Historical Economic Integration in Europe:

Application of a Threshold Auto-Regressive Model

With Price Data from: 1295 – 1914

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Abstract

The purpose of this integrative exercise is to analyze the levels of economic integration between cities in Europe. The research extensively uses a data set compiled by Bob Allen with commodity prices ranging from the year 1295 to 1914. I estimate the levels of economic integration between these cities by means of the threshold auto-regressive framework. Through this analysis I obtain estimates of the speed of reversion for the real exchange rate and size of transaction costs between cities, which serve as proxies for the level of economic integration between them. With these estimates, I run a second stage regression to elicit the effect that well documented trade frictions (such as: political affiliation, distance between cities, etc.) have on the economic integration between two cities. The results indicate that speed of exchange rate convergence is slower and subsequently the size of transaction costs higher during this time period covered in this study relative to the present day. In addition, political affiliation, access to ports and distance prove to be the most significant factors underlying the estimated transaction costs during the time period covered in this study.

Introduction:

Purchasing Power Parity is a fundamental concept in the field of international macroeconomics. Absolute Purchasing Power Parity states that when a price level from one economy is converted into the currency of another economy price levels between the two economies should be equal. Relative PPP argues that the real exchange rate, defined as a ratio of price levels between two economies, should be constant over time. Due to short run business cycle fluctuations, PPP doesn't hold very well in the short run. Conversely, PPP may hold in the long run. That being said, the data makes it clear that deviations in exchange rate levels away from those consistent with PPP are frequent and their effects persistent.

Underlying PPP theory is the Law of One Price (LOOP). LOOP states that an individual good should be the same price in one country as it is in another when denominated in a common currency. This intuitively should be true because if it were not, speculators would buy the good in the undervalued market and sell it in the overvalued market. In this way arbitrage regulates the prices of commodities across countries in the international macro economy. Since this rationale should hold true for individual goods, it also makes sense for PPP given the fact that PPP is simply a weighted average of different commodities. However, this relationship changes in the face of trade frictions.

Exchange rate deviations from levels consistent with PPP can be explained by the presence of trade frictions, which limits the profitability of export and trade. In this way, trade frictions form what Zussman (2003) referred to as a "band of inaction". Put another way, the band of inaction is an estimate of the range of values that the real exchange rate can take where an arbitrage opportunity still does not exist. If the real exchange rate between two economies were to go outside the band of inaction, speculators would realize that an arbitrage opportunity existed and exploit it until the price level was brought within the band of inaction again. This would mean that Absolute PPP would likely not hold between two economies because the real exchange rate could fluctuate to any of the points within the band of inaction and not cause any equilibrating process. Therefore, the band of inaction implies that real exchange rate behavior between two economies follows two different processes, depending on whether or not the exchange rate level falls inside or outside the band of inaction. When the exchange rate lies outside the band of inaction, there will be a negative trend towards the band of inaction. When the exchange rate is within the band of inaction, it will essentially follow a random walk process. The difference in the behavior of the real exchange rate depending on its position within or outside the band of inaction is the theoretical basis for the threshold auto regressive analysis undertaken in this study.

This study is a contribution to the emerging literature that estimates the effects that trade frictions have on real exchange rate deviations away from levels consistent with those set out by PPP. I apply a threshold auto regression to historical commodity data to elicit the rate of convergence to the band of inaction when the exchange rate lies outside the band. In addition, the threshold auto regressive analysis yields an estimate for the band of inaction itself. These estimates are then used in a second cross-sectional regression to test for the effect that trade frictions have on both the rate of convergence and band of inaction for a city pair. This study provides further support that the presence of trade frictions results in larger estimates of the band of inaction and slower reversion rates to the band of inaction.

This study is an original contribution to the growing literature on historic economic integration as the data for the cities in this study have not been used for this type of analysis before. The analysis of real exchange rate behavior necessitates a large sample size similar to the one used in this study. Research in this area of economics is limited because of the low predictive power of unit root tests such as the Dickey-Fuller test. Without the ability to reject the presence of a unit root in historical price data, research from there on out is useless. Therefore, this study is not only an original contribution to this body of literature; it is also a rare contribution due to the scarcity of usable data for this type of analysis.

Literature Review:

Although the Law of One Price underlies many of the economic concepts in international macroeconomics, it does not hold empirically. Rogoff (1996) [1] provides an extensive overview of the research conducted on the empirical validity of PPP. From this study it is made evident that PPP does not hold in the short run at all. As stated by Rogoff "for many years researchers found it difficult to reject the hypothesis that major-country real exchange rates follow a random walk under floating exchange rate regimes." Essentially, many of the earlier studies of PPP (circa: 1980-1990) were unable to prove that fluctuations in data were not random. In this case, not only does PPP not hold in the short run but also it is completely rejected.

The presence of a unit root in price data contradicts the empirical validity of Relative PPP. Theoretically, Relative PPP asserts that the real exchange rate will grow at a constant rate over time. The definition of a unit root process is that the beta coefficient in an autoregressive

[1] Rogoff, Kenneth. "The Purchasing Power Parity Puzzle." in Journal of Economic Literature, June 1996, 34(2), pp. 647-668.

function is equal to 1, and thus the only varying part of the equation is an error term that is assumed to be stochastic. It is evident that if a unit root process exists in the data then the Relative PPP could not hold because there would be no reversion to a long run growth rate. Instead the fluctuations in the real exchange rate would be completely stochastic and unpredictable.

The inability to reject the presence of a unit root in exchange rate data was largely due to the high number of observations necessary for standard unit root tests, such as the Dickey-Fuller test, to draw accurate conclusions. Frankel (1986, 1990) asserted that the reason that researchers were unable to reject the presence of a unit root in exchange rate data was due to the lack of power.[2] This seems intuitive because if real exchange rate shocks take a long period of time to dampen out, there would need to be a sufficient amount of data coverage to explain this behavior accurately. Frankel made use of annual Dollar/Pound exchange rate data from 1869-1984 and was able to reject the null hypothesis that a unit root process characterized the data.

The lack of convergence in real exchange rate data to levels consistent with PPP, in the mid to long run is puzzling. It seems that if these deviations from PPP were to exist for extended periods of time, speculators would exploit them and bring the exchange rate back into equilibrium. Rogoff (1996) points to trade frictions as a possible solution to the substantial half-lives that characterized real exchange rate data. Rogoff says that trade frictions could include: transportation costs (distance), transaction costs (insurance), tariffs and the existence of different preferences internationally in commodities. This means that real exchange rate levels could vary between cities for a number of reasons, most of which have to do with the expected volume of

[2] Frankel, Jeffery A. "International Capital Mobility and Crowding-out in the U.S. Economy: Imperfect Integration of Financial Markets or Good Markets?" in *How open is the U.S. economy?* Ed.: Rik W. Hafer. Lexington Books, 1986, pp. 33-67.

trade between two economies. If two economies trade less with one another, the equilibrating process of arbitrage will take longer and subsequently deviations in the real exchange rate away from Relative PPP will last for longer.

The intuitions from Rogoff's assertion that trade frictions between two economies determine the level of economic integration between them is the theory behind the threshold auto regressive analysis used in this study. The estimates of the band of inaction are estimates of the range of values that the real exchange rate could take and still be in line with Relative PPP in this framework. Deviations outside the band of inaction are assumed to simply revert to the band, but not a value of one as would be dictated by the theory of Absolute PPP.

Historical price data lends itself particularly well to the study of market integration between economies using the Relative PPP framework. This is due to the fact that a high number of observations are necessary to reject the presence of a unit root process in the data. There are two main ways that Relative PPP is tested for in these studies. Some researchers choose to use conitegrative techniques, and others choose to use bilateral frameworks. Examples of both are considered in this literature review.

"Did European Commodity Prices Converge During 1500-1800?" an economic study by Suleman Ozmucur and Sevket Pamuk, estimates the levels of market integration for a set of European cities from 1500 to 1800 AD.[3] They find evidence that markets became more integrated during this time period. This result parallels the findings of this study that also finds reason to believe markets in Europe were internationally integrated in the modern era.

[3] Ozmucar, Suleyman and Pamuk, Sevket, "Did European Prices Converge During 1500-1800?", The New Comparative Economic History, Conference in Honor of Jeffrey G. Williamson, Ed. Hatton, Timothy, O'Rourke, Kevin and Taylor, Alan, The MIT Press, Cambridge, Massachusetts, (2007): pp. 59-86.

The cities used in Ozmucur and Pamuk's study are: Amsterdam, Barcelona, Istanbul, London, Madrid, Paris, Sopron, Vienna, Modeno and Tuscany. Their study covers commodity data for: wheat olive oil, rice, honey, sugar, soap, meat, and butter. The visualization of the time series data for their study shows that once prices were converted into grams of silver, they appeared to follow similar trends over the period in question. This is a first pass observation of market integration.

It is interesting that Ozmucur and Pamuk (2007) stick to individual commodities as opposed to measures of CPI or an aggregated basket of goods. The inclusion of a CPI measure shed more light on general economic integration across commodities and might eliminate some of the problems with missing data values in their data set. In contrast, this study makes use of CPI estimates to test for general levels of market integrations between cities in the sample.

Ozmucur and Pamuk make use of 25-year averages of prices for the different commodities over time and use those in the visualization of the data. Due to the sparse indivudal commodity data coverage in this study, the construction of moving averages was impossible in this time frame. With the use of interpolation to fill in some of the missing data values, this study could adopt a similar framework and it might be more accurate given the long duration of time covered in this study. As it is constructed now, this study normalizes the data trends using a single estimate of an average over a 600-year time frame. Although the use of floating averages allows for the variation in price levels over time, one could argue that the use of moving averages might underplay the fluctuations in price levels in the short run.

Ozmucur and Pamuk acknowledge that "The traditional approach to market efficiency looks at the correlation of prices or the speed of adjustments to an equilibrium price differential between markets in bilateral trade."[4] Instead of adopting the bilateral framework, the type that is used in this study, they instead use cointegrative methods to test for the economic integration between economies. Essentially, their study takes two price series at a time, subtracts one from the other and runs a Dickey-Fuller test to see if the residuals from the resultant differenced series converges over time. This intuitively tests for the trend in deviations from a long run growth rate. For example, it the difference between the price data for London and that of Paris had residuals that became larger over time, this would imply that the economies were becoming progressively less integrated. They find that under this theoretical framework only Amsterdam's and Vienna's prices for wheat were cointegrated.[5] Said another way, the real exchange rate data for Amsterdam and Vienna were the only pairing consistent with Relative PPP in the long run.

Additionally, Ozmucur and Pamuk (2007) make use of the coefficient of variation as a measure for the levels of integration between these cities. The coefficient of variation is defined as:

$$CV = \frac{\sigma}{\mu}$$

Here σ is the estimated standard deviation and μ is the estimated mean of the series. The coefficient of variation is a measure of dispersion of a probability distribution. They then use stationarity tests, such as the Augmented Dickey Fuller test, to determine whether the estimates of CV are trend stationary over time. It should be noted that they use a 25-year moving average as an estimate for μ. In this way they hoped to decrease the probability that social/technological changes would bias the results of the measure of the coefficient of variation. What they find is

[4] Ozmucur and Pamuk (2007), pg. 7.
[5] Ozmucur and Pamuk (2007), pg. 12.

that the results based on the coefficient are mixed. The only solid conclusion made from this analysis was that the prices of rice, olive oil, meat and soap show convergence over time.

While cointegrative analysis is mathematically rigorous and takes a lot of statistical power to estimate correctly, it still falls short in descriptive power. For example, Ozmucur and Pamuk are able to say that some prices are mean reverting in the long run but are unable to say what values of the real exchange rate constitute as a mean reverting state. Essentially, they just test for the relationship over time and are unable to make many concrete statements from a cardinal perspective on the levels of integration between the cities in their sample. The threshold auto regressive model, as outlined in Zussman (2002) [6], answers these concerns and allows this study to make comparisons between the levels of market integration between commodities for the cities in my sample.

Asaf Zussman's (2002) paper "The Limits of Arbitrage: Trading Frictions and Deviations from Purchasing Power Parity" makes use of a threshold auto regressive model to measure the pattern and rate of convergence for real exchange rates across countries. Zussman (2002) uses the concepts of the Law of One Price and Purchasing Power Parity to provide a theoretical framework for the long run behavior of prices between economies. Essentially, prices between economies equilibrate as their markets become more integrated through trade. The theory underlying this price equilibration is arbitrage. Arbitrageurs will exploit price discrepancies between economies until prices regulate to equal amounts in real terms. Zussman (2002) highlights that arbitrage will only be profitable if the revenue from performing arbitrage is

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[6] Zussman, Asaf, "The Limits of Arbitrage: Trading Frictions and Deviations from Purchasing Power Parity", *Stanford Institute for Economic Policy Research,* (2002), Available at: http://siepr.stanford.edu/publicationsprofile/481.

greater than the transaction costs associated with shipping and selling a good in a foreign market. This gives rise to Zussman's non-linear, threshold auto regressive model for real exchange rates:

$$\Delta q_t = \lambda\left(q_{(t-1)} - c\right) + e_t, \qquad When\ q_{t-1} > c$$

$$\Delta q_t = e_t, \qquad When - c < q_{t-1} < c$$

$$\Delta q_t = \lambda\left(q_{(t-1)} + c\right) + e_t, \qquad When\ q_{t-1} < -c$$

Where Δq_t is equal to the growth in the real exchange rate from period (t-1) to (t). q is equal to the real exchange rate between countries, c is the estimated trade costs and λ is the estimated rate of convergence for the real exchange rate back within the band of inaction. λ and c will therefore be the measures of the level of market integration. The level of market integration is negatively related to the value of c and positively related to the value of λ.

Zussman (2002) runs this statistical model on annual data for real exchange rates from 108 countries during the time period 1960-1996. The data was gathered from the PWT (Penn World Tables). The average estimated width of the band of inaction, or the estimated transaction costs is 0.23, with a standard deviation of 0.21.[7] This means that on average, real exchange rate deviations greater than 23% away from levels consistent with Relative PPP tend to be arbitraged away. Equivalently, trade frictions caused potential arbitrage profits to be negative for real exchange rate deviations under 23% of that expected by PPP.

What makes Zussman (2002) a more comprehensive study of market integration is that it analyzes the specific effects that trading frictions have on the estimated size of transaction costs, as outlined in Rogoff (1996). Mathematically, Zussman sets up a regression of the form:

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[7] Zussman (2002), pg. 15.

$$C_{ij} = \propto_0 + \propto_1 \text{ distance} + \propto_2 (\text{distance}^2) + \propto_3 \text{ tariffs} + \propto_4 \text{ NERV} + \varepsilon_{ij}$$

C_{ij} is the estimated trade costs provided from the threshold auto regression between real exchange rates in countries i and j. The explanatory variables given in the above equation are the ones that Zussman (2002) found to be statistically significant in his study. NERV stands for the nominal exchange rate volatility and it is measured as the standard deviation of the one year period change in the log nominal exchange rate between countries i and j. Interestingly, the distance variable has a nonlinear effect on trade costs. Lastly, Zussman (2002) found that countries that don't share a land boundary or that don't have access to the ocean/sea tend to have wider bands of inaction. Similarly, this study finds that cities that have ports tend to have more economically integrated economies compared to cities without a port.

Zussman (2002) stands in stark contrast to Ozmucur and Pamuk (2007) in terms of their approach to the measurement of the same thing (the presence of Relative PPP). As seen above, Zussman (2002) allows for the real exchange rate to vary within a band of inaction, which is an estimate for the costs of trade between the two economies in question. This in turn allows a second, cross-sectional regression to be run to elicit the specific effects that trade frictions have on the estimated level of market integration between two economies. This extra level of analysis is what made me want to undertake Zussman's methodology as opposed to the cointegrative techniques found in Ozmucur and Pamuk (2007). The final piece of the analytical framework for the threshold auto regression is to find documented trade frictions that have played a role in determining the levels of market integration between economies in past studies.

Charles Engel and John Roger's (1996) seminal study "How Wide is the Border?" clearly demonstrates the negative effect that trade frictions can have on price ratio convergence. [8] They cleverly look at a sample of cities in the U.S.A. and Canada to elicit what relationship political borders have on price convergence. In turn, they also compare the relative effect that distance has on price ratio convergence, which turns out to be smaller than the estimated negative effect of political border differences.

They use modern data on disaggregated CPIs for the U.S.A. and Canada. Due to this fact, the commodities used in Engels and Rogers (1996) are broad measures of consumption such as "food at home" as opposed to the individual goods purchased for consumption at home. The cities used in the study are: Baltimore, Boston, Chicago, Dallas, Detroit, Houston, Los Angeles, Miami, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis, Washington D.C; Calgary, Edmonton, Montreal, Ottawa, Quebec, Regina, Toronto Vancouver and Winnipeg.

The results overwhelmingly show that both distance between cities and the border are significant influences on price ratio convergence. In fact, political border differences seem to have a greater effect on price convergence than the distance between cities. Engel and Rogers (1996) asserts that, on average, the border accounts for 32.4 percent of the standard deviation of price ratios, whereas the average distance between cities in the sample only accounts for about 20.3 percent.[9] These results are supported in this study where political allegiance of cities played a significant role in determining the integration of two cities' economies. In general, two cities

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[8] Engel, Charles and Rogers, John H. "How Wide is the Border?" *The American Economic Review,* Vol. 86, Issue 5, (1996): 1112-1125, Available at: http://www.jstor.org/stable/2118281.

[9] Engel and Rogers (1996) , pg. 1120.

that fell under the same political state observed higher economic integration than those that were not in the same political state.

The observed border effect articulated in Engel and Rogers (1996) is now an established trade friction and is used in modern studies of PPP frequently. What's interesting about contemporary research concerning trade frictions are the redefinitions of borders from a more ethnological standpoint. Schulze and Wolf (2007)[10] take the border effect a step further and expose that for a subset of Eastern European cities within the Habsburg trade community, similar ethno-linguistic communities traded more with one another and consequently formed internal borders between the different ethno-linguistic groups. These artificial cultural borders negatively influenced price ratio convergence across different cultural groups. This would have been an interesting consideration to use in this study. However, the large range of time this study covers makes it hard to take into account ethnological considerations as the demographics of these countries changed dramatically over time. However, with the use of interpolation and specific time period analysis, this study could also makes use of the ethnological trade frictions.

In addition, Wolf (2007)[11] asserts that administrative borders, as well as ethno- linguistic differences between communities within Germany posed significant barriers to trade within Germany from 1885-1933. The inclusion of administrative borders is another consideration that this study could benefit from. Again, its inclusion in the analysis of this study would make the analysis of specific time periods in the data set essential, as opposed to just an aggregate analysis

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[10] Schulze, Max-Stephan and Wolf, Nikolaus, "On the Origins of Border Effects: Insights from the Habsburg Empire", *Journal of Economic Geography*, Vol. 9, Issue 1, (2009): pp. 117-136, Available at SSRN: http://ssrn.com/abstract=1315938 or doi:lbn040.

[11] Wolf, Nikolaus, "Was Germany Ever United? Evidence from Intra- and International Trade, 1885-1933", *CESifo Working Paper Series,* (2008), No. 2424, Available at SSRN: http://ssrn.com/abstract=1284966.

as seen in the current study. It would also imply that more historical research should be undertaken to find out how these countries were organized from an administrative standpoint.

With the models and methodological framework used in this study laid set out in the literature review, the last piece of the puzzle is to describe data set used in this study. The data set was taken from the historical economist Robert Allen and concludes the literature review.

Robert C. Allen's (2001) study "The Great Divergence in European Wages and Prices from the Middle Ages to the First World War" traces the evolution of European prices/wages from 1295-1914 for a set of 16 cities. [12] Allen is able to show that the divergence in real incomes observed in the 19'Th century was produced between 1500 and 1750. This was due to the fact that real incomes fell in most European cities except for the cities that were economic leaders (most notably London).

One of the most significant aspects of Allen's study is the data set he created for the statistical analysis. He compiled commodity data for 16 different cities in Europe from the time period 1295-1914. The high number of cities and the long time period covered in the sample lends itself well to the threshold auto regressive framework used in this study. Furthermore, the fact that price data for individual commodities is included in the data set makes it possible to measure the levels of economic integration between cities for specific goods.

The price data in Allen's study is denominated in both nominal terms and silver. The present study makes use of the silver prices for commodities because then there is then no need to account for the nominal exchange rate (both currencies in question are denominated in a

[12] Allen, Robert C., "The Great Divergence in European Wages and Prices from the Middle Ages to the First World War." *Explorations in Economic History,* Vol. 38, (2001): 411-447. Available at: http://www.nuffield.ox.ac.uk/users/allen/greatdiv.

common currency: silver). During this the timer period cities used silver coins but the amount of silver in a coin differed between cities. An area of concern that Allen comments on is the fact that the price data used in his study was drawn from the price histories, which reflect prices generally paid by important institutions.[13] This is more of a concern for Allen's analysis because he is interested in historical wage deviations during this time period and implies that he must look at this trend from the perspective of an individual laborer. Regardless, so long as the prices these institutions recorded were proportional to the prices paid by consumers then the relationship will be captured in the statistical analysis.

This study concerns itself with the level of economic integration between cities and does not stand to be hurt because the prices for commodities reflect the prices paid by merchants. In fact, this might be a better representation for determining when an arbitrage opportunity existed because the people that would be able to take advantage of an arbitrage opportunity during this time period would be merchants. The merchants would then buy a commodity for a low price in one economy, transport and sell it to merchants in another economy where it could be sold at a profit. In this way the wholesale prices paid by larger institutions might be more fitting for the theoretical implications of arbitrage as examined in this study as opposed to retail prices paid by the consumer.

Allen stresses that bread prices were the most complicated to include in his analysis. Again, the bread price is essential for his analysis when talking about the levels of real wages between these cities (bread was a central part of a laborer's consumption during this time period). The problem arises from the fact that large institutions baked their own bread and thus didn't record the price for the finished product. However, he contends that during the early modern

[13] Allen (2001), pp. 418-419.

period (1500-1800 C.E.) municipal authorities regulated the price of bread, making it equal to the inputs plus a mark-up for labor and taxes. Allen uses this rule to create a regression that estimates the price of bread subject to the wage rate and price of grain across cities. This regression displays an R-squared value of .92 and is thus an acceptable estimate of bread prices.[14] Allen subsequently uses these regression results to fill in blanks for the price of bread where data coverage is sparse.

Again, the problems in the estimation of bread prices are of little concern for this study because bread is not examined as an individual commodity. However, Allen's measurement of CPI serves as a large data source for this study and it does incorporate the price of bread into its measurement. Again, since the CPI is a weighted average of multiple commodities included in the data set, the potential biased effects of bread prices in the measure of CPI will likely be negligible as they represent only one part of CPI.

Allen's measurements of CPI vary slightly in their composition between different city pairs. This is due to the fact that climates and cuisine differ between cities and thus their price coverage for commodities are different. Consider London where beer was a staple of an individual's consumption and Madrid where the same role for an individual's consumption was filled by wine. Allen affirms that the only goods that were used interchangeably in measurements of CPI were beer/wine and butter/olive oil. Again, this would indicate that the potential bias introduced to the measurements of CPI because of this factor will be negligible.[15]

Allen's measurement of CPI is mathematically constructed using a Laspeyres Index. The Laspeyres Index is constructed by comparing commodity prices in any time period relative to

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[14] Allen (2001), pg. 419.
[15] Allen (2001), pp. 420-421.

those of a selected base time period. The index is computed with a commodity's relative price (the price in the current time period divided by the price in the base year) weighted by the commodity's relative importance in the consumption bundle during the base year. This differs from a Geometric Index, which allows consumption to vary with price. The potential problem with use of a Laspeyres Index is that it tends to overstate price increases because it doesn't allow for consumers in time periods to switch their consumption habits according to prices. Due to this fact, Allen creates a Geometric Index for CPI and compares it to his original Laspeyres Index. He concludes that the two indexes are minimally different and decides to use the Laspeyeres Index and this consequently serves as the estimate of CPI in this study.

Finally, rent was excluded from Allen's calculations of CPI but this did not have a significant effect that Allen attributes to the fact that "rent…generally amounted to less than 10% of expenditure".[16] As a final check for the accuracy of his construction of CPI, Allen compares his estimate with those of Lindert and Williamson (1983) and Feinstein (1998). Allen's CPI measurement follows the Feinstein measurement very well and avoids the large drop found in Williamson's measurement after 1820. Allen concludes that his estimate of CPI is thus as legitimate as any other measure put forth for this time period.

The preceding papers illuminate the theoretical and empirical basis for the analysis performed in this study. Rogoff (1996) provides empirical examples of the failure of Relative PPP in short to mid-run studies. Also, Rogoff (1996) explicitly cites trade frictions as the reason that observed half-lives of real exchange rate deviations are so persistent (in the order of 3-5 years). This feeds into the empirical analysis of Relative PPP and the underlying LOOP in historical data.

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[16] Allen (2001), pg. 422.

Ozmucur and Pamuk (2007) use cointegrative methods, as well as, the behavior of the coefficient of variation to examine market integration between European cities between the years of 1500 and 1800. Their results were mixed and didn't indicate that much economic integration existed between the cities in their sample during this time period. The cointegrative approach of Ozmucur and Pamuk differs greatly from the threshold auto regressive model used in Zussman (2002).

This study makes use of the threshold auto-regressive framework outlined in Zussman (2002) to compare the economic integration between bilateral city pairs (estimated by the speed of reversion to equilibrium levels and the size of transaction costs). It also uses a second cross sectional regression to elicit the effect that trade frictions have on the real exchange rate's speed of reversion to levels consistent with those of Relative PPP. Again, the methodology for the second cross sectional regression is outlined in Zussman (2002).

Trade frictions that are examined in this study are derived in large part from the preceding literature on border effects. Engel and Rogers (1996) shows that for a sample of cities in Canada and the United States that political borders have more of an influence on deviations in price levels consistent with LOOP than the geographical distance between cities. In addition, the results of Schulze and Wolf (2007) and Wolf (2007) provide evidence that ethnographic considerations play an important role in the measurement of trade frictions.

The data set for this study came from Robert Allen's (2001) study on deviations in real wages between cities in Europe during the time period from 1296-1914. Although Allen undertakes some estimation techniques to fill in missing data values for bread, the potential effect this could have on the results of this study are negligible. Allen's measure of CPI, which is used extensively in this study, follows the same trend as the other estimates put forth for this time period. Therefore, the data set is appropriate for the analysis included in this study and the results herein should not be biased by the construction of the data set.

Model Methodology:

1. Threshold Auto Regression Derivation

The threshold auto regression, as outlined in Zussman (2002), is used to estimate the speed of reversion that the real exchange rate experiences when it deviates significantly from levels consistent with relative PPP (e.g. it lies outside the estimated band of inaction). Significant deviations from relative PPP imply arbitrage opportunities will exist and be exploited by arbitrageurs, thereby pushing the real exchange rate into equilibrium as prices adjust.

Consider the existence of arbitrage opportunities between Country 1 and Country 2. Further, assume that both countries produce a single good. Let, the prices of the good in Country 1 and Country 2 be P_1 and P_2, respectively. Producers in either country have a choice to sell the good domestically or export the good to the other country. The conditions under which a producer in either country would choose to export the good to the foreign economy are written mathematically below:

$$P_1 * (1 + C) < P_2$$

$$P_2 * (1 + C) < P_1$$

Where c is a measure of the transaction costs associated with shipping this good from either economy and selling it in the foreign economy. These costs are assumed to be ice berg costs, as explained in Samuelson (1954).[17] Essentially, these estimated transaction costs are proportional to the price of a commodity. This model assumes that the estimate of C is constant between both cities. Therefore, shipping a good from Country 1 to Country 2 is equivalent to the cost of shipping a good from Country 2 to Country 1. From these equations, it is evident that an arbitrage opportunity doesn't exist if the following is true:

$$\frac{1}{(1+C)} \leq \frac{P_2}{P_1} \leq (1+C)$$

Let the real exchange rate be defined by $\frac{P_2}{P_1} = Q$. Converting this measure of the real exchange rate into a logarithmic form results in:

$$q = \ln\left(\frac{P_1}{P_2}\right)$$

Taking the logarithm of the above no arbitrage opportunity condition, the condition becomes:

$$-c \leq q \leq c$$

There is no need to account for the nominal exchange rate in this study because all prices are denominated in silver. This process turns the real exchange rate into percentage terms allowing the values for the bands of inaction, which are estimates of transaction costs, to be denominated in percentage terms as well.

After values of q are found for each city pair they are then made to have a mean of zero. This process is described by the equation:

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[17] Samuelson, P.A., (1954), The Transfer Problem and Transport Costs II: Analysis of Effects of Trade Impediments, The Economic Journal, 64: 264-289.

$$q = q - mean(q)$$

After the data is "de-meaned" using the above process, the value of the real exchange rate between two cities should on average be zero. This method is undertaken in Taylor and Taylor (2004) for the normalization of their price data.[18]

The benefits of using the threshold-autoregressive model to explain the behavior of real exchange rates is that it is theoretically straightforward and allows a second cross sectional regression to be used for the determination of what factors actually influence the level of transaction costs between two cities. The model assumes that significant deviations in the real exchange rate away from levels that satisfy relative PPP will result in an arbitrage opportunity that will be exploited by a savvy arbitrageur. When an arbitrage opportunity exists (IE the real exchange rate > transaction costs) a linear regression can be used to measure the speed of reversion back towards equilibrium. The estimate of the speed of reversion can then be used in a second cross-sectional regression to estimate the effects of trading frictions on the length of deviations from relative PPP (this is explained in greater detail later in the second part of the methodology section).

The equation for the threshold auto regression is written out below:

$$\Delta q_t = \lambda\left(q_{(t-1)} - c\right) + e_t, \qquad When\ q_{t-1} > c$$

$$\Delta q_t = e_t, \qquad When - c < q_{t-1} < c$$

$$\Delta q_t = \lambda\left(q_{(t-1)} + c\right) + e_t, \qquad When\ q_{t-1} < -c$$

18 Taylor, Alan M., and Mark P. Taylor 2004 "The purchasing power parity debate," Journal of Economic Perspectives 18, 135–58

In this equation c is an estimate of transaction costs associated with shipping a good from one economy and selling it in a different economy. λ Represents the speed of convergence towards the area within the bands of inaction, or what could be considered as a level of equilibrium. The estimate of e_t is random error and is white noise. As can be seen in the equation above there are actually two separate regressions that make up the threshold auto regression. One regression is run on the observations that lie outside of the band of inaction and estimates the value of λ. The other is a regression for inside the band that essentially follows a random walk process.

Determining appropriate values of c, or the transaction costs associated with shipping and selling a good in one economy to another is a pain staking process. There is no way to know appropriate values of c for any pair of cities simply through intuition. Because the real exchange rate is expressed in percentage terms, the values of c will also be given in percentage terms. For example, setting c=.01 would imply that the cost of shipping a good from one economy to another would be 1%. Given that the data is de-meaned so that it is centered around 0, this means that deviations away from equilibrium that are greater than 1% will result in an arbitrage opportunity that theoretically will be exploited by arbitrageurs. This process will then push the real exchange rate back to a level that satisfies relative PPP.

It becomes evident that the complicated aspect of the threshold auto regression is picking the appropriate levels of c and consequently the best estimate of lambda. Essentially, the researcher needs to vary the levels of c and run the band regression for each, add the Sum of Squared Residuals for both the outside and inside band regressions and find the minimum aggregated Sum of Squared Residuals to determine the best estimate of c. To give some perspective on this, consider the CPI data that was used in this study. There is data from 17 cities that can be compared bilaterally 136 ways. Each pair of cities has regressions run for multiple values of c ranging from .05 (5%) to .65 (65%) by increments of .01 (1%). There are then 60 threshold auto regressions run for each city pair. The number of regressions run total for CPI data is 60 (different values of c) * 136 (total bilateral city pairs), which is equal to 8,160 threshold auto regressions. The time associated with this type of analysis, given the time available for completion of this senior project, is so great that it necessitates the use of programs to help automate the process.

The program used for the band regressions in this project is included in the Appendix under Entry D. A quick summary of the program is that it does exactly the process that is outlined above. Essentially, it creates a ratio of prices for each commodity, takes the logarithm of the ratio and de-means the resultant data. After this step the data is denominated in percentages and the program sets about running regressions on data both inside and outside of estimates of the bands of inaction for various values of c. It then records the regression results and identifies the minimum sum of squared residuals between the two regressions. Finally it goes through the stored regression results one by one and finds the best estimates given the SSR for each city pair and exports the result to an excel file.

2. Cross Sectional Regression Using Trade Frictions

The second part of the analytical process is concerned with estimating the effects that trade frictions have on the length of deviations from relative purchasing power parity between a pair of cities. The collected estimates of λ_i's from the threshold auto regressions are used as a dependent variable for a cross sectional regression. The second stage regression is:

$$\lambda_i = \beta_0 + \beta_1 dist_i + \beta_2 dumport_i + \beta_3 dumpolitical_i \dots . + e_i$$

In this equation $dist_i$ is a measure of the distance between the two cities in question. $port_i$ Is a dummy variable to account for whether one or both of the two cities has a port and $dumpolitical_i$ is a dummy variable to account for whether or not the two cities were under the same political regime. β_0 Is a constant and e_i is an error term.

The equation given above is just one example of a cross sectional regression that uses well known trade frictions as independent variables to help explain the speed of reversion observed in the real exchange rate between two cities. These are by no means all of the factors that could have a systematic effect on the speed of reversion. One could theoretically account for many more factors than the ones given above. Of course, the number of variables that can be included relies on the number of observations in the sample. Again the time available for the completion of this project was a limiting factor for the number of variables that could be tested in the second stage regression analysis of this study.

A problem with the data used in this study is that it covers such a large span of time. On the one hand this results in a good number of observations for each city pair and consequently in a good number of statistically significant estimates of λ that can be used in the second stage of cross sectional analysis. Unfortunately, there is so much change during this period, economically and politically, that using some of the better known sources of trade frictions to account for the different estimates of λ can be problematic. Specifically, political borders and language are two well documented trade frictions that are hard to apply to this data. For example, Strasbourg can be considered as both a part of France and the Holy Roman Empire during this time period. Therefore, the more ethnological trade frictions, such as those found in Wolf (2007) are not included in this analysis.

Research and Results:

1. Overview

The data used in this study was taken from Bob Allen's homepage and was used in his paper "The Great Divergence in European Wages and Prices from the Middle Ages to the First World War.". This study was published in *Explorations in Economic History*. Allen constructs measures of CPI, as well as calculations of PPP based on wage and price data for a set of European cities. The cities covered in Allen's data set are:

London	Munich	Warsaw	Krakow	Gdansk
Vienna	Augsburg	Leipzig	Madrid	
Strasbourg	Paris	Amsterdam	Antwerp	
Naples	Valencia	Milan	L'viv	

Unfortunately, the data coverage across cities is not uniform and made comparison between some pairs of cities are difficult. Due to the inconsistency in data coverage, this study focuses on 6 commodities that had the most data coverage between cities. These commodities are Allen's measure of CPI, peas, candles, wheat, beer, barley and rye. The results are presented and discussed in the following section.[19]

The second cross sectional regression borrows some of the dependent variables used in studies such as Engel and Rogers' "How Wide is the Border" and Schulze, Wolf's "On the Origins of Border Effects: Insights from the Habsburg Empire". The variables used in each second stage regression were:

[19] Data coverage was too sparse for peas, candles, beer and barley to analyze individually. They are included in an aggregate commodity data set explained later in this section. In addition to these commodities, charcoal, firewood and herring were tested individually but not included in the appendix (extreme lack of observations).

- Average CPI ratio between the two cities
- Distance in miles between the two cities
- Dummy variables to account for whether one, both or neither of the cities in question had ports.
- Dummy variables to account for whether or not the two cities in question were in the same political state (insert footnote here to talk about the Poland, HRE and Spain dummies).
- Dummy variable to test for the effect of a shared political border between cities.

This study used multiple measures for the level of integration between two cities for the cross sectional regression analysis for these commodities. In addition to λ, a measure of the rate of price reversion between two cities, this study uses a measure of the half-life of shocks and the estimated values of the bands of inaction as proxies for the level of economic integration between two cities. Finally, this study combines a ratio of the estimated λ and c (the size of the band of inaction) to estimate another type of economic distance between the two cities. This makes sense because the width of the band of inaction and the speed of reversion between two cities are both dependent on transaction costs. The width of the band is likely due to physical transaction costs associated with shipping and selling commodities in different markets. On the other hand, the speed of reversion can be affected by information flows. Creating a ratio of these two measures is a way to incorporate both of these influences into one descriptive statistic.[20]

2. CPI Data Analysis

CPI data coverage is better than any other commodities used in this study. These were constructed using the prices, denominated in silver, and weighted using a geometric weighting system. Naturally, the commodities included in this measure vary slightly between cities. For example, southern cities such as Madrid and Valencia don't have price coverage for beer and

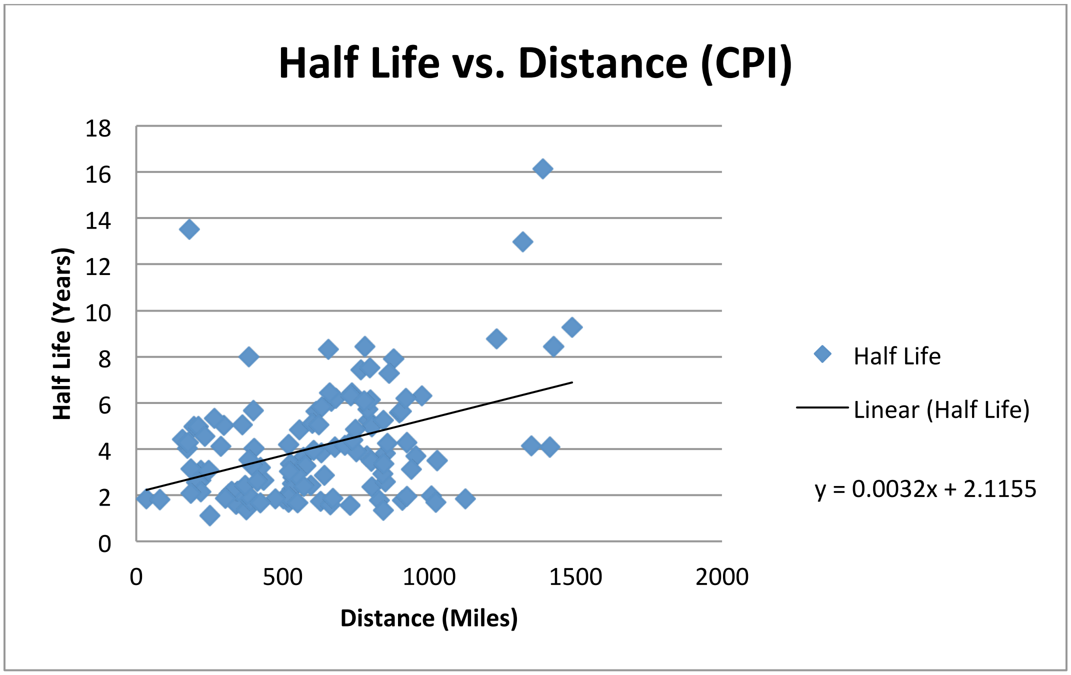
[20] Ratio = $-C/\lambda$

subsequently beer isn't included in the measure of CPI for Madrid and Valencia. However, in cities such as Warsaw and London beer was a significant part of consumption and is thus included in their data sets, as well as, their measures of CPI.

Of the 136 possible city combinations, the threshold auto regressions run on CPI data resulted in 127 usable estimates of λ, or the speed of reversion towards the band of inaction. The mean estimated size of the band of inaction was .1315, or 13.15%. The average estimated half-life of shocks that resulted in a price ratio that lies outside of the band of inaction was 4.38 years. The average estimated value of λ was -0.196 which is the percentage of the gap between the observation and the band of inaction that dies away each year.

The second cross sectional regression shows a positive, significant relationship with the distance between the two cities in question and the half-life of price shocks to CPI between the two cities. At the top of the next page is a chart that plots the estimated half-lives against the distance between two cities.

Figure 1.



It seems obvious from this scatter plot that distance has a positive effect on the estimated half-life of real exchange rate deviations from relative PPP. A trend line was fit to the data and estimates a positively slope, again implying that distance between cities on average increase the half-life of real exchange rate deviations. This makes intuitive sense because presumably cities that were further away from one another would be limited in their ability to trade with one another due to high costs of transporting commodities. What's surprising is that the dummy variables made to account for whether one or both of the cities in question had ports were only marginally significant. Since water transport is the cheapest means of shipping commodities it would only make sense that cities with significant ports would trade more frequently and thus see quicker price stabilization.

Political alignment proved to be a significant factor when trying to break down these transaction costs from the CPI data. Both a dummy accounting for whether or not the cities in question were in Poland or members of the Holy Roman Empire showed extremely significant beta coefficient estimates. These were .120 and -.0391 respectively. Again, these were significant at $p<0.01$ and $p<0.12$, respectively. What's troubling about these results is the positive sign on the beta coefficient estimate for the Poland political dummy. This would imply that, given both cities are part of Poland, shocks would die out slower and in turn permit longer deviations from relative purchasing power parity. This might imply that trading within Poland's political state, at least historically, didn't provide cities therein with constant prices. The regression results, along with the equation for the second stage regression for CPI are:

CPI Cross Sectional Regression Equation:

$$\lambda_i = \beta_0 + \beta_1 distancemiles_i + \beta_2 polanddummy_i + \beta_3 H.R.E.dummy_i + \varepsilon_i$$

Regression Results:

Variables	**Beta Coefficient Estimate**	**Standard Error**
distancemiles	0.000100***	(2.69e-05)
Poland Dummy (0,1)	0.120***	(0.0366)
H.R.E Dummy (0,1)	-0.0391×	(0.0247)
Constant	-0.259***	(0.0199)
Observations		127
R-squared		0.201

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**
× p<0.12

Given these counterintuitive results, it seems worthwhile to discuss them in relation to those found in Zussman's (2002) paper. The average band size for Zussman's study was about .23. The average value of λ in Zussman's study was -.45.[21] As stated earlier, the average value for c, the band of inaction, was .1315 or 13.15%. On average, for measures of CPI between these cities whose deviations in the real exchange rate that were greater than 13.15% tend to be arbitraged away. This value for the estimates created from CPI measures is almost half that of the one found in Zussman. Given that Zussman's sample is of 108 countries from the time period between the years 1960 and 1996, the results found in this section would imply that transaction costs have gone up considerably over time. This could be explained by the rise of the global economy and the political/bureaucratic manner in which international trade is conducted in today.

Another possible explanation for the seemingly smaller bands of inaction in this historical data could be due to an Aggregation Bias with the calculation of a CPI measure. Chen and Engel (2004) point to aggregation bias as a reason that estimated half-lives of real exchange rate shocks tend to die out more slowly than expected.[22] Essentially, it has to do with the weighting of the inputs into a measure of CPI. If goods that are more volatile are weighted more heavily, then it could make the estimated price reversion of that sample artificially large. On the contrary, if less volatile commodities were weighted more heavily, it could make the estimated reversion speed artificially small. To test if this is something that is present in the data for CPI, I use data for individual commodities, to test whether their estimated speeds of convergence are more in line with those described in Zussman (2002)

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[21] Zussman (2002), pg. 11.
[22] Chen, Shiu-Sheng and Charles Engel. 2004. "Does 'Aggregation Bias' Explain the PPP Puzzle?" Working Paper Series No. 10304, National Bureau of Economic Research, February.

3. Commodity Data Analysis

a. Pooled Commodity Data Analysis

As stated before, the commodities that I research in this study are: wheat, rye, barley, beer, candles and peas. Unfortunately, the data coverage is too sparse for most goods to derive significant results with statistical analysis of only one commodity. Wheat and rye have enough data coverage and have individual analysis later in this section. For candles, the threshold auto regressive analysis only yielded 14 usable estimates of λ and severely limited the power of the second stage cross sectional regression to examine trade costs.

In response to the problem of sparse data coverage, this study pools all of the commodity data into one aggregate data set and performs cross goods analysis on this in order to test for the effect of trade frictions. I am able to maintain the individual characteristics that different commodities have by creating a new variable that is equal to the distance between the two cities multiplied by a dummy variable that accounts for which commodity the estimate of λ or C was derived from. Mathematically, these dummy variables can be written as:

$$distance(peas)_i = distance_i * dummypeas_i$$

$$distance(beer)_i = distance_i * dummybeer_i$$

$$distance(wheat)_i = distance_i * dummywheat_i$$

$$distance(barley)_i = distance_i * dummybarley_i$$

$$distance(candles)_i = distance_i * dummycandles_i$$

I exclude the dummy variable for rye, so the coefficients of these estimates are understood relative to the distance effect of rye. For example, if the estimated beta coefficient on $distance(peas)$is negative, this would imply that the distance between cities has less of an effect on convergence rates when peas are traded as opposed to rye. Also, there is a general distance variable included in the regression that tests for the effect of distance across commodities. That is, it will test for the presence of an average effect of distance across commodities. Lastly, I include the political dummy variables in the aggregate commodity regression. The results from the cross sectional regression for the aggregate commodity data set are:

Aggregate Commodity Data Cross Sectional Regression Equation (C):

$$C_i = \beta_0 + \beta_1 distancemiles_i + \beta_2 distpeas_i + \beta_3 distbeer_i + \beta_4 distwheat_i + \beta_5 distbar_i + \beta_6 distcan_i + \beta_7 port2_i + \beta_8 polanddummy_i + \beta_9 H.R.E.dummy_i + \beta_9 spaindummy_i + \varepsilon_i$$

Regression Results:

Variables	**Beta Coefficient Estimate**	**Standard Error**
dist	0.000126***	(4.08e-05)
distpeas	-2.12e-05	(5.02e-05)
distbeer	-0.000215***	(4.58e-05)
distwheat	-0.000108***	(3.89e-05)
distbar	-1.43e-05	(4.55e-05)
distcan	-0.000321***	(4.51e-05)
port2	0.00252	(0.0228)
polandhalf	-0.0622**	(0.0289)
hrehalf	-0.00948	(0.0218)
spainhalf	0.0559*	(0.0333)
Constant	0.292***	(0.0262)
Observations		146
R-squared		0.409

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Aggregate Commodity Data Cross Sectional Regression Equation (λ):

$$\lambda_i = \beta_0 + \beta_1 distancemiles_i + \beta_2 distpeas_i + \beta_3 distbeer_i + \beta_4 distwheat_i + \beta_5 distbar_i + \beta_6 distcan_i + \beta_7 port2_i + \beta_8 polanddummy_i + \beta_9 H.R.E.dummy_i + \beta_9 spaindummy_i + \varepsilon_i$$

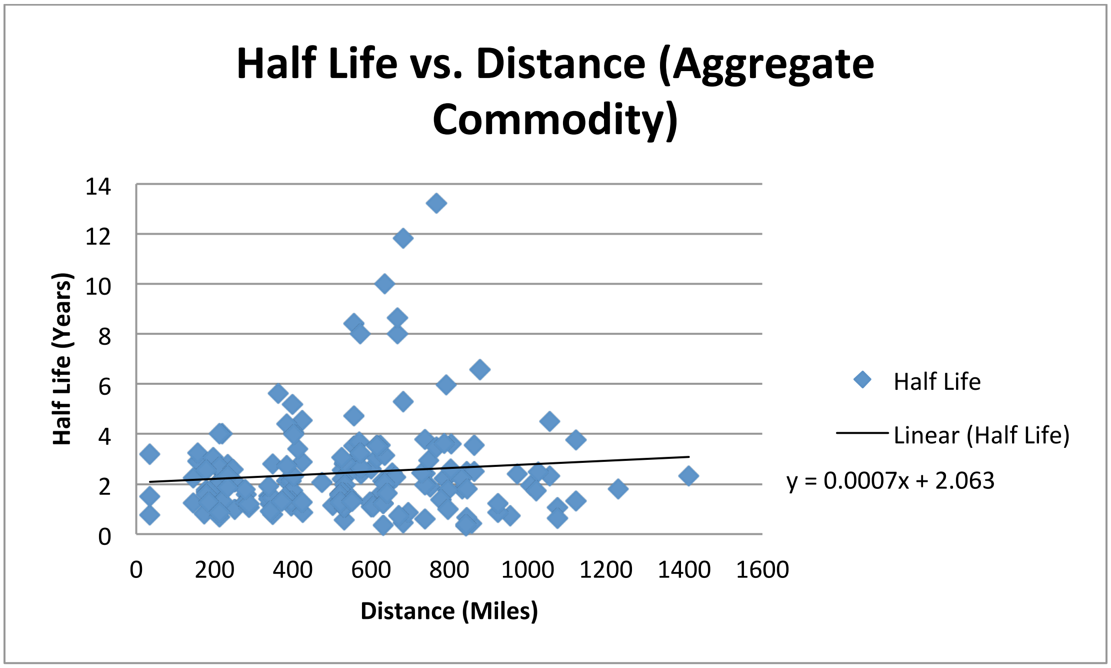
Regression Results:

Variables	**Beta Coefficient Estimate**	**Standard Error**
dist	0.000192**	(8.12e-05)
distpeas	-0.000321***	(9.98e-05)
distbeer	-9.95e-05	(9.11e-05)
distwheat	-0.000164**	(7.73e-05)
distbar	-0.000420***	(9.05e-05)
distcan	-7.93e-05	(8.98e-05)
port2	-0.139***	(0.0454)
polandhalf	-0.110**	(0.0574)
hrehalf	-0.00948	(0.0433)
spainhalf	-0.240***	(0.0662)
Constant	-0.204***	(0.0521)
Observations		146
R-squared		0.354

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

The distance variable is positive and statistically significant at the p<.05 level in both regressions on the band of inaction and speed of reversion estimates. The estimated beta coefficients for these regressions are .000128 and .000192, respectively. On average, a 100 mile increase in the distance between two cities during this time period would result in a .0128 increase in the estimated value of C, the band of inaction. Similarly, a 100 mile increase in distance between two cities would on average yield a .0192 decrease in the speed of reversion for the real exchange rate to the band of inaction (this is because the estimate of λ is negative). The graph at the top of the next page plots estimate half-life of deviations in the real exchange rate against the distance between the two cities. It can be seen from this graph that there is a general positive effect that distance has on the estimated half-life of deviations.

Figure 2.



In both regressions, the distance/commodity dummy variables all displayed negative beta coefficient estimates. This would mean that the distance between cities, for all commodity data entries, is less significant an influence on C/λ than the distance between cities for rye data entries. Essentially, rye has the largest relative effect on C/λ of the commodities covered in this study.

The port dummy variable gave mixed results in these regressions. In the regression that made use of C as the dependent variable, the beta coefficient estimate associated with the port variable is positive and insignificant. The estimated value of the beta coefficient is .00252, which implies that on average the fact that both cities in question had a port would result in an increase of .00252 in the estimate of the band of inaction. This is counterintuitive however because access to ports should increase the volume of trade between cities. In this case, it would be expected that the beta coefficient estimate on the port dummy variable would be negative.

A more theoretically acceptable estimate of the beta coefficient on the port dummy variable comes from the regression results in Entry C of the Appendix. In this regression, λ is used as the dependent variable. The estimated value of the beta coefficient on the port dummy is -0.139 and is significant at the $p<.05$ level. This would imply that on average the fact that two cities had access to ports increased the estimated speed of reversion for the real exchange rate by -.139, or 13.9%. This dramatically decreases the estimated half-life of deviations in the real exchange rate between two cities. This result makes sense as we would expect the relatively easier trade between cities with water access to result in higher trade volumes, thus making the exploitation of arbitrage opportunities faster.

The political dummy variables gave mixed results in the cross sectional analysis for the aggregated commodity data. A table that includes the beta coefficient estimates from the political dummy variables, along with their standard errors, is displayed on the top of the next page:

Figure 3.

Variables:	**Beta Coefficient Estimate (C)**	**Standard Error (C)**	**Beta Coefficient Estimate (λ)**	**Standard Error (λ)**
Poland Dummy	-0.0622**	(0.0289)	-0.110**	(0.0574)
H.R.E. Dummy	-0.00948	(0.0218)	-0.00948	(0.0433)
Spain Dummy	0.0559*	(0.0333)	-0.240***	(0.0662)

Standard errors:
***** p<0.01, ** p<0.05, * p<0.1**

Each of the political variables above takes a value of 1 if both cities of the observation fall under the same political state, 0.5 if one country falls under the given political state and 0 if neither.

Almost all beta coefficient estimates for the political variables are negative. Intuitively this makes sense as this result implies that cities within these larger, more influential political states had more efficient market structures. This is an acceptable result because large political states engaged in more international trade than smaller, less influential political states. Therefore, prices in cities that were under political regimes that engaged in international trade on a relatively large scale would be more influenced by the international price of commodities, and their prices would likely adjust to an international equilibrium price, barring the effects of trade frictions.

The one beta coefficient estimate that is positive is attached to the Spanish/Hapsburg political variable for the cross sectional regression the used C, the estimate of the band of inaction, as the dependent variable. This implies that cities that fell under Spanish rule on average observed higher transaction costs that those who were not under Spanish rule. More specifically, the estimates value of 0.0559 implies that if both cities in the sample were under Spanish rule, the estimated level of transaction costs increased by .0559 or 5.59%. If only one city were under Spanish rule then transaction costs would be expected to increase .0279 or 2.79%. This could be the result of tariffs meant to limit the amount of international trade imposed by Spain. It could also generally mean that Spain engaged in less international trade, with the commodities covered in this study, than cities in either Poland or the Holy Roman Empire.

The results from the cross sectional regression that uses the estimates of λ as the dependent variable follow the intuition laid out by studies such as Engel and Rogers (1996). Given that all of the beta coefficient estimates are negative; this model shows that cities under the rule of these large political states saw faster real exchange rate reversion to levels consistent with Relative PPP (values within the band of inaction). This would make sense as one would expect the volume of international trade from these economies to be greater than cities that fell under less affluent/influential political states. For example, the beta coefficient estimate on the Spanish political dummy is significant at the $p<.01$ level and takes a value of -0.240. This would imply that on average, if both cities in the sample were under Spanish rule that the rate of convergence for the real exchange rate would increase by -0.240. Put another way, the distance between the estimated level of transaction costs and the real exchange rate would die out by an extra 24% annually if both cities in question were in Spain. Subsequently, if one city in the data sample was under Spanish rule, the estimated value of λ would increase by -0.12 or 12%.

To add more specificity to the data analysis in this study, the next section covers the individual cross sectional analysis for the commodities wheat and rye. Again, these commodities had the most expansive data coverage and other cross sectional regressions based on different commodity data did not have enough observations to achieve an acceptable amount of power. Nonetheless, the cross sectional regression results for peas, barley and candles are still included in the Appendix. They are under entries A, B and C, respectively.

b. *Wheat Data Analysis*

The data coverage for wheat was the most expansive of the commodity data. There were 79 significant values of λ that were generated from the threshold auto regression process. Regression results for this analysis are:

Wheat Cross Sectional Regression Equation:

$$\lambda_i = \beta_0 + \beta_1 bothports_i + \beta_2 polanddummy_i + \beta_3 spaindummy_i + \varepsilon_i$$

Regression Results:

Variables	Beta Coefficient Estimate	Standard Error
bothports	-0.101*	(0.0540)
polandvariable1ifboth5ifone	-0.134	(0.0883)
spainvariable1ifboth05ifone0ifne	-0.185***	(0.0594)
Constant	-0.223***	(0.0435)
Observations		79
R-squared		0.197

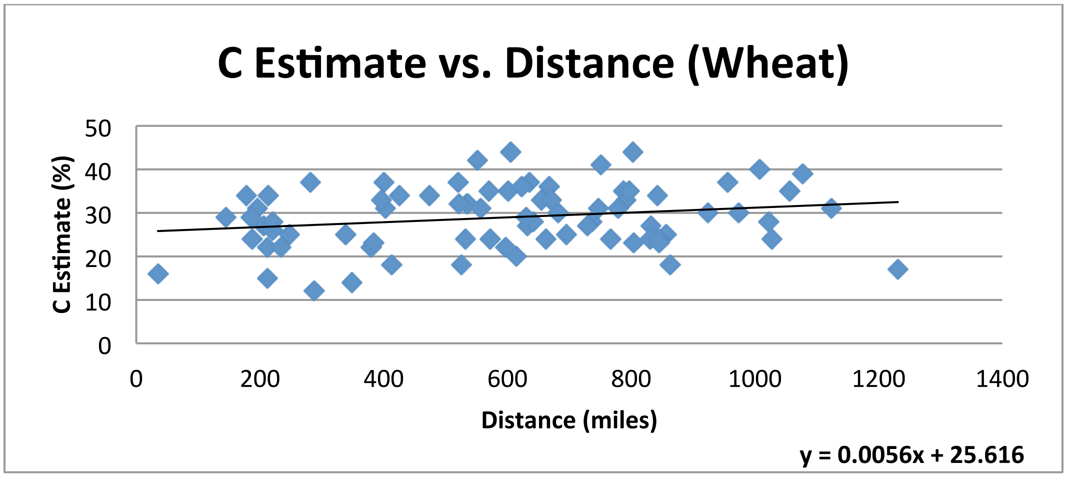
Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Where $bothports_i$ is a dummy variable that results in a 1 if both cities in the city pair have ports and 0 if one or neither has a port. Both $polanddummy_i$ and $spaindummy_i$ are dummy variables that take a value of 1 if both cities are in Poland/Spain and 0 if one city is not in Poland/Spain.

The β_1 estimate is -0.101 and is significant at $p<0.01$. In essence, if both cities in a given city pair had ports, the speed of price reversion (λ) is expected to decrease by .10 or 10%. This means that arbitrage opportunities were exploited quicker between cities that were ports as opposed to one or neither being a port, which makes sense economically given that sea transportation was less costly that land transportation. A dummy variable that took a value of 1 when one city in the sample was a port and 0 if neither were a port was insignificant in this regression. The estimate of β_3 is -0.185 and is significant at $p<0.01$. This can be interpreted as an expected increase in the estimated λ between two cities of .185 or 18.5% given that both cities are in Spain. Again this larger negative effect implies that prices reverted quicker between cities that were within the same political state and is theoretically satisfactory. The estimate of β_2, while not significant at traditional levels, is significant at $p<0.22$. Most importantly its value is negative and again implies that cities that fell under the same political state were more economically integrated than those that were not.

Although distance between cities was not found to be a statistically significant factor for measures of estimated economic integration with the wheat data, there still seems to be a slight negative effect that distance plays in economic integration. Below is a graph of the estimated values of C, the band of inaction, against the distance between cities. It’s evident that there is a slight upward trend in the estimate of C as distance increases. The positive relationship between distance and the estimated value of C implies that distance a general negative effect on economic integration in this data.

Figure 3.



c. Rye Data Analysis

The data coverage for rye was the second most extensive after wheat in this study. The threshold auto regression analysis yielded 25 significant estimates of λ that could be used in the second stage cross sectional regression. The regression results are:

Rye Cross Sectional Regression Equation:

$$\lambda_i = \beta_0 + \beta_1 samecountrydummy_i + \beta_2 polanddummy_i + \varepsilon_i$$

Regression Results:

Variables	Beta Coefficient Estimate	Standard Error
samecountrydummy1	-0.146***	(0.0314)
polandvariable1ifboth5ifone	0.241***	(0.0748)
Constant	-0.328***	(0.0383)
Observations		25
R-squared		0.507

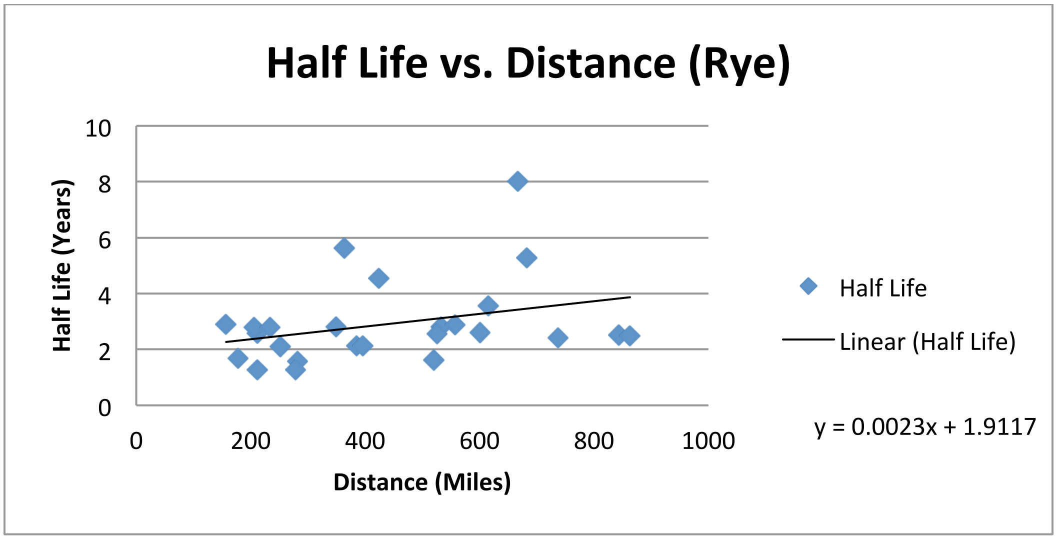
Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Where $\text{samecountrydummy}_i$ is a dummy variable to indicate whether the cities in question were in the same country. This variable takes a value of 1 if both cities are in the same country and 0 if not. The polanddummy_i variable is a dummy variable that takes a value of 1` if both cities in question were in Poland and 0 if not.

The cross sectional regression for wheat had the highest R-squared value of any of the cross sectional regressions at .507. Given that this is historical data, this level of explanative power in a model is considerable. The estimate of β_1 is -0.146 and is significant at the p<0.01 level. This again lends a hand to the underlying theoretical framework of the model and shows that countries in the same political state are more economically integrated than those that are not. The estimate of β_2 is somewhat problematic. It is estimated at 0.241 and is troubling because it is positive. This would imply that given two cities are in the same country and that country is Poland, the net effect would be that lambda would decrease by .095 (because both cities are in the same country and that country is Poland ($\beta_1 + \beta_2$)). This implies that cities within Poland were economically less integrated, when it came to rye, than those outside of Poland. This is contrary to the findings from both the pooled commodity data and data for CPI.

Similar to the data for wheat, distance does not play a statistically significant role in the determination of estimated measures of economic integration for the rye data in this study. However, there still seems to be an average positive effect that distance between cities has on the estimated half-life of real exchange rate deviations between them. Below is a graph that maps distance against estimated half-life for the rye data. The fitted trend line displays a positive slope, implying that distance has a positive effect on half-life.

Figure 4.



Summary and Final Insights:

Figure 5.

Data Sets:	CPI	Aggregate Commodity	Wheat	Rye	Zussman
C Estimate:	0.131	0.275	0.289	0.321	0.23
λ Estimate:	-0.196	-0.326	-0.33447	-0.244	-0.45
Implied Half Life:	3.177	1.757	1.702347	2.478	1.159

Above is a table that displays the mean values for both estimates of the band of inaction (C) and the real exchange rate adjustment speed parameter (λ) across the data sets used in this study. As a point of reference, I include the mean estimates for these parameters from Zussman (2002). It's evident that the estimates of CPI created by Allen (2001) is subject to some type of aggregation bias, as the mean estimates of C and λ are significantly lower than those for the commodities included in the data set. The estimates of C and λ are much lower than those seen in Zussman (2002), which seems to imply that international markets have become less integrated over time.[23] Consequently, the implied half-life of deviation in the real exchange rate is 3.17 years, as opposed to 1.159 years for Zussman (2002).

In contrast the estimates of C and λ derived from the commodity data in this study are more in line with those in Zussman (2002). The commodity data estimates of C in this study are higher and estimates of λ lower than those found in the Zussman (2002) study. These results suggest that transaction costs have gone up significantly over time. Equivalently, the speed of reversion for the real exchange rate increased over time. These observations make sense theoretically because communicative technology and international trade have become markedly more efficient over time. In essence, the estimates of market integration between the cities in the data used in this study and the results from Zussman (2002) differ slightly but in a way that is logical and easily explained.

The analysis of CPI data was possible because of its substantial coverage. Political allegiance is a significant factor in the cross sectional regression for CPI. Specifically, the dummy variables for Poland (1 if both cities, 0 if else) and the H.R.E. Poland (1 if both cities, 0 if else) are statistically significant. The distance in miles variable between the cities in the sample is very significant and again implies that distance between cities negatively influences the level of economic integration between them.

To avoid the problem of low individual commodity data coverage, the data for all commodities was aggregated into a single data set. Cross sectional analysis on the estimates of C

[23] Zussman (2002) uses data from roughly 1960-1996

and λ elicits several statistically significant trade frictions. In both regressions, the distance between two cities is highly significant and has a negative influence on the estimates of economic integration. The port variable (1 if both cities have a port, 0 if else) is highly significant and suggests that the presence of a port in both cities in the sample positively influences the rate of real exchange rate convergence (λ). Conversely, the port variable was insignificant in the cross sectional regression that uses C as a dependent variable. The Polish dummy variable (1 if both cities in Poland, .5 if one and 0 if else) is significant in both regressions and positively influences the estimates of economic integration between cities. Similarly, the Spanish dummy variable (1 if both cities in Spain, .5 if one and 0 if else) is statistically significant in both regressions. However, the Spanish dummy variable yielded a counter intuitive beta coefficient estimate in the regression that uses C as a dependent variable. The Holy Roman Empire dummy variable (1 if both cities in H.R.E., .5 if one and 0 if else) is insignificant in both regressions.

The two individual commodities covered in this section are wheat and rye. This is due to the fact that the data coverage for the other commodities is too sparse for significant results to be derived from regression analysis. In opposition to the results from CPI and the aggregated commodity data set, the distance variable is insignificant for both commodities. The Polish dummy variable (1 if both cities in Poland, .5 if one and 0 if else) is significant for rye data and seems to negatively influence the estimates of economic integration between two cities. The Poland dummy variable in the wheat regression is theoretically acceptable (it positively effects the estimate of λ) but is statistically insignificant. The port dummy variable (1 if both cities have a port, 0 if else) is significant in the wheat cross sectional regression and not for rye's.

Additionally the Spanish dummy variable (1 if both cities in Spain, .5 if one and 0 if else) is significant for wheat and not for rye.

Model Critiques and Extensions:

The construction of the real exchange rate estimates in this study implies that the costs associated with shipping a commodity from one economy and selling it in another are iceberg costs. Essentially, the assumption that transaction costs are iceberg costs means that transaction costs can be estimated as a fraction of the price that is charged for a commodity. Consider an example where a city wants to export bananas to another city. According to the iceberg trade costs criteria, the exporting city has to produce and ship $x > c$ bananas to hit the export market. The bananas that are shipped and sold in the international market ($x - c$ bananas) "melt" on their way to the foreign market and this "melting" is an estimate of the trade costs between the two cities. In sum, the assumption that trade costs are ice berg costs implies that transactions costs are proportional to the price of the exported commodities.

However, if costs were of a different nature, then the construction of the real exchange rate used in this study may be less appropriate. For example, if there is a fixed price to ship a good using a commercial barge to another market then the estimated transaction costs generated from the iceberg theoretical framework could be inaccurate. This is due to the fact that iceberg costs are proportional to the value of the goods being shipped from one market to another. Under iceberg costs, this would imply that shipping a 2 ton cargo of gold for export would be more expensive than shipping a 2 ton cargo of feathers. Since shipping costs are fixed in this scenario, ice berg costs do not accurately explain transaction costs.

A potential way that the results of this study could be refined further is to try the same analysis with different construction of the real exchange rate. One way to accomplish this would be to use a differenced estimate of the prices of commodities so that the real exchange rate would be defined as the difference between the prices, denominated in silver, between the price charged in the home and foreign economies. The estimate of the band of inaction would then be denominated in grams of silver and the results would be able to give estimates of total transaction costs, as opposed to, a percentage of a commodity's value. Fixed costs could be exposed because total estimated transaction costs across commodities would theoretically have very similar estimates. In the current framework, it is hard to compare the total levels of transaction costs between commodities.

The assumption that transaction costs, denominated in percentages or silver, stays constant over a 500+ year period is a limiting aspect of this study, due to the computational constraints. Ideally, the estimated value of bands should be allowed to vary over time as new factors that affect the efficiency of international trade come into the market. The most straight forward way to accomplish this would be to break down the data set into sub samples (e.g. period 1: 1300-1400, period 2: 1400-1500, etc.) and estimate a value for the size of the band of inaction for each time period.[24] However, this could prove difficult because many cities have data coverage for different time periods. When they are compared against one another in any one time period there will be a few cities that do not have price data coverage for the time period in question. It would therefore be difficult to obtain a statistically significant value of C in many periods given the current state of the data set. This problem could be remedied with the use of interpolation. There are multiple ways to interpolate data and the determination of the most

[24] This method is undertaken in Ozmucur and Pamuk (2007).

appropriate method of interpolation could help the analysis of this study immensely. Interpolation of missing data values was implemented in Taylor and Taylor (2004) as a way to gain more statistical power through a higher number of observations. Not only would this allow for time varying estimates of transaction costs but it would also allow for individual commodity analysis to yield statistically significant results.

Conclusions:

This study examines the historical levels of economic integration for a set of cities in Europe. Within the study, the speed of reversion for the real exchange rate when it is outside levels consistent with Relative PPP and the estimated size of transaction costs serve as proxies for the level of economic integration between cities. Using the threshold auto-regressive framework outlined in Zussman (2002) and Taylor and Taylor (2004) this study is able to generate estimates for λ (the estimated speed of real exchange rate reversion) and C (the estimated band of inaction) that can be used in a second, cross-sectional regression to elicit the effects of trade frictions on these measures of economic integration.

Real exchange rate estimates are created for 5 individual commodities (wheat, barley, rye, peas and candles) and Robert Allen's CPI estimates. This study finds that the estimates of λ and C derived from the CPI data is considerably out of line with the results found in Zussman (2002). The estimates that come from this data imply that international economic integration was more prevalent in the time sample covered in this study (1290-1914) as opposed to the time period covered in Zussman (2002) (1960-1996).

The counterintuitive results from the estimates generated by the CPI data, coupled with a lack of data coverage for individual commodities inspired the pooling of commodity data into an aggregate data set. Additionally, two individual commodities were evaluated (wheat and rye) because their data coverage is sufficient to generate statistically significant estimates for the effect of trade frictions on economic integration. Both the aggregate data set and the individual commodities estimate values of C and λ more in line with those in Zussman (2002). This fact points to a possible aggregation bias effect in the data for CPI.

Multiple trade frictions have a significant effect on the level of economic integration between cities in this study. The distance between cities is highly significant and has a negative effect on the level of economic integration between cities in both the CPI data and the pooled commodity data. The presence or a port in both cities is also a significant, positive factor for economic integration for cities in wheat and pooled commodity data sets. Cities that fell under the Polish political state appear more economically integrated across cities than those who were not. Falling under Polish rule in almost all data sets has a positive correlation with the levels of economic integration between two cities. Similarly, cities that were under Spanish rule in this data set appeared more economically integrated across cities. Cities under the Holy Roman Empire did not display a statistically significant effect on the levels of intra city economic integration.

In sum, markets have become more integrated over time. The half life of deviations away from levels consistent with Relative PPP are still persistent in the present day but are much less so than the estimates found in this study. The effects of distance and political borders on estimated levels of economic integration between cities in this study fall in line with the results of Engel and Rogers (1996). Therefore, this study offers more support that the process of international economic integration has continued over time. Interestingly, this study shows that the regulatory forces of arbitrage can accurately explain the behavior of the real exchange rate between cities in this sample. This implies that the European cities in this sample were economically integrated during this time period and responding to trends in the international macro economy.

Appendix

Entry A:

Pea Cross Sectional Regression Equation:

$$\lambda_i = \beta_0 + \beta_1 portdummy(1\ port)_i + \beta_2 H.R.E.dummy_i + \varepsilon_i$$

Regression Results:

Variables	Beta Coefficient Estimates	Standard Error
port	-0.254***	(0.0839)
hredummy1ifboth0otherwise	-0.156×	(0.0951)
Constant	-0.264***	(0.0549)
Observations		18
R-squared		0.387

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**
× p<0.13

Entry B:

Barley Cross Sectional Regression Equation:

$$\lambda_i = \beta_0 + \beta_1 distancemiles_i + \beta_2 portdummy(both\ ports)_i + \beta_3 polanddummy_i + \varepsilon_i$$

Regression Results:

Variables	Beta Coefficient Estimate	Standard Error
distancemiles	-0.000199*	(0.000111)
bothports	-0.443**	(0.176)
polandvariable1ifboth5ifone	-0.445	(0.358)
Constant	-0.0670	(0.209)
Observations		23
R-squared		0.363

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Entry C:

Candle Cross Sectional Regression Equation:

$$\lambda_i = \beta_0 + \beta_1 portdummy(1\ port)_i + \ \varepsilon_i$$

Regression Results:

Variables	**Beta Coefficient Estimates**	**Standard Error**
port	0.121*	(0.0598)
Constant	-0.343***	(0.0452)
Observations		14
R-squared		0.254

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Entry D:

```
foreach city of varlist dm*{
 generate abs`city' = abs(`city')    "absolute value of data to see whether values are out or inside
 generate lag`city' = l.`city'        the band"
 generate xmin`city' = 100
 local counter = 1
 forvalues bands = .05(.01).65 {              "loop through all possible values of C"
  local c = int(`bands'*100)
  local c1 = int(`bands'*100) - 1
  quietly generate outss`city'`c' = `city' if abs`city' >= `bands'  "creates values that are outside the
  quietly sum outss`city'`c'                                          band"
  quietly gen Nout`city'`c' = r(N)
  quietly generate inss`city'`c' = `city' if abs`city' < `bands'    "creates values that are inside the
  quietly sum inss`city'`c'                                          band"
  quietly gen Nins`city'`c' = r(N)
  if Nins`city'`c' < 3{
   quietly replace inss`city'`c' = .0425                        " if there are fewer than 3 obs. inside
  }                                                           the band or outside then they are replaced
  if Nout`city'`c' < 3{                                    with a constant. They will never be winning regs.
   quietly replace outss`city'`c' = 1                  this avoids potential early termination"
  }
  drop Nins`city'`c'
  drop Nout`city'`c'
  capture{
   quietly regress inss`city'`c'
```

```
    quietly generate irs`city'`c' = e(rss)
    quietly generate dist`city'`c' = `city' - `bands' if `city' > `bands'
    quietly replace dist`city'`c' = `bands' + `city' if `city' < -`bands'
    quietly regress D.outss`city'`c' l.dist`city'`c'
    est store A`city'`c'
    quietly generate ors`city'`c' = e(rss)
    local x = ors`city'`c' + irs`city'`c'
   }
   if xmin`city' > `x' {                    "Logical command to see if present regression is the
    replace xmin`city' = `x'                  minimum in terms of rss"
    if `counter' == 1{
     quietly generate winrss`city' = ors`city'`c'
     local counter = `counter' + 1
    }
    if `counter' > 1{
     replace winrss`city' = ors`city'`c'
    }
   }
  }
  forvalues d = 5(1)64{          "Recalls all stored regression results"
   capture{
   est restore A`city'`d'
   quietly generate beast`city'`d' = e(rss)
   if beast`city'`d' < winrss`city' | beast`city'`d' > winrss`city'{    "This is equivalent to saying if
    est drop A`city'`d'                                                   the estimated rss of any regression
    drop beast`city'`d'                                                 is not the minimum rss of all regressions,
    drop outss`city'`d'                                              drop all estimates associated with it"
    drop inss`city'`d'
    drop irs`city'`d'
    drop dist`city'`d'
    drop ors`city'`d'
   }
   }
  }
 quietly outreg2 [A*] using CandleFinal, excel append   "The last stored regression results are
 est drop A*                                              those with the minimum rss. This is the
 drop beast*                                            winning regression and is outputted to excel.
 drop outss*
 drop inss*
 drop irs*
 drop dist*
 drop ors*
 }
```