OESTERREICHISCHE NATIONALBANK
Stability and Security.

WORKING PAPER III

EUROPEAN FINANCIAL MARKET INTEGRATION IN THE GRÜNDER-BOOM AND GRÜNDERKRACH: EVIDENCE FROM EUROPEAN CROSS-LISTINGS

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WITH COMMENTS BY LUIS CATÃO AND BY ISABEL SCHNABEL

EUROSYSTEM

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Imprint: Responsibility according to Austrian media law: Guenther Thonabauer, Secretariat of the Board of Executive Directors, Oesterreichische Nationalbank
Published and printed by Oesterreichische Nationalbank, Wien.
The Working Papers are also available on our website (http://www.oenb.at) and they are indexed in RePEc (http://repec.org/).

Editorial

On the 30th of September and the 1st of October 2005 the first Economic History Panel: Past, Present, and Policy, co-sponsored and hosted by Oesterreichische Nationalbank was held in Vienna. The Economic History Panel is a project that is jointly sponsored by the Institut d'Etudes Politiques de Paris and the Center for Economic Policy Research in London. Its motivation is the considerable advances that Economic History has achieved in the past, and the growing recognition of its contribution to shape policy responses and to inspire new theoretical research.

The first meeting on the topic "International Financial Integration: The Role of Intermediaries" was jointly organized by Marc Flandreau (Sciences Po, Paris and CEPR) and Eduard Hochreiter (Oesterreichische Nationalbank). Academic economists and central bank researchers presented and discussed current research and tried to review and assess the historical role of financial intermediaries in shaping the patterns of financial globalization. A number of papers and the contributions by the discussants presented at this panel are being made available to a broader audience in the Working Paper series of the Oesterreichische Nationalbank. A selection of these papers will also be published in the *European Review of Economic History*. This volume contains the fourth of these papers. The first ones were issued as OeNB Working Paper No. 107-109. In addition to the paper by Markus Baltzer the Working Paper also contains the contributions of the designated discussants Luis Catão and Isabel Schnabel.

January 13, 2006

European Financial Market Integration in the Gruenderboom and Gruenderkrach: Evidence from European Cross-Listings

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JEL classification: F3; G15; N23

Keywords: cross-listing; financial market integration; information transfer; price building process

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1. Introduction

Comparing stock price data of the same stocks listed on different European stock exchanges serves as a perfect instrument for the investigation of (historical) financial market integration starting from the *law of one price* (*LOP*).

Interestingly, cross-listing of stock companies is still in the beginning to attract the attention of economists and economic historians. Financial economists have been developing an increasing attention for cross-listings for the last decade only.[1]

Covering the period of the early 1870s contributes to the debate on "autarky" of the pre-1880 period. Clemens and Williamson (2004) are in line with Obstfeld and Taylor (2004) when characterizing the pre-World War I period "as transition from autarky (around 1870) to integrated world capital markets (around 1913)." The results by Neal (1985, 1987, 1990) for the 18th century show that financial integration was at least on the leading European markets a much earlier phenomenon. Neal was the pioneer in the field of financial history who used cross-listed data and combined the results with the topic of financial integration and the *LOP*. Likewise, the nexus of the globalization with the introduction of the gold standard was strongly rejected by Flandreau (2004) who performed all kind of *LOP*-tests (mostly for bullion) for the period before 1873 and found a striking degree of international financial integration despite Europe not being on a gold standard.

As mentioned above, Larry Neal was the first in the field of financial economic history who looked on cross-listed stocks. Neal (1987, 1990) tested for integration of the London stock exchange and the Amsterdam Beurs with respect to English stocks in the 18th century, and then compared the results with the degree of integration of the 19th century stock markets with respect to US railroad stocks during panics, when disruptions are likely to be greatest. Neal (1985) explicitly tested for the financial *LOP*. Recently, Sylla, Wilson, and Wright

[1] Rosenthal and Young (1990) were among the first to look at price differences of cross-listed stocks. Cf. for instance Oxelheim (2001) for an extensive bibliography of publications of the last decade; latest studies by Grammig, Melvin, and Schlag (2005) and Eun and Sabherwal (2003) on high frequency (tick) data.

(2004) tested cross-listed stocks for the *LOP* and found that financial integration between London and New York began at least by the second decade of the nineteenth century, despite the slowness of trans-Atlantic communications. A looser test of market integration involving not exactly the same assets in different markets but for example government-securities yields showed a convergence of financial integration from 1870 to 1913.[2]

While Neal found a close and stable financial integration already for the 18th century, Michie (1985) argued that Edinburgh and London stock exchanges were not well-integrated before a telegraph connection was made between the two cities in 1840. Neal contradicted this view and argued that Michie's samples of stocks were most unfavourable cases for showing integration.[3]

This paper wants to improve Neal's pioneering work in two ways. First, for the second half of the 19th century a daily frequency of data is the only appropriate one for an investigation of European market integration. While during the 18th century a frequency of two weeks fully reflects the contemporary possibilities of information transfer between Amsterdam and London, the establishment of the telegraph and of newspapers published twice a day demands at least a daily frequency if the information transfer was modeled to some extent realistically.

Secondly, the applied methodology improved substantially during the last 15 years. When Neal published his studies cointegration analysis and the concept of a vector error correction model (VECM) was still in its infancy. However, it was especially this concept that opened new possibilities for the analysis of cross-listed stocks. One of the new studies dealing with it was due to Hasbrouck (1995) to which most of the current studies still refer.

This new approach offers an insight into the price building process of the stock price as well. We want to know in which market of a cross-listed stock was most of the information

[2] Neal (1992); Ferguson (2001), chap. 9.
[3] Neal (1993), pp. 229f.; Neal (1992), p. 93. Cf. Toniolo, Cone, and Vecchi (2003) who show for the Italian case instead of telegraphs and railways a delay of financial market integration due to the institutional setting.

set? There is a recent study due to by Sylla, Wilson, and Wright (2004) compared the price building process between London and New York in the first half of the 19th century. The authors found by studying the intensity of response of lagged values that the responses of London price changes to New York price changes were considerably larger than the responses of New York price changes to London's. Thus, they concluded that most of the information shares were included in New York. As they were looking on U.S. government debt securities and equity securities issued by American corporations it was the home market which they found to be the dominant one for the price building process. This result is in line with most of the modern studies going back to the definition by Garbade and Silber (1979) of dominant and satellite markets.

In our case there might be further hypotheses than the discussion of the home and the satellite markets. As we are looking at a period of extreme speculation the investigation of cross-listed stocks is a question of transmission of financial crises as well.[4] In our sample we focus on daily stock price data of two Austrian railroad companies and one Austrian bank from 1869 to 1974. The shares of these stock companies were cross-listed on different European stock exchanges and belonged to the most internationally traded ones with the highest liquidity. On most markets they were listed as spot and forward ("ultimo") prices, on some (Paris, London) exclusively as forward prices what underlines their importance for the speculative trading as this mainly took place in the forward trading. That is why we use for our analysis these forward prices. Therefore, the analysis might help to understand how speculation tended to globalize. Looking at the price building process, on the one hand we would expect Vienna as the dominant market because Vienna was the home market. On the other hand we know that the Gruenderboom and the Gruenderkrach had its origins in Berlin before spreading to Vienna and other places. Thus, this study will give us some hints how intense these shares acted as vehicle for the transmission of financial crises.

[4] Kindleberger (1990, p. 109) explicitly mentions arbitrage in commodities or securities as one connection between national economies that might be responsible for the transmission of boom, distress, and panic.

The paper proceeds as follows. Section 2 describes the historical background and institutional details. section 3 presents the data, section 4 introduces the econometrics, section 5 shows the empirical results and section 6 concludes.

2. Historical background and development of cross-listing

Franco-Prussian war and ´Gruenderzeit`

The period covered by this study from 1869 to 1874 was characterized by quite a few turbulent moments on the European stock exchanges. Figure 1 shows the development of the Berlin stock exchange by a stock index due to Ronge (2002) and by the daily forward prices of the three stocks used for this study. The index is of weekly frequency and includes the 30 biggest German stock companies. The exogenous shock caused by the outbreak of the Franco-Prussian war can be observed in the index as well as in the single stocks. After having noticed that the battles mostly took place on French territory the investors quickly recovered from their fright and stocks in Berlin quickly bounced back to the level they had before. The effects on the Paris Bourse were much more severe. The Paris siege, and the Commune, along with the moratorium on French bills introduced a lot of disruptions on the Paris stock exchange. The Berlin – Paris economic relation broke totally down when the Paris Bourse had to close for several months. For this time we miss any listings of the Paris prices.

With the peace agreement of Versailles and the foundation of the German Reich in January 1871 we can observe a continuous and stable increase of the stock prices in Germany (Gruenderboom) having its peak by the end of 1872. France did not experience a comparable boom because parts of the reparation payments to Germany which it had to pay were financed by tax increases. In Britain, investors were very skeptical for new and euphoric investments

on the stock exchange after experiencing the railroad boom in 1847 and the break down of the bank Overend, Gurney & Co. that caused the so called panic of 1866.[5]

The situation in Germany was different. The new founded German Reich received an immense amount of reparation payments of 5.5 billion Francs or 1.5 billion Thaler.[6] The government mainly used this money to pay back the government bonds so it could start free from any debts. As a consequence the investors had to look for alternative investments and orientated to the more risky stocks, including the capital market in Vienna what heated up the stock market in the Habsburg monarchy as well.[7] It followed a euphoric booming period which one can be observed in the stock index quite well. In the beginning of 1873 the turning point on the stock exchange was reached followed by a several years lasting downturn. The so-called Gruenderkrach or Gruenderkrise was stated by McCartney as the first significant international financial crisis.[8] To be precise, there were several panics of 1873 in different international markets. But despite of the international entanglement of the capital markets there still were some country-specific differences concerning the experience of the downturn's intensity of the stock markets. While the Gruenderkrach hit the German and the Austrian market with a sudden and substantial crash, France and the United Kingdom were touched in a comparatively moderate way.

Following a model for financial crises due to Kindleberger (1996), in the beginning of the crash there should be a "displacement" or autonomous event or shock that changes the investment opportunities: "Some old lines of investment may be closed down, but especially some new are opened up. Prices in the new lines rise. Gains are made. More investment follows. The process can cumulate, accelerate, pick up speed, become euphoric, and verge on irrationality."[9] Kindleberger (1990) mentions ten main and three minor aspects that might

[5] Cf. Kindleberger (1990), pp. 312ff.
[6] Soetbeer (1874).
[7] Cf. Gömmel (1992).
[8] McCartney (1935), p. 85. Cf. Kindleberger (1996), p. 121.
[9] Kindleberger (1990), p. 311.

have been parts of the displacements responsible for the downturn in the international stock markets. Most of these displacements can be associated with Germany which underlines the "driving" function of the German stock market during the boom as well as during the crash period.[10]

The close connection of the financial centers at that time can be seen in the statement of the baron Meyer Carl von Rothschild who complained to his banker Bleichröder in 1875 facing international stock market depressions that the whole world were one city.[11]

Microstructures

At the end of the nineteenth century the investor composed his portfolio without being restricted by any national constraints. The capital was made readily available to the investor by international organized stock exchanges. A pre-condition for a secondary cross-listing was a foreign exchange market on the respective stock exchange to ensure arbitrage what can be found in Paris, London, Frankfurt, and Berlin.[12] To choose exactly these places for a secondary trading goes in line with the argument of Flandreau and Jobst (2004) that these markets formed a "clique" because of cross quotations.

While initially limited to government securities, a growing demand of capital especially in the railroad industry led to an increasing number of cross-listings of foreign railroads on the various European exchanges in the middle of the 19th century.[13] Thus, the main impetus for listing stocks on foreign markets was the pressure to acquire fresh capital from a wider range of investors.

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[10] Kindleberger (1990, p. 312) mentions the Prussian-Austrian war of 1866, the *Wunderharvest* in wheat in Austria in 1867, the Franco-Prussian war of 1870-1, the astounding success of paying back the 5-billion-franc indemnity payment paid by France to Prussia, the mistake of German monetary authorities by organizing the currency change from silver to gold, relaxation of German banking laws. Cf. Gömmel (1992), 153ff., who shows that the incentive for the Gruenderkrise came from Germany.

[11] Stern (1977), p. 189.

[12] Cf. Flandreau and Sussman (2005) and Bordo, Meissner, and Redish (2005).

[13] Davis, Neal, and White (2003), pp. 125f.

Therefore, it is not surprising that especially the big railroad corporations were candidates for possible cross-country listings as they had an immense demand of fresh capital. But of course, banks also were strongly interested in operating and listing abroad giving them easy access for new investments in these exchanges.[14]

With the concentration of the vast majority of ownership of shares in Western Europe and the United States by the eve of the nineteenth century, it was consequently in this part of the world where the largest, most active and best organized markets were established.[15] From the five places under inspection, the exchanges in London and Paris were clearly the major international exchanges that attracted the most business worldwide by offering an enormous variety of issues. Whereas Paris developed as the central exchange for Europe and the Mediterranean area, London emerged as the major market for the rest of the world. In this role, London did not only offer securities of its extensive Empire but also became the most important market for the continental investments in the U.S.[16]

Until the foundation of the German Reich, Frankfurt was the most important German stock exchange. As it mainly concentrated on government bonds its national importance declined when the stocks became more and more important which were mainly listed and traded in Berlin.[17] In 1866, the stock exchange in Vienna had already reached a more important role than Frankfurt, and the difference became greater in the following years.[18]

Speculation

By the end of the 1860s the three Austrian stocks we use in this study were traded simultaneously on spot and forward markets in Vienna, Berlin, and Frankfurt.[19] The trade in

[14] For instance, London was a very interesting place for German and Austrian banks at the eve of the nineteenth century because of its huge amount of issues of securities by the United States, cf. Michie (1988), pp. 56f.
[15] Cf. Michie (1988), p. 49.
[16] Michie (1988), p. 57.
[17] Gömmel (1992), pp. 142ff.
[18] Gömmel (1992), p. 148.
[19] Cf. Saling's Börsenpapiere (1874), vol. 1, p. 12.

the forward market was much more active than in the spot market. The outstanding importance of the three forward traded stocks for the Berlin stock exchange becomes obvious by a statement in the contemporary stock exchange guide where these three speculative stocks were seen as a representative indicator for the whole Berlin stock market.[20] In Paris and London the different importance of forward and spot markets for the speculation was the same. That is why the Austrian stocks were listed in the forward markets only.[21]

From the end of the 1860s on, the forward trading became more and more important.[22] In 1867, the spot market in Berlin started to switch from continuous quotations to the announcement of one closing price.[23] This was a decisive impulse for the speculative orientated investors and arbitrageurs to turn from the trading in the spot market to speculative operations in the forward market where a continuous trading was still possible.

On the formal forward market for securities there were agents buying and selling bonds for a special date, usually the end of the month. The cashing day was called the date of "liquidation". Beside the possibility of continuous trading the forward market was the market of choice for speculators because they could operate with a much smaller capital: the investor would buy forward by leaving only a margin requirement (small deposit). At the date of "liquidation" he could renew his position, by only paying or cashing the price difference. That is why these operations also were called "difference transactions" and why they were described by contemporaneous sources as extremely "dangerous".[24] Many small speculators were attracted by the possibility of the "repo"-market to prolong the contracts by paying the difference of the current date of liquidation and the next one if the price of the date of

[20] Saling's Börsen-Papiere (1874). Vol. 1, p. 12.
[21] Saling's Börsen-Papiere (1874). Vol. 1, p. 12, and p. 94.
[22] Löb (1896), p. 263. A considerable volume of trades in forward traded stocks seems not to be reached before the end of the 1850s when in Berlin the "liquidation" prices were introduced (cf. ibd.).
[23] Cf. Löb (1896), p. 261.
[24] Saling's Börsen-Papiere (1874). Vol. 1, p. 141.

liquidation did not fulfill their expectations. To manage this trading and to fix the liquidation prices all important stock exchanges had official liquidation offices.[25]

Arbitrage trading

About which factors had an arbitrageur to care to do trading between two international markets? As already mentioned above, the internationally cross-listed "speculative" Austrian stocks were of great importance for the international arbitrage trading.[26] One of them (Südbahn) even served as an example to explain the transformation of the different international transaction prices to make them comparable.[27]

The main difference between the stock exchanges was a payment of fixed interest rates in some places that is not common anymore.[28] These nominal interest rates had to be added *pro rata temporis* from start of the fiscal year up to the detachment of the interest voucher in Berlin, Frankfurt, and Vienna. In contrast, stock prices in London and Paris already included accrued interest rates what did not necessitate additional calculations when stocks were bought or sold. German nineteenth century sources clearly identified this praxis of additional interest rate payments as old-fashioned and counterproductive for an internationalization of the markets.[29] Nevertheless the investors had to deal with them during the investigation period. In our data we included this additional payments for the respective stocks to make them comparable.[30]

Dealing with forward prices means that we have backwardation and contango rates that became known shortly before the liquidation date and that were not included into the quoted prices. Unfortunately, there exists no listing, so we have to neglect them in our study

[25] Struck (1890), pp. 685f.
[26] Cf. Saling's Börsen-Papiere (1874). Vol. 1, p. 158; and Ehrenberg (1890), p. 788.
[27] Saling's Börsenpapiere (1874), vol. 1p. 47.
[28] At the beginning of the 1870s the accrued interest rates ranged between four and five percentage points depending on the stock exchange.
[29] Saling's Börsen-Papiere (1874). Vol. 1, pp. 48 ff. In the same way the authors of Saling's Börsenpapiere argued for a listing with two decimal places instead of complicated fractions with a denominator of up to sixteen as it was common use on German stocks in the beginning of the 1870s.
[30] For a detailed discussion of the interest rate payments cf. Ronge (2002), pp. 73ff.

even if they might have differed between the international exchanges due to different liquidation dates and different volumes of selling and buying orders.[31] However, as we concentrate on the long-run equilibrium and the price-building process and not on direct arbitrage trading these rates are of minor importance for our study. Transaction costs were very comparable at the different exchanges. The commission normally ranged on each market between 1/3% and 1/8% of the total amount of the respective trade.[32]

Another question of importance is the currency exchange. Up to World War I the bill of exchange system was the relevant and main finance instrument to price foreign currencies. For the main bills of exchange the different national stock exchanges delivered continuous and official price fixings.[33] We could imagine an investor buying forward in one market and selling forward in the other one. Ideally, he should safeguard this deal by a forward exchange contract that was exactly fixed on the liquidation day. The urgent needs of such an instrument for international trading is mentioned in literature as one reason for the development of a forward exchange market in countries whose currency floated (as in Vienna) in the late 19th century.[34] Of course, situation was different for countries for which there was a common specie standard and convertibility like Berlin, Frankfurt, Paris, and London. For them, the forward exchange rate was more or less known (it had to be close to the parity). The official forward quotations between Berlin and Vienna started after the end of our investigation period[35] – however, some studies suggest that this market existed already in earlier time what might be one reason for a better integration between these markets.[36]

Even if this is true we miss official quotations and thus have to create a workaround. For the period under inspection, the most active trading was mainly in long-sighted bills, that

[31] Cf. this hint in Saling's Börsen-Papiere (1874). Vol. 1, pp. 74. Mentioning this problem explicitly for the three Austrian stocks shows that arbitrage trading between the international exchanges was very common.
[32] Saling's Börsen-Papiere (1874). Vol. 1, p. 63 (Berlin), p. 74 (Frankfurt), pp. 85ff. (London), p. 95 (Paris), and pp. 108ff. (Vienna).
[33] Cf. Flandreau and Jobst (2004) to the markets for bills of exchange and Schneider and Schwarzer (1986) to the origins of bills of exchange.
[34] Cf. Flandreau and Komlos (2001).
[35] Cf. Flandreau and Komlos (2001), Footnote 69.
[36] Cf. Yeager (1969).

were redeemable only two or three months after they were made out. We transform them into short sighted bills by using the technique explained in the appendix. Consequently, we assume that this short sighted price was the relevant one for the investor when comparing different forward prices on different markets. We have to note that here the arbitrage is an approximation because we cannot technically swap a stock in Vienna against a stock in Berlin on the end of month "liquidation" day. But on the other hand we are encouraged by contemporaneous work that recommend the same currency quotations for this kind of arbitrage trading.[37]

Transfer of information and trading hours

How could information asymmetries between the European markets be reduced at the beginning of the 1870s and - maybe more important - how much time did the transport of information throughout Europe take?

The most widely spread and most frequently used information medium was the daily press. In Berlin, for example, several newspapers were published twice a day. The reason for two daily issues was mainly to ensure that the subscribers were provided with the latest development of the stock markets. In its morning issue, the Berliner Börsen-Zeitung published the previous closes of the other European stock exchanges including an accompanying commentary. In the evening issue these newspapers published a detailed review of the Berlin market of the day with an extensive list of stocks listed on the Berlin stock exchange and information concerning currencies and bills of exchange. In addition, the development of Vienna and sometimes further German or other European stock exchanges of the same morning were shortly summarised entitled as "telegraphic communications". This header could be taken literally as these notices were normally unchanged inclusions of cable messages. The use of the telegraph technology was a crucial step on the way to link

[37] Saling's Börsen-Papiere (1874). Vol. 1, p. 48.

international markets more tightly: „With the developments of international telegraphic communications from the mid-nineteenth century onwards, the barriers that had preserved the independence and isolation of national exchanges were progressively removed, leading slowly to the creation of a world market for securities.“[38] The reaction of this increasing internationalization of the stock trading can be seen by the increasing amount of international stock exchange reports in the newspapers.

The telegraphic communication contributed in a decisive way to a reduction in long-lasting inter-market price differentials and thus facilitated the creation of unified markets within as well as across countries. At the beginning of the 1870s the telegraphic communication in Western Europe was well established and was open to everybody.[39] The most important and for our study relevant connections between the main European financial centers were already built up by the mid of the 19th century.[40] Therefore, the information gap between the different stock places shrank to clearly less than one day.

As we will use daily closing stock prices we have to take into account the exact closing hours of the different stock exchanges to get a chronological order for the VECM. The uniform time zone in central Europe has not been introduced before 1893 so we will convert the closing times into the Berlin time to make them comparable. As Table 1 shows the earliest daily close of the market was in Vienna and the last one in London. The different exchanges closed between 1:12 p.m. and 3:07 p.m. Berlin time.

3. Data and sources and descriptive statistics

We use continuous daily stock price data for two Austrian railroad companies and one Austrian bank that were listed on different European forward markets focusing on the five years period from 1869–74. Figure 2 shows a scheme of the data with the different listings

[38] Michie (1988), p. 56.
[39] Cf. Schöning (1985), p. 40.
[40] Cf. Schöttle (1883), pp. 6ff. and Reindl (1993), p. 90.

used in this study. We include the stock exchanges of Vienna, Berlin, Frankfurt, Paris, and London.

We collected this data from various newspapers as the *Nationalzeitung*, *Berliner Börsenzeitung*, the *London Times*, and from the weekly journal *Der Aktionär*. As mentioned above we had to face a period from Sep 1870 to June 1871 where we only got data for the Paris stock exchange very rarely or not at all because of being closed. Of course, apart from the *London Times* the sources were published in Germany which might put the quality of the data into question. When we did some cross-checking we could not find any irregularities. As we are dealing with some of the biggest stocks of the international arbitrage trading the error ratio should not be high even if the prices before publication had to be transmitted from Paris or London to Berlin (*Berliner Börsenzeitung, Nationalzeitung*) or Frankfurt (*Der Aktionär*).

The "Kaiserlich-königliche Österreichische Kreditanstalt für Handel und Gewerbe" (in the following: Kreditanstalt) was established during the first foundation wave of credit banks in 1855 and was based on the model of the French Crédit Mobilier. Shortly after its initial public offering on the Viennese stock exchange it was already listed on the German exchanges. We will use daily data of the exchanges in the home market Vienna, in Berlin, and in Frankfurt.

The other two stock companies of the sample are two of the biggest and most important railroad companies that benefited from the foundation of the Kreditanstalt by using it as capital provider: the „Österreichische Staatseisenbahn-Gesellschaft" (in the following: Staatsbahn) and the „Vereinigte Südösterreichische, Lombardische und Central-Italienische Eisenbahngesellschaft" (in the following: Südbahn). At the beginning of the 1870s, both companies comprised different formerly independently working railway lines whose respective start of construction traces back to the 1850s. During this decade, both of them had their initial public offerings on the Viennese stock exchange and were listed without much delay on the foreign stock exchanges. For the Staatsbahn we use daily price data from the

home market Vienna, Berlin, Frankfurt, and Paris and for the Südbahn daily price data from the home market Vienna, Berlin, Frankfurt, Paris, and London.

Table 2 presents the usual descriptive analysis presenting an overview of our sample with observation numbers and covered periods. Figure 3 shows the daily deviations between Berlin and Vienna in absolute numbers.

To address the topic of stationarity, two unit root tests are used: the Augmented Dickey-Fuller (ADF) test, and the Phillips-Perron (PP) test. For the ADF test, the lag length value is set to the order selected by the Schwarz information criterion. We apply the two tests to data in level and then in first differences to test for the degree at which prices are stationary. Table 4 presents the results of the two tests. The stock prices, in log levels, are integrated by order 1. Both tests clearly confirm on the 1% significance level that the first differences are stationary.

4. Econometric model

In the econometrics we first look for a long-term equilibrium. In a next step we analyse if we can find *LOP* between the different market pairs and between all markets on which one stock is listed. Finally we will analyze the price building process to assess on which market most information was included.

Long-term equilibrium

The basic idea of the cointegration analysis is due to Engle and Granger (1987) and deals with time series that follow a random walk. The series are cointegrated if there exists a linear combination of the series that is stationary. Finding such a stationary linear combination means that the series are tied together in the long run and that consequently an equilibrium exists. This allows the investigation of a number of important long-term relationships in economics and in economic history where this technique is used for different fields.

To test for a long-term equilibrium we start with a bivariate case applying the Johansen (1988, 1995) approach. Having two markets 1 and 2, the starting point for our analysis with only one lag can be written in the following way:

$$\begin{pmatrix} p_1 \\ p_2 \end{pmatrix}_t = \begin{pmatrix} \pi_1 \\ \pi_2 \end{pmatrix} \begin{pmatrix} p_1 \\ p_2 \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix}_t \quad \varepsilon_{it} \sim i.i.d.(0,\Sigma) \tag{1}$$
$$\Leftrightarrow \mathbf{P}_t = \phi_{t-1}\mathbf{P}_{t-1} + \boldsymbol{\varepsilon}_t \qquad \boldsymbol{\varepsilon}_t \sim i.i.d.(0,\Sigma)$$

The price vector $\mathbf{P}_t$ includes the non-stationary log share price series of both markets which are adjusted for currency differences. To make this bivariate vector $\mathbf{P}_t$ stationary we take on both sides of (1) the first difference of the price vector:

$$\Delta\mathbf{P}_t = \phi_{t-1}\mathbf{P}_{t-1} - \mathbf{P}_{t-1} + \boldsymbol{\varepsilon}_t = \Pi\mathbf{P}_{t-1} + \boldsymbol{\varepsilon}_t, \qquad \Pi \overset{def.}{=} \phi_{t-1} - I \tag{2}$$

Now, the difference on the left-hand side of (2) is stationary (we get the returns) whereas we know that the lagged price vector $\mathbf{P}_{t-1}$ on the right-hand side follows a random walk. Thus, it is integrated by order 1 and not stationary. Consequently there are two possible solutions for the matrix Π to satisfy the equation. Either Π is the zero matrix which means that there is no cointegration relationship between the series, or Π is of reduced rank (rank 1 in our bivariate case). Provided a cointegration relationship exists, we can decompose the matrix Π in the following way: $\Pi = \alpha\beta^t$. By normalising $\beta = (1/\beta_2)^t$ we get a unique form of the equation system (2) that is known as the representation of a VECM for a bivariate case:

$$\Delta p_{1,t} = \alpha_1(p_{1,t-1} + \beta_2 p_{2,t-1}) + \varepsilon_{1,t} \tag{3}$$
$$\Delta p_{2,t} = \alpha_2(p_{1,t-1} + \beta_2 p_{2,t-1}) + \varepsilon_{2,t}$$

If we find such a relationship we know that there exists a linear combination of both series indicating a long-term equilibrium. To fulfill the theoretical pre-considerations we have to put further restrictions on the cointegration vector β. Our hypothesis states that there is one implicit efficient price for both markets. Therefore we expect a cointegrating vector between the two markets of $\beta = (1/-1)'$ which simplifies (3) in the following way:

$$\begin{aligned} \Delta p_{1,t} &= \alpha_1 (p_{1,t-1} - p_{2,t-1}) + \varepsilon_{1,t} \\ \Delta p_{2,t} &= \alpha_2 (p_{1,t-1} - p_{2,t-1}) + \varepsilon_{2,t} \end{aligned} \qquad (4)$$

Equation (4) includes the long-term equilibrium that the transaction price in market 1 equals the transaction price in market 2. To be more precise we get the long-term relationship that $p_{1,t} = p_{2,t} = p_{2original,t} + e_{1/2,t}$ with $e_{1/2,t}$ as the respective log price of the exchange rate between market 1 and market 2 at time t.

Price building process

In the next step we want to analyze the price building process. Therefore, we introduce a simple microstructure model which is again based on cross-listed shares in two markets, for example Berlin and Vienna. In this part we will use the transaction prices in the original currency. By using currency transformed prices it might be possible that the effect of the price building is misleading due to currency effects (cf. e.g. Grammig, Melvin, and Schlag 2005). We assume that the implicit price of the stock company is exclusively set in the home market Vienna which corresponds to market 1 in the model. This means that new information that makes the implicit price moving appears exclusively on the stock exchange in Vienna. Thus, we can describe the stock price in Vienna as a random walk that introduces new price information as $\varepsilon_{1,t}$:

$$p_{1,t} = p_{1,t-1} + \varepsilon_{1,t} \tag{5}$$

The transaction price in Berlin, $p_{2,t}$, does not deliver any new information for the implicit stock price. It adjusts to the last observed home-market price and also includes a random term, $\varepsilon_{2,t}$, to reflect any Berlin-based randomness that may be due to liquidity orders, or any other idiosyncratic source.

$$p_{2,t} = p_{1,t-1} + e_{1/2,t-1} + \varepsilon_{2,t} \tag{6}$$

The innovations $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are assumed to be both serially and contemporaneously uncorrelated with zero mean.

By simple transformations of both equations we get the following:

From (5) we get: $p_{1,t} - p_{1,t-1} = \varepsilon_{1,t}$ (7)

From (6) we get: $p_{2,t} - p_{2,t-1} = (p_{1,t-1} + e_{1/2,t-1} - p_{2,t-1}) + \varepsilon_{2,t}$

$$\Leftrightarrow$$

$$\Delta p_{1,t} = 0 \cdot (p_{1,t-1} + e_{1/2,t-1} - p_{2,t-1}) + \varepsilon_{1,t}$$

$$\Delta p_{2,t} = 1 \cdot (p_{1,t-1} + e_{1/2,t-1} - p_{2,t-1}) + \varepsilon_{2,t}$$

The equations in (7) correspond to a specific form of equation (4) where we put restrictions on the cointegration vector β to fulfill the *LOP*. As we looked now at non- currency-transformed prices we deal with the cointegration vector of $\beta = (1/1/-1)$.

At that point we have not given yet any information concerning the vector α. It gives the intensity of the cointegrating vector β entering the equation of the VECM. Therefore, the coefficients of α are also referred to as adjustment parameters. They express the speed or the dynamics of the single series to revert to the long-term equilibrium. We can use this measure to quantify the contributions to the process of price discovery by the different markets

following a method that was first suggested by Schwarz and Szakarmy (1994). They proposed the relative magnitude of the adjustment parameters to assess the contributions of the two markets to price discovery of the implicit price:

$$(1-\Theta) = \frac{|\alpha_1|}{\alpha_2 + |\alpha_1|} \qquad (8)$$

$$\Theta = \frac{\alpha_2}{\alpha_2 + |\alpha_1|}$$

If the price discovery process takes place exclusively in market 1 – as we assumed in our microstructure model – we get θ=1 because in this case the adjustment factor of market 1 is equal to zero. The whole adjustment process is left to market 2. Analogically we have θ=0 if the process of adjustment takes exclusively place in market 2.

The charming simplicity of this method does not mean that it is of less reliability or quality than other more complicated approaches, as Theissen (2002) showed.

5. Empirical results

Firstly we want to search for the existence of a long-term equilibrium. Therefore we apply the Johansen (1988, 1995) approach to test for cointegration by using a VECM. The choice of lag length was determined by the Schwarz Information Criterion (SIC) and is shown in the second row of Table 5. All in all we deal with 9 market pairs. There are two market pairs for the Kreditanstalt, three for the Staatsbahn, and four for the Südbahn. By finding a cointegrating rank of 1 the Johansen trace statistic clearly supports the hypothesis of one cointegrating vector among the 2 variables for all market pairs. These results encourage us to extend the analysis by including all transaction prices for each stock. We get a system of three markets for the Kreditanstalt, four markets for the Staatsbahn and five markets for the

Südbahn. Even now, the Johansen trace statistic still signals stable cointegration relationships – two for the Kreditanstalt, three for the Staatsbahn and four for the Südbahn.

By these findings of long-term equilibria we met the prerequisites to test for the *LOP*. Table 6 shows the results for the different cointegration relationships. *CV 1* for example describes the long-term relationship between Berlin and Frankfurt after having normalized the cointegrating vector to $\beta = (1/-\beta_1)'$. The estimated cointegration parameter β_1 is shown with the p-values in brackets. Note that the results for the estimated cointegration parameters are rounded to two decimal places. Even if the estimated cointegration vector seems to be the expected one ($\beta = (1/-1)'$ for two markets) this does not automatically mean that the *LOP* can be statistically confirmed. That is why we apply a likelihood ratio test summing the cointegrating vector to zero, given one cointegration relation. The test is distributed as a chi-squared with one degree of freedom for the market pairs. In the last row of Table 6 we find the results.

The *LOP* is accepted for Berlin – Frankfurt for all three companies. For the market pair Berlin – Vienna we get a mixed picture as the *LOP* holds for the railroad companies, while it is rejected on the 5%-level for the Kreditanstalt. Nevertheless, the estimated and significant cointegration vector meets after rounding to two decimal places the prerequisites. We find the same for the other market pairs and the respective market systems. Even if the L.R.-test refuses the restriction to the cointegration vector it equals after rounding exactly the expected cointegration vector. Table 7 shows the same test but this time we look separately at the transaction prices and the exchange rates. We get the same results for the L.R.-test but the cointegration vectors differ a bit more. Especially for the market pair Berlin – Paris we get a bigger deviation from the theoretically expected one of $\beta = (1/-1/-1)'$.

In a next step we look at the price building process. How fast do prices revert to parity? Doing some Granger causality tests for the different market pairs justifies the choice of a VECM as we find mutual influences. To learn something about the intensity of these

impulses we look at the parameters of the vector α. Table 8 shows for each market pair the adjustment factors of both the Berlin and the second market price. Before going into detail we find that these error correction terms have the expected sign. If the price in Berlin is greater than the price in the other market, it is followed by a downward adjustment in the price in Berlin and an upward adjustment in the other market. The adjustment factors are significant on the 10% level for all market pairs and mostly on the 5% level as well. It is striking that for the market pair Berlin – Vienna the biggest part of the price building process did not take place in the home market but in Berlin. In case of the Kreditanstalt we get 60% up to almost 80% in case of the Staatsbahn. Another interesting result is the information sharing between Frankfurt and Berlin. Results in Table 8 show that the price building process between Frankfurt and Berlin divides into almost equal parts for all three stocks with a slight advantage for Frankfurt. For the Kreditanstalt most of the price building takes place in Berlin (56%), whereas for the two railroads the price building in Berlin is a bit smaller than in Frankfurt (46% in both cases). The market pair Berlin – Paris shows balanced results in the way that for the Staatsbahn Paris seems the dominating market (70%) whereas for the Südbahn it is Berlin (66%). The comparison between London and Berlin gives clear results that most of the price building takes place in Berlin (85%).

Figure 1 illustrates that we cover a period containing different phases, especially a strong boom and a crash. As it might be possible that the weights of the price building process changed we split our period into three sub-periods. Table 3 shows that the characteristics of the stock prices for these sub-periods are quite different whereas the means and the standard deviations within a sub-period for the same stock on the different markets are almost the same. The first period goes from January 1869 to December 1870 and includes the disruptions of the Franco-Prussian war. Overall and instead of these turbulences the stock prices reached at the end of this first period more or less the level they had in the beginning. The second period covers the boom from January 1871 to November 1872, and the third period includes

the crash from December 1872 to December 1874. We have a closer look at the market pair Vienna – Berlin to disentangle the unexpected result that the home market did not have the leading position in the price building process. Table 9 shows the interesting result that for both the boom and the crash period the Berlin market had in all three stocks the leading position in the price building process in a range from 65% to 95%. The picture is different for the first period up to December 1870. Here, we only find for the Staatsbahn a leading position in the price building process. Whereas for the Kreditanstalt both markets added the same parts to the price building process the main part of the price building for the Südbahn takes place in Vienna.

6. Conclusion

In this study we used daily stock price data from three Austrian corporations that were listed on different European stock exchanges with a focus on the five years period from 1869-74.

Firstly, we discovered a stable long-term relationship between the different market pairs. These cointegration relationships were also confirmed when looking on all transaction prices of one stock in one system. Therefore, we can confirm the assumption of a long-term equilibrium which short-term deviations.

Secondly, the *LOP* can be fully accepted for the market pair Berlin and Frankfurt. For the market pair Vienna and Berlin it shows some weakness. Even if the estimated and rounded cointegration vectors seem to support the *LOP*, the likelihood ratio test rejects this restriction for both other market pairs, Berlin – Paris, and Berlin – London. The slight deviations from the idealistic cointegration vector become more visible by looking at the transaction prices and the currency exchanges separately. We find that the deviations between Berlin and Paris are the biggest. The high degree of integration between Berlin and Frankfurt can be well explained by the missing currency risk. The close relation Berlin – Vienna might support the assumption that there already existed a forward exchange market between both

places facilitating arbitrage trading. The relation Berlin – Paris seems to be the worst which might be attributed to the French franc that was made inconvertible because of the war making arbitrage relations between Berlin and Paris more difficult without people having a forward exchange market to cover.

Thirdly, Berlin played a very important role for the price building process of these stocks. We know that by the end of the 1860s the "ultimo"-trading became extremely important for speculation. Even the contemporaneous sources regularly blamed them after there were market crashes.[41] We found a rather high information transfer from the cross-listed stocks in Berlin to other stock exchanges. Especially the high information share of stocks cross-listed with Vienna was astonishing because it contradicts the general assumption that the home market should lead the price building process. Therefore, we had a closer look on this relationship and found that for both the boom and the crash period Berlin clearly dominated Vienna in all three stocks. Only for the first sub-period from January 1869 to December 1870 we got mixed results concerning the price building process. Thus, it seems to turn out that parts of the dominance of Berlin in the price building process can be explained by the Gruender period. In consequence that means that as the speculation of the Gruenderboom started on the Berlin stock exchange the cross-listed stocks were a decisive vehicle of transferring the boom and later-on the crash to other markets. Especially the stock market in Vienna was influenced by these impulses what might be due to the high degree of financial market integration between both places.

[41] Saling's Börsen-Papiere (1874). Vol. 1, p. 183f.

Acknowledgements

We thank Jörg Baten, Marc Flandreau, Joachim Grammig, Gerhard Kling, the Tübingen Economic History Research Group, and an anonymous referee for important comments on earlier versions.

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Table 1: Closing hours of the various stock exchanges

	Local closing hour	Closing hour in local Berlin time	Source
Vienna	1:00 p.m.	1:12 p.m.	Gömmel (1992), p. 180.
Berlin	2:00 p.m.	2:00 p.m.	Gebhard (1928), p. 14.
Frankfurt	2:30 p.m.	2:11 p.m.	Baehring (1985), p. 127.
Paris	3:00 p.m.	2:16 p.m.	Haupt (1894), p. 585.
London	4:00 p.m.	3:07 p.m.	Haupt (1894), p. 438.

Time conversion according to the listing in Haupt (1894), p. 18.

Comments on the different trading practice:

Vienna: Even if there was an afternoon and evening trading, the official closing price being reported in the daily press was already established at this early point in time. From the closing to the official announcement it usually took another half an hour.

Berlin: The revised exchange regulations from April 1866 managed amongst others the official trading hours.

Frankfurt: In Frankfurt the so-called Effekten Societät was in the early and middle nineteenth century a keen competition to the official exchange. Founded in 1825, this semi-official club – using doves for transporting news from Paris and Madrid – had a much bigger transaction volume during its morning and afternoon trading sessions than the official stock exchange. However, the introduction of the telegraph led more and more to a loss of influence and with the revised exchange regulations from 1881 trading after the official closing at 2:30 p.m. was forbidden.

Paris: Following an official Act of Parliament from 1867, the trading hours on the Paris stock exchange went from 12:00 p.m. to 3:00 p.m. Even if the non-official trade went on till 4:00 p.m., the newspapers already published the official closing date.

London: After 3:00 p.m. the trading in London went on for one hour inside of the exchange building before the official closing price was announced.

Table 2: Descriptive Statistics of the three stock prices (log) in German currency on the different markets

Stock (log in Thaler)	Market	No. of obs.	Period	Mean	Std. Dev.	Skew.	Kurt.
Kreditanstalt	Berlin	1818	01/1869 – 12/1874	5.07	0.16	0.43	2.20
	Frankfurt	1831	01/1869 – 12/1874	5.07	0.16	0.37	2.28
	Vienna	1799	01/1869 – 12/1874	5.07	0.16	0.44	2.21
Staatsbahn	Berlin	1822	01/1869 – 12/1874	5.33	0.08	- 0.14	2.80
	Frankfurt	1832	01/1869 – 12/1874	5.33	0.08	- 0.21	3.02
	Vienna	1794	01/1869 – 12/1874	5.33	0.08	- 0.16	2.90
	Paris	1595	01/1869 – 12/1874	5.33	0.08	- 0.24	3.11
Südbahn	Berlin	1824	01/1869 – 12/1874	4.71	0.17	- 0.16	2.08
	Frankfurt	1827	01/1869 – 12/1874	4.71	0.17	- 0.17	2.08
	Vienna	1799	01/1869 – 12/1874	4.71	0.16	- 0.16	2.08
	Paris	1594	01/1869 – 12/1874	4.73	0.17	- 0.46	2.21
	London	1838	01/1869 – 12/1874	4.71	0.16	- 0.19	2.13

Table 3: Descriptive Statistics for different periods

Stock (log in Thaler)	Market	01/1869 – 12/1870			01/1871 – 11/1872			12/1872 – 12/1874		
		No. of obs.	Mean	Std. Dev.	No. of obs.	Mean	Std. Dev.	No. of obs.	Mean	Std. Dev.
Kredit-anstalt	Berlin	612	5.01	0.10	578	5.19	0.15	628	5.03	0.17
	Frankfurt	609	5.01	0.10	587	5.19	0.15	635	5.03	0.17
	Vienna	600	5.00	0.09	577	5.19	0.15	622	5.03	0.17
Staats-bahn	Berlin	611	5.32	0.08	582	5.39	0.06	629	5.28	0.04
	Frankfurt	610	5.32	0.09	588	5.39	0.05	634	5.28	0.03
	Vienna	601	5.32	0.08	573	5.39	0.06	620	5.28	0.03
	Paris	517	5.31	0.09	449	5.40	0.06	629	5.29	0.04
Süd-bahn	Berlin	611	4.81	0.15	583	4.74	0.11	630	4.59	0.14
	Frankfurt	605	4.81	0.16	588	4.74	0.11	634	4.59	0.14
	Vienna	601	4.81	0.15	578	4.74	0.11	620	4.59	0.14
	Paris	517	4.85	0.13	448	4.79	0.09	629	4.60	0.14
	London	613	4.81	0.15	590	4.74	0.11	635	4.59	0.14

Table 4: Unit root tests

		Log Levels		First Difference	
Stocks	Markets	ADF	PP	ADF	PP
Kredit-anstalt	Berlin	- 1.66	- 2.07	- 22.04 ***	- 43.55 ***
	Frankfurt	- 1.17	- 1.83	- 16.13 ***	- 47.53 ***
	Vienna	- 1.88	- 1.91	- 45.58 ***	- 45.50 ***
Staats-bahn	Berlin	- 2.45	- 3.13 **	- 21.99 ***	- 46.28 ***
	Frankfurt	- 2.90 **	- 3.19 **	- 18.91 ***	- 48.65 ***
	Vienna	- 3.12 **	- 3.15 **	- 41.32 ***	- 41.42 ***
	Paris	- 2.18	- 2.55	- 42.81 ***	- 42.64 ***
Südbahn	Berlin	- 0.40	- 0.65	- 22.90 ***	- 44.90 ***
	Frankfurt	- 0.45	- 0.68	- 18.36 ***	- 47.55 ***
	Vienna	- 0.44	- 0.55	- 31.49 ***	- 44.28 ***
	Paris	- 0.36	- 0.39	- 34.93 ***	- 49.80 ***
	London	- 0.67	- 0.74	- 48.29 ***	- 48.19 ***

Confidence intervals for Phillips-Perron (PP) test and for Augmented Dickey-Fuller (ADF) test according to MacKinnon (1996) one-sided p-values. One asterisk indicates significance at the 10% level (- 2.57), two asterisks significance at the 5% level (-2.86) and three asterisks significance at the 1% level (-3.43). The lag length of the ADF orientates on the Schwartz information criterion. For the PP test we use Newey-West bandwith and the Bartlett kernel as spectral estimation method.

Table 5: Test of long-run equilibrium using Johansen-approach

Stock	Market relationships (Number of lags in the VECM)	$H_0(r_0)$	Trace statistic
Kreditanstalt	Berlin – Frankfurt (4 lags)	r=0 r≤1	90.13 *** 0.06
	Vienna – Berlin (3 lags)	r=0 r≤1	333.04 *** 0.33
	Vienna – Berlin – Frankfurt (7 lags)	r=0 r≤1 r≤2	214.83 *** 93.27 *** 0.74
Staatsbahn	Berlin – Frankfurt (2 lags)	r=0 r≤1	213.38 *** 0.002
	Vienna – Berlin (3 lags)	r=0 r≤1	311.35 *** 0.31
	Berlin – Paris (5 lags)	r=0 r≤1	92.75 *** 0.08
	Vienna – Berlin – Frankfurt – Paris (7 lags)	r=0 r≤1 r≤2 r≤3	655.02 *** 95.52 *** 24.49 *** 1.29
Südbahn	Berlin – Frankfurt (2 lags)	r=0 r≤1	98.30 *** 2.06
	Vienna – Berlin (3 lags)	r=0 r≤1	264.29 *** 0.86
	Berlin – Paris (4 lags)	r=0 r≤1	89.64 *** 0.31
	Berlin – London (3 lags)	r=0 r≤1	114.09 *** 1.63
	Vienna – Berlin – Frankfurt – Paris – London (5 lags)	r=0 r≤1 r≤2 r≤3 r≤4	471.73 *** 308.15 *** 175.43 *** 62.51 *** 0.45

All prices are transformed into German Thaler. The trace statistic refers to the Johansen (1988, 1995) cointegration approach. Critical values are those from Osterwald-Lenum (1992).

Table 6: Cointegration vectors and test for the law of one price (all prices converted into German Thaler)

Cointegration relationship:

CV 1: $p_{Berlin} = \beta_1 p_{Frankfurt\ in\ Taler}$ *CV 2:* $p_{Berlin} = \beta_2 p_{Wien\ in\ Taler}$

CV 3: $p_{Berlin} = \beta_3 p_{Paris\ in\ Taler}$ *CV 4:* $p_{Berlin} = \beta_4 p_{London\ in\ Taler}$

Stock	Markets	Standardized cointegration vectors in the VECM				*Law of one price* L.R.-test
		CV 1	*CV 2*	*CV 3*	*CV 4*	
Kredit-anstalt	Berlin – Frankfurt	1.00 - 1.00 (0.000)				0.04
	Vienna – Berlin		- 1.00 (0.000) 1.00			5.44 **
	Vienna – Berlin – Frankfurt	0.00 1.00 - 1.00 (0.000)	- 1.00 (0.000) 1.00 0.00			11.04 ***
Staats-bahn	Berlin – Frankfurt	1.00 - 1.00 (0.000)				0.40
	Vienna – Berlin		- 1.00 (0.000) 1.00			3.00 *
	Berlin – Paris			1.00 - 1.00 (0.000)		35.12 ***
	Vienna – Berlin – Frankfurt – Paris	0.00 1.00 - 1.00 (0.000) 0.00	- 1.00 (0.000) 1.00 0.00 0.00	0.00 1.00 0.00 - 1.00 (0.000)		18.39 ***
Süd-bahn	Berlin – Frankfurt	1.00 - 1.00 (0.000)				0.03
	Vienna – Berlin		- 1.00 (0.000) 1.00			1.69
	Berlin – Paris			1.00 - 1.00 (0.000)		30.13 ***
	Berlin – London				1.00 - 1.00 (0.000)	13.58 ***
	Vienna – Berlin – Frankfurt – Paris – London	0.00 1.00 - 1.00 (0.000) 0.00 0.00	- 1.00 (0.000) 1.00 0.00 0.00 0.00	0.00 1.00 0.00 - 1.00 (0.000) 0.00	0.00 1.00 0.00 0.00 - 1.00 (0.000)	25.52 ***

The last column reports the chi-squared distributed likelihood ratio statistic to test if the cointegrating vectors are summing to zero, given one or more cointegration relations. One asterisk indicates significance at the 10% level, two asterisks significance at the 5% level and three asterisks significance at the 1% level.

Table 7: Cointegration vectors and test for law of one price with prices in home currency and separate exchange rate

$CV1:\ p_{Berlin} = \beta_1 p_{Frankfurt}$ $\qquad CV2:\ p_{Berlin} = \beta_2 p_{Vienna} + \beta_3 e_{B/V}$

$CV3:\ p_{Berlin} = \beta_4 p_{Paris} + \beta_5 e_{B/P}$ $\qquad CV4:\ p_{Berlin} = \beta_6 p_{London} + \beta_7 e_{B/L}$

Stock	Markets	Cointegration vectors in the VECM				*Law of one price* L.R.-test
		CV1	*CV2*	*CV3*	*CV4*	
Kredit-anstalt	Exch. (B/V)		- 1.01 (0.006)			6.63 **
	Vienna		- 1.00 (0.001)			
	Berlin		1.00			
Kredit-anstalt	Exch. (B/V)	0.00	- 1.01 (0.006)			11.07 **
	Vienna	0.00	- 1.00 (0.001)			
	Berlin	1.00	1.00			
	Frankfurt	-1.00 (0.000)	0.00			
Staats-bahn	Exch. (B/W)		- 1.00 (0.005)			3.59
	Vienna		- 1.00 (0.000)			
	Berlin		1.00			
	Exch. (B/P)			- 0.97 (0.061)		38.74 ***
	Berlin			1.00		
	Paris			- 0.99 (0.012)		
Staats-bahn	Exch. (B/P)	0.00	0.00	- 1.04 (0.048)		72.69 ***
	Exch. (B/W)	0.00	- 0.99 (0.006)	0.00		
	Vienna	0.00	- 1.00 (0.001)	0.00		
	Berlin	1.00	1.00	1.00		
	Frankfurt	- 1.00 (0.000)	0.00	0.00		
	Paris	0.00	0.00	- 1.01 (0.010)		
Süd-bahn	Exch. (B/W)		- 1.00 (0.010)			0.21
	Vienna		- 1.00 (0.001)			
	Berlin		1.00			
	Exch. (B/P)			- 1.08 (0.022)		29.50 ***
	Berlin			1.00		
	Paris			- 1.02 (0.005)		
	Exch. (B/L)				- 0.99 (0.006)	19.43 ***
	Berlin				1.00	
	London				- 1.00 (0.004)	
Süd-bahn	Exch. (B/L)	0.00	0.00	0.00	- 1.00 (0.004)	160.85 ***
	Exch. (B/P)	0.00	0.00	- 1.09 (0.016)	0.00	
	Exch. (B/W)	0.00	- 1.01 (0.007)	0.00	0.00	
	Vienna	0.00	- 1.00 (0.001)	0.00	0.00	
	Berlin	1.00	1.00	1.00	1.00	
	Frankfurt	- 1.00 (0.000)	0.00	0.00	0.00	
	Paris	0.00	0.00	- 1.02 (0.003)	0.00	
	London	0.00	0.00	0.00	- 1.00 (0.003)	

The last column reports the chi-squared distributed likelihood ratio statistic to test if the cointegrating vectors are summing to zero, given one or more cointegration relations. One asterisk indicates significance at the 10% level, two asterisks significance at the 5% level and three asterisks significance at the 1% level.

Table 8: Adjustment factors for the respective cointegration relationships

Cointegration relationships:

CV1: $p_{Berlin} = \beta_1 p_{Frankfurt}$ *CV2:* $p_{Berlin} = \beta_3 p_{Vienna} + \beta_4 e_{BV}$

CV3: $p_{Berlin} = \beta_5 p_{Paris} + \beta_6 e_{BP}$ *CV4:* $p_{Berlin} = \beta_7 p_{London} + \beta_8 e_{BL}$

Stock	Markets	Adjustment factors of cointegration relationships							
		CV 1	$\Theta_{B/F}$	*CV 2*	$\Theta_{B/W}$	*CV 3*	$\Theta_{B/P}$	*CV 4*	$\Theta_{B/L}$
Kredit-anstalt	Berlin Frankfurt	- 0.14 (0.045) 0.18 (0.051)	0.563						
	Currency exch. Vienna Berlin			0.068 (0.016) 0.391 (0.049) - 0.267 (0.052)	0.594				
Staats-bahn	Berlin Frankfurt	- 0.21 (0.038) 0.18 (0.042)	0.462						
	Currency exch. Vienna Berlin			0.188 (0.022) 0.406 (0.045) - 0.117 (0.051)	0.776				
	Currency exch. Berlin Paris					0.005 (0.005) - 0.112 (0.023) 0.047 (0.023)	0.296		
Süd-bahn	Berlin Frankfurt	- 0.15 (0.042) 0.13 (0.048)	0.464						
	Currency exch. Vienna Berlin			0.078 (0.023) 0.283 (0.064) - 0.153 (0.066)	0.649				
	Currency exch. Berlin Paris					0.007 (0.005) - 0.059 (0.027) 0.113 (0.035)	0.657		
	Currency exch. Berlin London							0.007 (0.003) - 0.040 (0.027) 0.229 (0.028)	0.851

Table 9: Adjustment factors for the market pair Berlin – Vienna for different periods

Cointegration relationships:
CV2: $p_{Berlin} = \beta_3 p_{Vienna} + \beta_4 e_{BV}$

Stock	Markets	Adjustment factors of cointegration relationships					
		CV 2 01/1869 – 12/1870	$\Theta_{B/W}$	*CV 2* 01/1871 – 11/1872	$\Theta_{B/W}$	*CV 2* 12/1872 – 12/1874	$\Theta_{B/W}$
Kredit-anstalt	Currency exch.	0.061		0.157		0.079	
		(0.030)		(0.035)		(0.023)	
	Vienna	0.345		0.242		0.455	
		(0.080)		(0.077)		(0.098)	
	Berlin	- 0.366	0.485	- 0.132	0.647	- 0.204	0.694
		(0.093)		(0.070)		(0.100)	
Staats-bahn	Currency exch.	0.220		0.185		0.117	
		(0.037)		(0.039)		(0.036)	
	Vienna	0.527		0.257		0.267	
		(0.081)		(0.089)		(0.063)	
	Berlin	- 0.156	0.772	- 0.032	0.889	- 0.089	0.750
		(0.092)		(0.089)		(0.076)	
Süd-bahn	Currency exch.	0.124		0.015		0.065	
		(0.042)		(0.046)		(0.035)	
	Vienna	0.141		0.475		0.387	
		(0.130)		(0.108)		(0.100)	
	Berlin	- 0.255	0.356	0.026	0.948	- 0.118	0.766
		(0.135)		(0.104)		(0.108)	

Figure 1: Development of the Berlin stock market and the three companies listed in Berlin

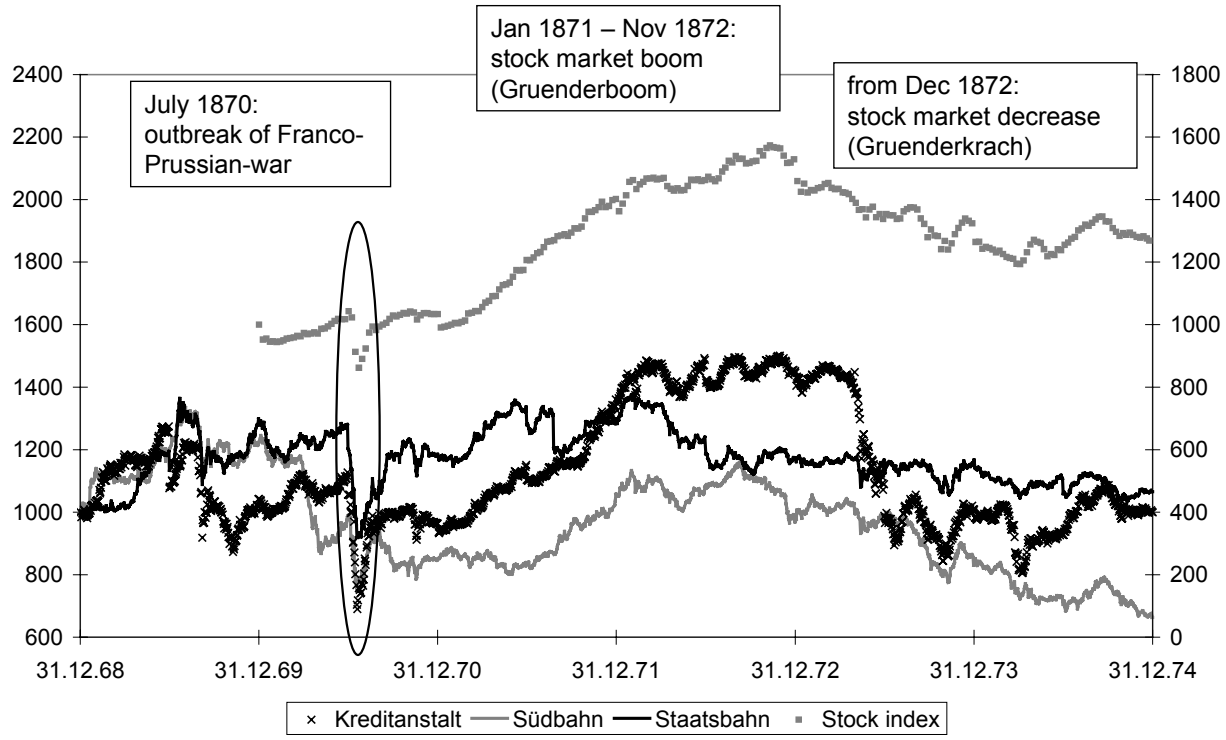


Figure 2: Diagram of the three stocks and the market interrelations

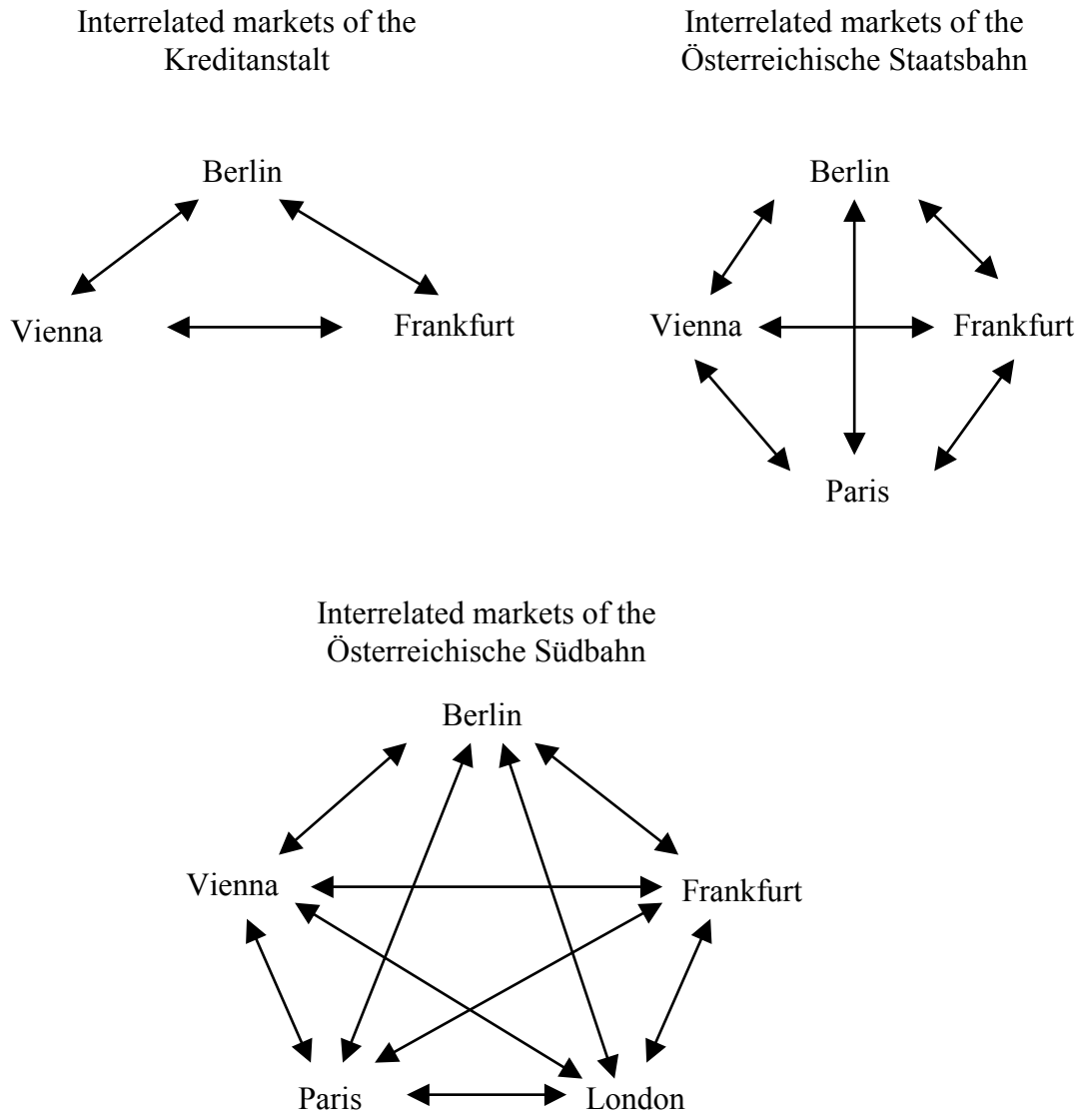
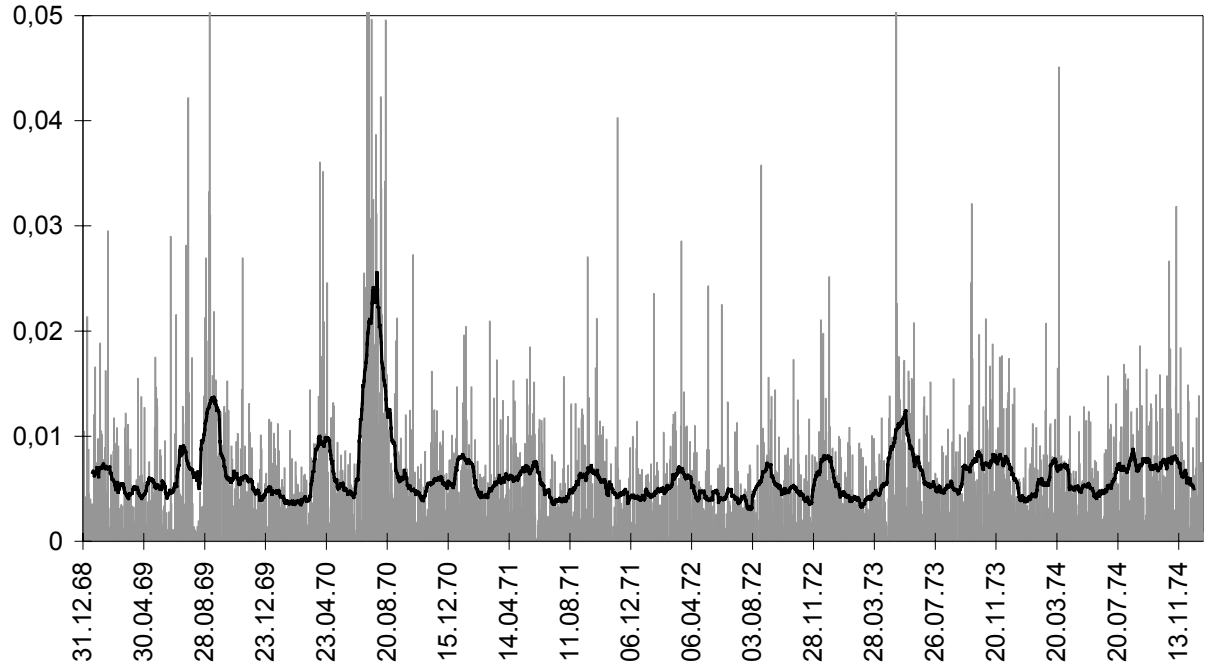


Figure 3: Percentage differences of the Südbahn prices in Berlin and Vienna, 1869 – 1874



The grey lines show the daily deviations, the black line indicates a 30-days moving average.

Appendix: *Recalculating long-sighted bills of exchange into short sighted ones*

A purchaser of a long-sighted bill e_{long} had a longer waiting time than a purchaser of a bill at sight e_{short}: $e_{long} < e_{short}$. The difference (e_{short} - e_{long}) is the interest element I that depends on both the discount rate i of the respective central bank and the maturity t of the bill of exchange that is expressed in days: $I = (i/100) \times (t/365)$. Furthermore, the long-sighted bill had an additional tolerance to its maturity of three days that must be included into an exact calculation.[42] Thus, the interrelationship between long- and short-sighted bill is the following:

$$e_{long} = e_{short}\left[1 - \frac{i}{100} \cdot \frac{(t+3)}{365}\right] \qquad (1)$$

Equation (1) shows an increase of the price difference between long- and short-sighted bills if there is an increase of either maturity t or discount rate i. As we want to get the price for a short-sighted bill we convert equation (1) into:

$$e_{kurz} = \frac{e_{lang}}{\left[1 - \frac{i}{100} \cdot \frac{(d+3)}{365}\right]} \qquad (2)$$

There is a discussion concerning the appropriate discount rate for the calculation of the bill of exchange. The arguments for the use of the discount rate of the country where the bill of exchange is traded (here: Berlin) are based on Davis and Hughes (1960), whereas the arguments for the foreign discount rate as computation base (in our example: other stock exchanges) goes back to Perkins (1975).[43] Apart from the different views the empirical evidence by Perkins (1975) showing a correlation between the implicit interest rate and the discount rate in the foreign country supports the decision to take the discount rates of the foreign stock places into account. Furthermore, the contemporary sources encourage to do so as they describe the calculation of short bills in the same way.[44]

[42] Officer (1996), p. 61 and p. 295.
[43] Cf. arguments in Davis and Hughes (1960), p. 53 and p. 56, and Perkins (1975), p. 405.
[44] Saling's Börsen-Papiere (1874). Vol. 2, pp. 1ff.

Discussion

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This is an interesting and well thought-out paper, for both what it does and the issues that it raises for future research. The paper speaks directly to a distinguished and thriving literature on international capital market integration spanning the period from the second half of the 19th century to the eve of World War I. Two key questions addressed in this literature are:

i. To which extent did the law of one price (LOP) held in financial markets during the period?

ii. To which extent was tighter arbitrage across countries fostered by hard currency pegs – in the form of either monetary unions in a handful of cases, or through fixed exchange rate arrangements commonly associated with membership of the international gold standard from the 1870s?

The main contribution of the paper is to put together a new, daily frequency dataset comprising three large Austrian stocks listed in multiple foreign exchanges between 1869 and 1874, and use modern time series methods to examine questions (i) and (ii).

As previous authors have found to be the case elsewhere (see the literature referred to in the paper), the empirical results are broadly supportive of the view that international capital markets were remarkably well integrated in the second half of the 19th century. This is not particularly surprising in light of the diffusion of telegraph lines across Europe at the time which surely helped shorten information lags, but the paper provides useful and new corroborating evidence in this respect. The second main result is that the absence of currency risk helps fosters arbitrage, as witnessed by shorter lags in stock price adjustment between Berlin and Frankfurt. In addition, the paper provides two other interesting findings. One is that the domestic market is not always dominant in terms of price innovation: more often than not, Berlin – rather than the home (Vienna) market – was the price "setter". In the jargon of the recent literature on the sources of international equity price volatility, the home "country" factor took the rear seat to the "global" market factor. Another interesting finding is that

informational geography appears to matter: arbitrage was significantly less speedy between Vienna and Paris than between Vienna and Berlin or Berlin and Frankfurt. As discussed further below, this result also has a parallel in a recent literature on the "geography" of financial markets using post-1970s data.

The main query I have with the econometric evidence pertains to the issue of structural breaks. The 1869-74 period contains a major boom and a major crash. To the extent that cross-country correlations and the scope for arbitrage in stock prices tend to be asymmetric both between booms and crashes as well as between high and low market volatility regimes, it is possible that the assumption of stable LOP coefficients, as embodied in the fixed regression coefficients spanning the whole 1869-74, may not hold.[1] In particular, this is likely to be the case in that period because it encompasses one major war (the Franco-Prussian), during the early stages of which European asset market volatility is said to have risen and arbitrage with the Paris bourse somewhat disrupted.

All this points to the need of testing the cointegration and the error correction regressions for the existence of structural breaks. Since the author has daily data and hence plenty of observations, he should not face degrees-of-freedom constraints in breaking down by various sub-periods. There are of course several ways of identifying such potentially significant breaks. One is simply to rely on qualitative historical information (e.g. the well-known early disruptive effects of the Paris siege); another is to identify shifts in volatility and distinguish between high and low volatility regimes using Garch or regime-switching models. Taking the last route has the advantage of imparting an extra value added to the analysis since no one has applied these methods to 19th century stock market data, at least as far as I know. The use of these techniques would also allow the author to examine whether market volatility significantly increased in the run-up to the 1873 crash and decreased in its aftermath. If so, this may also well lead to interesting parallels being drawn between his evidence based on early stock market data and what recent researchers have found using contemporary data.

At any rate, allowing for structural breaks might lead the author to find, for instance, that weaker arbitrage between Paris and Berlin/Vienna can be mostly or entirely attributed to the

[1] While stock return correlations, market integration, and price cointegration are obviously not synonymous, post-1970 evidence provided in Catão and Timmerman (2004) is suggestive that there might be important differences in the degree of arbitrage across national stock markets between low volatility and high volatility regimes.

war disruptions. If not, that would be an interesting finding in itself too. For it would highlight a significant role for language, geography, and perhaps other institutional factors in determining the speed and possibly volume of flows across national financial centers.[2]

Similarly, allowing for the possibility of structural breaks may also lead him to find that the prominence of Berlin in price building of the three Austrian stocks over the entire period is mainly or entirely influenced by observations around the 1873 crash in the German market. If so, this is a finding that would further highlight the role of cross-listings in the transmission of episodic "contagion" across national markets: since the three stocks are typically associated with non-tradable (or at least non-export) sectors, thereby being less directly vulnerable to external trade shocks, the stock market channel was clearly the predominant transmission mechanism at play in depressing those stock prices; and, as often the case, the finding establishes that the direction of the causality was from the more developed/liquid market to the (relatively) less liquid or "peripheral" market.

I also have two other minor suggestions regarding the econometric evidence. First, it would be interesting to check the robustness of these results to other cointegration tests and alternative specifications of the error correction model (see, e.g. Pesaran and Shin, 1998). While I don't think this will alter the thrust of the results, it is an easy extension and would help dispel any residual doubt about the tightness of market integration then. Second, it would be nice to report the speed of adjustment in cross-market arbitrage in terms of the half-life metric.[3] That is, how long in terms of the respective time unit (a day in this case) does it take for half of the discrepancy between price differences in any two stock markets be dissipated? This is a standard way of presenting evidence in the purchasing power parity literature and using it here would make the results more intuitive and more easily interpretable by the reader.

Let me now turn to what is arguably the easiest but also the most unfair task of a discussant. And this is to ask for more: more sectors, more countries, longer time series ... The title of the paper in a sense invites this since it suggests a broader inference on European financial integration. Even within pre-WWI Austro-Hungarian borders, there are reasons to doubt that

[2] See Portes and Rey (2005) for evidence supportive of this "geography of information" view based on evidence from equity flow data and also Catão and Timmerman (2004) using 1973-2002 stock return data for thirteen advanced economies.

[3] The formula is H=ln(0.5)/ln(1-|□|), where □ is the reported estimate of the error correction coefficient.

the three stocks are representative of the behavior of arbitrage and equity pricing elsewhere; so it would be interesting to see whether similar results hold for smaller caps and less extensively or internationally traded Austrian stocks. Looking beyond Austrian borders, it is likewise doubtful that Austria can be taken as representative of the European periphery. Important differences include the existence of forward currency market (at least from the mid-1870s if not earlier), a more liquid home financial market than other peripheral European economies, and greater exchange rate stability – relative to gold as well as in nominal effective terms.[4] So, the bottom line is that it would be very useful to extend this data, both cross-sectionally within the country as well as across countries. Such a data collection effort is clearly daunting; but it is also something likely to yield handsome benefits to our historical understanding of international financial market integration, with salient macroeconomic implications.

This takes me to some final remarks on broadening this research agenda. While much emphasis in the existing historical literature has been giving to testing the LOP, there are other important uses for historical data on equity cross-listings that, in my opinion, merit much more attention. We know that cross-listings can facilitate financial contagion as discussed above, but also that they have potentially important and beneficial macro effects. Some of these effects have been studied by a recent literature but grossly overlooked – at least to my knowledge – in the economic and financial history literatures. One important finding of recent studies is that cross-listings tend to increase liquidity in the home financial market.[5] Contrary to the initial fears of policy makers in several emerging markets that cross listings of domestic firms in large world stock exchanges would squeeze domestic market liquidity, quite the opposite has happened in recent years. Insofar domestic financial market liquidity fosters long-run growth (cf. King and Levine, 1993), the long-run effect of cross-listings on countries' welfare thus tends to be positive. Second, there is persuasive evidence that cross-listings tend to reduce home bias in stock holdings, thus facilitating international risk sharing.[6] Last but not least, if it is true that painful "sudden stops" in international capital flows and resulting exchange rate volatility are both exacerbated by the low international

[4] See Catão and Solomou (2005) for evidence on exchange rate volatility in the European periphery between 1870 and 1913.
[5] See, e.g., Levine and Smuckler (2004) and Korczak and Bohl (2005).
[6] See Edison and Warnock (2003).

liquidity of domestic assets in many countries, then the beneficial effects of cross-listings on domestic liquidity should also help mitigate the "sudden stop" problem.[7]

This in turn raises an important causality issue pertaining to the conventional wisdom – sometimes echoed in the gold standard literature – that nominal exchange rate stability and hard pegs foster a country's integration within world capital markets. While the results of the paper provide some support for the view that a common currency or nominal exchange rate stability tend to facilitate cross-border asset market arbitrage, those results do not rule out the possibility that the causality runs the other way around. That is, was the kroner (or later the Florin) more stable compared to some other "peripheral" countries due to more extensive cross-listings which helped boost the international liquidity of Austrian assets? Or was the greater stability of the Austrian (and subsequently Austria-Hungary) currency relative to gold what spurred cross-listings and greater equity market integration?

To have a long cross-country historical database on cross-listings should allow us to shed new light on these important questions. Therefore, the investment of patience and talent in extending such a database should not be deemed a mere historical curiosity but something likely to be very helpful in deriving more grounded policy implications going forward.

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7 Low international liquidity of domestic assets exacerbate the sudden stop problem to the extent that increases in investors' risk aversion tends to foster fire-sales of less active assets which appear to affect proportionately more the securities issued by emerging market countries.

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Markus Baltzer's paper starts from an interesting, but still unresolved question: How integrated were financial markets before World War I? More specifically, he asks whether the forward prices of three Austrian stocks (two railroad companies and one bank) obeyed the "law of one price," implying that these prices should be more or less the same across different stock exchanges where the stocks are listed. The considered time period is known as the *Gründerboom* and *Gründerkrach* in Germany, 1869 until 1874. This episode is interesting because it offers the possibility of assessing the impact of the strong boom and subsequent crash in the German market on the degree of financial integration in Europe.

There already exists a rather large literature exploiting the fact that stocks are cross-listed on several stock exchanges: Some are based on contemporary data (e.g., Hasbrouck 1995, Theissen 2002, Grammig et al. 2005), others on historical data (e.g., Neal 1985, 1987, 1990, Flandreau 2004). The paper adds to this literature in three respects: First, it uses high-frequency (daily) data for the study of a historical episode. Second, it uses up-to-date econometric procedures, such as cointegration and vector error correction models, in contrast to most of the papers on historical episodes. Third, it analyzes not only the validity of the "law of one price," but also the properties of the price-building process; again this has not been done for historical episodes.

The main results of the paper can be summarized as follows: First, the returns in different markets are cointegrated, indicating that there is a stable long-term relationship among the considered markets. Second, the results on the "law of one price" are, at least in my view, rather mixed. In fact, they point towards little financial integration *across* national borders. Only for the market pair Berlin versus Frankfurt can the "law of one price" never be rejected; for all other market pairs, the law is rejected in many, and sometimes even all, specifications. Finally, Berlin appears to play a major role in the price-building process. This seems to contradict the widely maintained hypothesis that the home market (in this case Austria) should be dominant.

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In my discussion of the paper, I would like to touch upon four issues: The data, the methodology, the interpretation of the results, and the robustness of the results.

1. Data

The main advantage of the data is its daily frequency. Given the information technology of the time, this frequency seems to be well-suited for the analysis. The main weakness of the data is the limited number of companies (namely three), which, moreover, are all from Austria. To get a more complete picture of financial market integration at the time, it would be desirable to look at a broader set of cross-listed stocks on European stock exchanges. Such data is certainly available, but, of course, the costs of data collection are quite large.

I am a little sceptical about the use of forward prices in the analysis because arbitrage in such markets is not straightforward, especially in the absence of forward exchange markets. Such impediments to arbitrage would tend to bias the analysis against finding financial market integration. Another potential shortcoming of the data is the lack of direct measures of exchange rates. It is hard to judge how good the used proxy is.

Finally, I would like to have some additional information on the data. For example, one would like to know whether there actually was any trade at the quoted prices, and whether short sales were allowed. Also the specific details of the forward contracts in different markets (for example, regarding settlement dates and delivery terms) would be of interest. It is quite likely that such terms differed across different stock exchanges. As a minor point, I found the existence of an accrued interest on stocks quite curious. Maybe it would be worthwhile to include a literal quotation from some original source, explaining this peculiar feature.

2. Methodology

The employed methodology seems to be well-suited for the question under study and conforms with what is done in the modern finance literature. There is only one thing that I found unsatisfactory. Many of the tests are conducted on market pairs. However, the choice of pairs seems to be quite arbitrary. I was wondering why the particular pairs were chosen, and why the results were not displayed for all market pairs. In theory, the choice of pairs may not be important, but in empirical work, such things typically do play a role. In the analysis of the

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price-building process, one would actually be most interested in the Vienna pairs, especially in the light of the hypothesis of domestic market dominance.

Finally, some estimation and test details are not well explained in the paper. This is especially true for the likelihood ratio test of the "law of one price." At the very least, the null hypothesis should be stated explicitly, and a source should be given where the test is explained in some detail.

3. Interpretation of results

In my view, the paper sets a very high hurdle for financial integration. There could be a number of reasons for the observed rejection of the "law of one price": As mentioned before, there may have been limited arbitrage in forward markets due to missing forward exchange markets. In this respect, it may be interesting to check whether there was arbitrage between spot and forward markets in *local* markets, and whether the "law of one price" was satisfied in the *spot* markets of different countries. The rejection of the "law of one price" could also be due to a measurement error in exchange rates, or to different closing hours at different stock exchanges (the difference amounted to almost two hours, which is substantial). Finally, there may have been "limits of arbitrage," as described, for example, by Shleifer and Vishny (1997). Such limits would be expected to be particularly severe in times of financial market turbulence. Hence, a rejection of the "law of one price" could also be due to the choice of the sample period. All these arguments made me wonder whether there is not a more continuous measure of financial integration. The proposed procedure either accepts or rejects the presence of financial integration. In reality, financial integration may rather be a continuous phenomenon.

Regarding the analysis of the price-building process, I would like to distinguish between different types of information that may be reflected in stock prices: For firm-specific information, it is quite plausible that the home market (in this case Austria) should be dominant. For macroeconomic information, this is less clear. Germany was an important market for Austria, both for railways and for banks. Hence it is not surprising that other markets are also important in the price-building process. Finally, there may also be pure contagion between markets, as was observed in the crash of 1987. Then comovements of markets do not reflect information flows at all. In my view, the paper should try to disentangle these alternative hypotheses.

4. Robustness of results

As a last point, the paper presented very few robustness checks of the results. For example, the results may be sensitive to the ordering of variables and the number of lags included in the regressions. In the analysis of the price-building process, Markus uses a simplified approach, referring to a study by Theissen (2005), which has shown that this procedure yields similar results to the original (and theoretically founded) method by Hasbrouck (1995). Nevertheless, it would be desirable to see whether this is also true in the data set on hand. As mentioned before, an analysis of spot prices would also be desirable (where such prices are available). Finally, it would be very useful to split the sample into crisis and non-crisis periods. This also promises to yield additional insights regarding the effect of market turbulence on financial integration and the price-building process. In fact, this seems to be one of the most interesting issues in the episode under study and should therefore be explored more fully.

Conclusion

Let me conclude by saying that this paper nicely combines an interesting economic topic, historical data, and an up-to-date methodology. My major suggestion is to clarify the main message of the paper. Specifically, the author has to take a clear stand on whether there was financial integration or not, and what kind of information flowed across national borders. These statements should then be checked for robustness in an appropriate way. Finally, the analysis of the effect of financial market turbulence on financial market integration would add an interesting twist to the empirical study.

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