$$R^2 = 0.1594, \quad DW = 1.7954$$

This model leads to the conclusion that we have a gradual adjustment of the Medina del Campo exchange rate and no reaction at the Seville market. Thus we get the same conclusion with respect to the market which adjusts to disequilibrium, but the impression of a gradual adjustment process is wrong. In addition, taking into account the threshold characteristic of the adjustment process improves the fit of the second equation tremendously.

Our results necessarily suggest the question why the adaptation of the two exchange rates took only place in Medina del Campo. This is probably brought about by two facts: First, that in Seville the silver market was very liquid given the large inflow of this metal from Latin America; and second that the costs of transportation by sea compared to those on land (as at least partly necessary to Medina del Campo) were much lower and less time-consuming. Therefore, we have to expect a faster adjustment of the relative prices of silver and gold in Seville. As a consequence, this market experienced relative changes of gold and silver prices first which were only later transmitted to Medina del Campo provided that the deviation was large enough to cover the transaction cost.

The analysis carried out so far has two drawbacks: first it gives no information on the sample variation of the threshold estimate. Second, the covariance matrix estimate for the EC coefficients is obtained on the assumption that the threshold value is known. In order to get some information on relevance of these issues we run 1000 bootstrap replications of tour TEC model. The mean, standard deviation, median and the 5% and 95% quantiles obtained by this exercise are reported in Table 3. With respect to the EC coefficients we get qualitatively the same results even if the sample variation is (as expected) indicated to be higher. Only the coefficient of the exchange rate in Medina del Campo is significantly positive (measured by its standard deviation or by the 95% confidence interval) whereas for the other three adjustment coefficients this is not the case. In addition the mean and median bootstrap estimate of the threshold is similar as that reported before.

Table 3: Statistics for 1000 Bootstrap Replications, Threshold Error Correction Model Log Exchange Rates in Seville (*x*) and Medina del Campo (*y*), Groat/Ducado 1565-1603

$$\begin{aligned}
\Delta x_t &= a_1 + \lambda_1 z_{t-1} + \varepsilon_{1t}, \ \ if \ abs(z_{t-1}) < \tau \\
\Delta x_t &= a_1 + \lambda_2 z_{t-1} + \varepsilon_{1t}, \ \ if \ abs(z_{t-1}) \geq \tau \\
\Delta y_t &= a_2 + \lambda_3 z_{t-1} + \varepsilon_{2t}, \ \ if \ abs(z_{t-1}) < \tau \\
\Delta y_t &= a_2 + \lambda_4 z_{t-1} + \varepsilon_{2t}, \ \ if \ abs(z_{t-1}) \geq \tau \\
&\lambda_1, \lambda_2 \leq 0; \ \ \lambda_3, \lambda_4 \geq 0
\end{aligned}$$

	λ_1	λ_2	λ_3	λ_4	τ
Mean	-0.3582	0.2839	-0.0143	0.7829	0.0575
Std	1.0976	0.2935	0.8089	0.2598	0.0152
Median	0.4777	0.3261	-0.0685	0.8040	0.0617
[Q05, Q95]	[-1.2374, 0.4399]	[-0.2354, 0.6797]	[-0.6214, 0.7326]	[0.2799, 1.1355]	[0.01983, 0.07422]

5. Conclusion

This paper carries out an empirical analyis of the dynamic adjustment of the exchange rate between the Spanish Ducado and the Dutch Groat in two different market places in Spain, namely Seville and Medina del Campo. In doing so annual data from 1564 to 1603 and a threshold vector error correction model are used. This framework does not only allow to estimate how large the deviations of exchange rates on the two places have to be in order to trigger arbitrage operations but which of the two market places adjusts to what extent. Our main finding is that deviations of up to 6 percent between the two market places were possible without leading to arbitrage operations. For larger deviations it takes a year for a full adjustment of the exchange rate in Medina del Campo to that of Seville. The fact that the adjustment took only place in Medina del Campo is probably brought about because first the silver market in Seville was very liquid given the large inflow from Latin America and secondly because of the lower cost of transportation on sea compared to those on land (as at least partly necessary to Medina del Campo) and the shorter time needed for it. Therefore, we can expect a faster adjustment of the relative prices of silver and gold in Seville only followed later by that in Medina del Campo.

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