

Real Exchange Rates in the European Price Revolution

Online Appendix

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A.1 Log Price Indexes and Real Exchange Rates

Figure A.1 shows log CPIs in silver (in black) and in local currency (in grey) for each city. The time span in the figure is 1450–1765 (where data are available) to put the price revolution in context by including data before it began. For each city the log price in silver (black line, left axis) and in local currency (grey line, right axis) are shown on the same vertical scale specific to that city. Thus the overall inflation in local currency can be compared to that in silver. In each case the grey line rises more than the black line. That difference reflects periodic depreciations or debasements of the local currency.

For several cities there are some not-so-gradual changes. For Augsburg, Strasbourg, and Vienna these spikes appear in prices in both local currency and in silver. For Augsburg the outliers appear as values in 1621–1623 and for Vienna 1621–1624. These are the early years of the Thirty Years’ War which brought cataclysmic events to both cities. For London, Munich, and Paris there are spikes in the value of the local currency relative to silver. For example, in London the price level appears unusually low in 1546–1551. In the Allen files this episode is due to a jump up in the price of silver, measured in pence/oz. His original source—Feaveryear (1931)—confirms these values, which occur at the time of the Tudor debasement. The debasement began in 1544, late in the reign of Henry VIII, and ended with the Elizabethan restoration of the coinage in 1560–1561. Gould (1970), Outhwaite (1982), and Challis (1989) provide the detailed history.

It is possible, though, that this spike in the price of silver in London is partly due to measurement error. The price of silver is in newly minted pence, but multiple coinages (and currencies) circulated and were not all debased. In other words, there were coins with the same face value that varied in silver content. To allow for the possibility that

spikes like these are due to measurement error, the text provides Perron’s modified ADF tests for stationarity that are robust to outliers. Table A.2 below provides estimates of mean-reversion by least absolute deviations (LAD).

The vertical scales in Figure A.1 differ across cities, so that one can observe city-specific outliers like these. But the focus here is on *relative* price revolutions. To begin to see how these measures may be connected, I next construct log real exchange rates. Call Valencia city *val* and label any other city by *j*. Label the log price as $p_{j,t}$, measured in silver for comparability across cities. The log real exchange rate or relative price is:

$$q_{j,t} = p_{val,t} - p_{j,t}, \tag{1}$$

so that an increase is a real appreciation in Valencia relative to city *j*. Figure A.2 graphs $q_{j,t}$ for each city. Now the graphs apply to 1503–1765, a span which provides the largest balanced panel.

A.2 Rent in Price Indexes

The Allen data do not include rent but several recent studies have carefully measured early modern residential rent and included it in price indexes. Drelichman and González Agudo (2014) measure rents in Toledo for 1490–1600. They combine this measure with a price index for Madrid that excludes rent to produce an overall index. They also integrate rent measures into Allen’s indexes for Amsterdam and Antwerp, for comparison. González Agudo (2019) constructs a new price index for Toledo for 1521–1650 that features a rent measure, some manufactured goods, and several basket changes over time.

I do not study real exchange rates using these broader indexes, for two reasons. First, Allen (2001) and Drelichman and González Agudo (2014) estimate that rent makes up 5–10% of the urban consumption basket. Both studies conclude that the effect of including rent on the price indexes is ‘detectable but not dramatic.’ Second, for measuring things like distance effects in reversion to PPP (as in this study) a large cross-section dimension is important. To my knowledge there is no panel of price indexes that includes rent on a consistent basis for many cities.

A.3 Latitude and Longitude Visualization

For simple visualization, Figure A.3 plots the longitude and latitude of each city, from Table A.3, along with its label from Table A.1.

A.4 Madrid

Treating Valencia as the base city allows study of a long time span, including the entire sixteenth century. However, Valencia (in Aragon) was not as central to the expansion of the Spanish money supply via imports of silver as were cities like Seville and Toledo (in Castile). Hamilton (1934, p 128) reported that silver arrived in Seville and was minted in Castile. But he also noted that Castilian reals were the main currency in Valencia during the 1500s.

The Castilian city in the Allen data is Madrid. It was a relatively small city until Philip II made it the capital in 1561. In the Allen data its price index begins in 1551, giving $T = 214$ observations until 1765. As a check on the findings, I calculated real exchange rates with Madrid as the base city. I included Valencia among the other J cities.

The results (not shown) are similar to those reported in the text. The real exchange rates appear stationary according to unit root tests, with or without allowing for additive outliers (AO). The half lives of departures from PPP have a cross-city average similar to that in Table 2, but vary less across cities, from 2.60 for Paris to 4.94 for Amsterdam. There is little evidence of a distance effect. For example, the real exchange rate for Valencia-Madrid is as persistent as the one for Vienna-Madrid.

A.5 Historical Debasements

Feaveryear (1931) noted that physical wear on coins gradually eroded their silver content so that the value of local currency in silver tended to drift down (i.e. there were gradual debasements). But this trend would lead to a trend in the nominal exchange rate only if there were *differences* in the rate of physical wear across cities.

Notice that not all of the paths of values of local currency in silver are monotone though. As noted in section A.1, London, Munich, and Paris exhibit sharp, V-shaped troughs in the value of the local currency: faster debasements followed by restorations.

For London, the trough in 1551 marks the end of the Great Debasement (1544–1551) begun under Henry VIII and continued then reversed under Edward VI. Feaveryear (1931), Gould (1970), and Outhwaite (1982) provide data and histories of this episode. For Munich, the trough is in 1622, early in the Thirty Years’ War. Kindleberger (1991) argued that sovereigns anticipated the war and accelerated minting and clipping to accumulate seigniorage. He suggested that the debasements then spread to other cities (especially in the Habsburg Empire) via Gresham’s Law, because many currencies circulated simultaneously, especially in smaller states. However, Figure A.1 does not show similar changes in currency values for Antwerp or Vienna, though prices in both silver and local currency spiked upwards in Augsburg. For Paris the trough is in 1720, which marked the end of John Law’s System and its associated paper money. Velde (2007) provides a concise summary of this dramatic episode.

A.6 American Metal

So far I have not found a valid instrument for Valencia inflation that would allow one to isolate its inflation shocks and then trace their effects in other cities. As the introduction noted, historians have long concluded that the price revolution arose from imports of precious metals to Spain. Inflation then radiated out from Spain, possibly via (a) the use of Spanish coins, (a) the spread and minting of silver or (b) a demand shock as output rose in Spain and other countries, as documented by Palma (2022).

A measure of metal inflows to Spain is *not* an instrument for inflation in Valencia or Madrid, at least in this context. Spanish coins minted in America circulated widely in Europe and so this inflow may have directly affected $p_{j,t}$ in non-Spanish cities. Moreover, Palma (2022) argues that Spanish silver was minted in other European countries. For example, chemical tests show English coins contained silver from the Americas. Thus this variable does not satisfy the exclusion restriction of instrumental-variables design.

For detailed evidence on the effects of American metal, treated instead as an exogenous variable, I refer the reader to Palma (2022) and Brzezinski et al. (2024). The former finds a positive effect on prices, pooled across six countries. The latter find insignificant effects of such imports on the aggregate Spanish price level.

Table A.1: Cities and Time Spans

City	Label	Time Span	Currency
Amsterdam	ams	1500–1910	guilder
Antwerp	ant	1399–1913	guilder
Augsburg	aug	1502–1800	pfennig
Krakow	kra	1409–1795	grosz
London	lon	1264–1913	pence
Madrid	mad	1551–1913	maravedi
Munich	mun	1427–1765	denar
Paris	par	1431–1786	livre tournois
Strasbourg	str	1386–1875	franc
Valencia	val	1413–1785	pence
Vienna	vie	1440–1800	kreutzer

Notes: The table gives the list of cities, their three-letter labels, their local currency, and the time span for their price index data in the Allen (2001) study.

**Table A.2: Mean Reversion in Real Exchange Rates: LAD Estimation
1503–1765**

$$q_{j,t} \equiv p_{val,t} - p_{j,t}$$

$$\Delta q_{j,t} = \alpha_j + \beta_j q_{j,t-1} + \epsilon_{j,t}$$

$$h_j = \frac{\ln(0.5)}{\ln(1 + \hat{\beta}_j)}$$

City	$\hat{\beta}_j$ (se/ <i>p</i>)	$\hat{h}_j$ (se/ <i>p</i>)
Amsterdam	-0.163 (0.039/0.00)	3.89 (1.03/0.00)
Antwerp	-0.084 (0.025/0.00)	7.87 (2.47/0.00)
Augsburg	-0.209 (0.041/0.00)	2.95 (0.65/0.00)
Krakow	-0.088 (0.027/0.00)	7.49 (2.37/0.00)
London	-0.112 (0.035/0.00)	5.83 (1.92/0.00)
Munich	-0.173 (0.037/0.00)	3.64 (0.86/0.00)
Paris	-0.375 (0.047/0.00)	1.47 (0.23/0.00)
Strasbourg	-0.142 (0.036/0.00)	4.52 (1.23/0.00)
Vienna	-0.131 (0.037/0.00)	4.95 (1.52/0.00)

Notes: Table 2 in the text contains OLS estimates of mean reversion and half-lives for real exchange rates. Table A.2 here gives the estimates with estimation by LAD, so as to be robust to outliers. The results are very similar. Brackets contain standard errors then *p*-values.

Table A.3: Cathedral Locations and Distances

City	Cathedral/Church	Latitude	Longitude	Distance d_j	Rank r_j
Amsterdam	Oude Kerke	52.374°N	4.898°E	1490	7
Antwerp	Our Lady	51.220°N	4.402°E	1357	5
Augsburg	Dom Maria	48.373°N	10.897°E	1337	4
Krakow	Wawel	50.055°N	19.936°E	1981	9
London	St. Paul's	51.514°N	0.098°W	1337	3
Munich	Frauenkirche	48.139°N	11.573°E	1358	6
Paris	Notre-Dame	48.853°N	2.350°E	1064	1
Strasbourg	Notre-Dame	48.582°N	7.751°E	1202	2
Valencia	St. Mary's	39.475°N	0.376°W	—	—
Vienna	St. Stephen's	48.208°N	16.374°E	1654	8

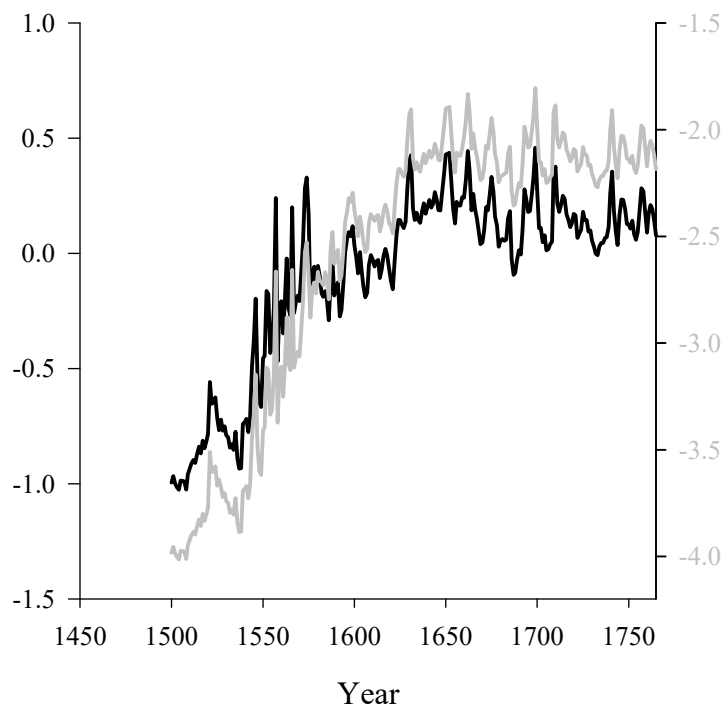
Notes: I measure distance by the great circle distance between the principal church or cathedral in each city (which plays the role of the city centre) and that in Valencia. Each of these church locations existed in 1503 at the start of the sample. (St Paul's Cathedral in London was built between 1675 and 1710 but it stands on the site of Old St Paul's.) The table lists the church or cathedral in each city, its latitude and longitude, and the great circle distance from Valencia Cathedral. Latitude and longitude are in decimal degrees. Distance is rounded to the nearest kilometre. It is calculated using the Vincenty formula from Adam Schneider's gpsvisualizer.com/calculator.

References

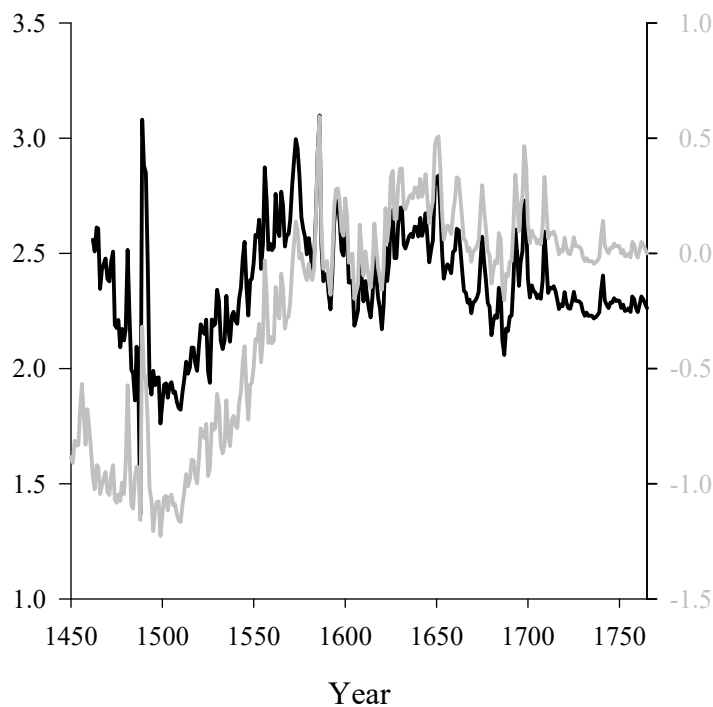
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Figure A.1: City Log Price Indexes in Silver and Local Currency

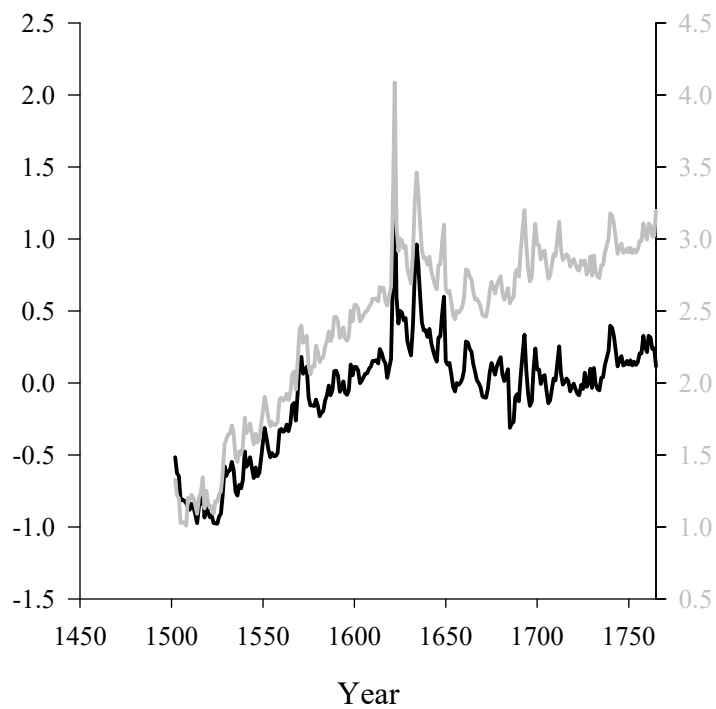
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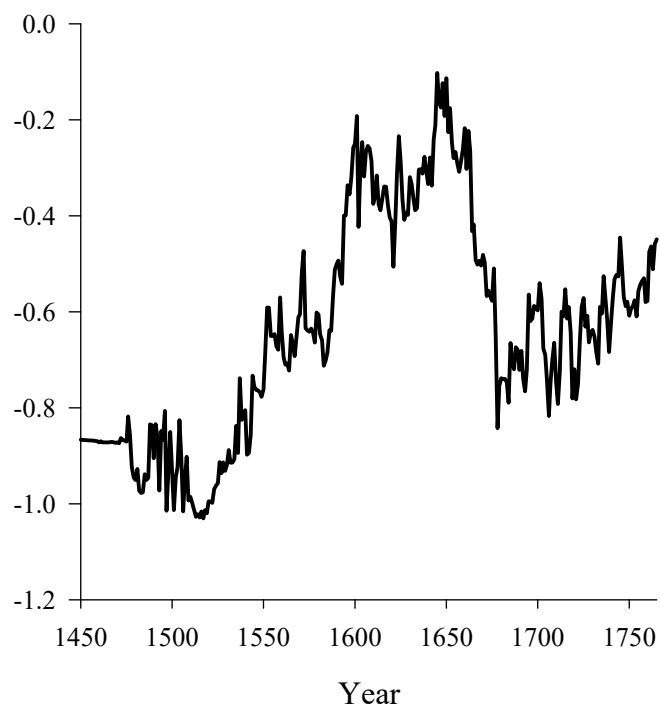
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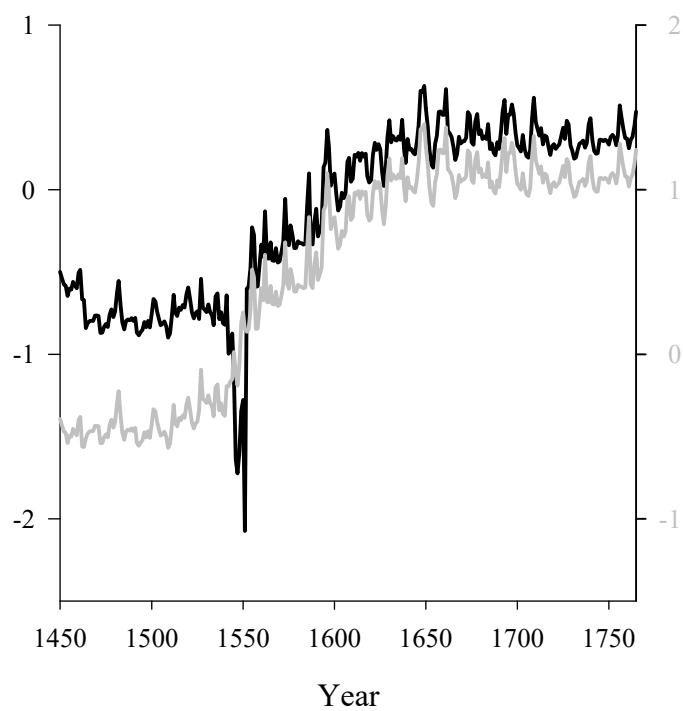
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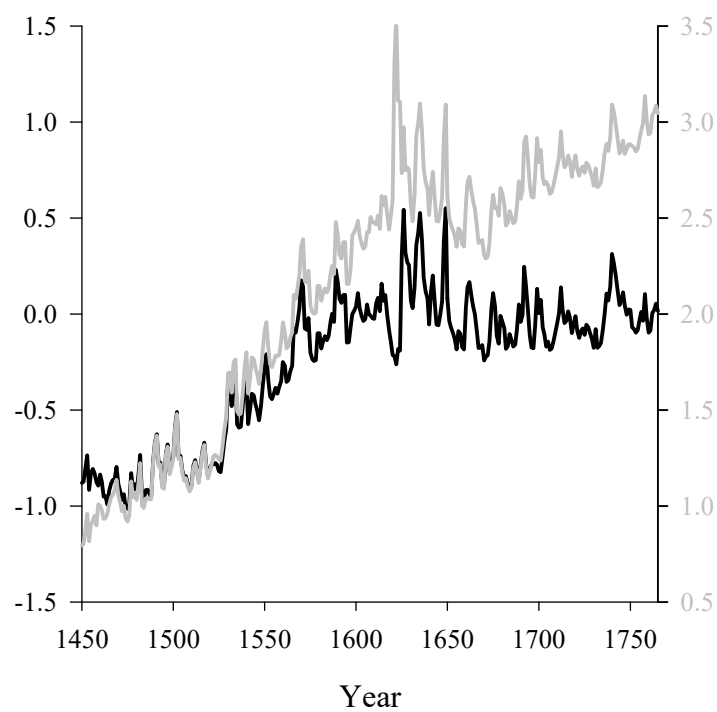
Krakov



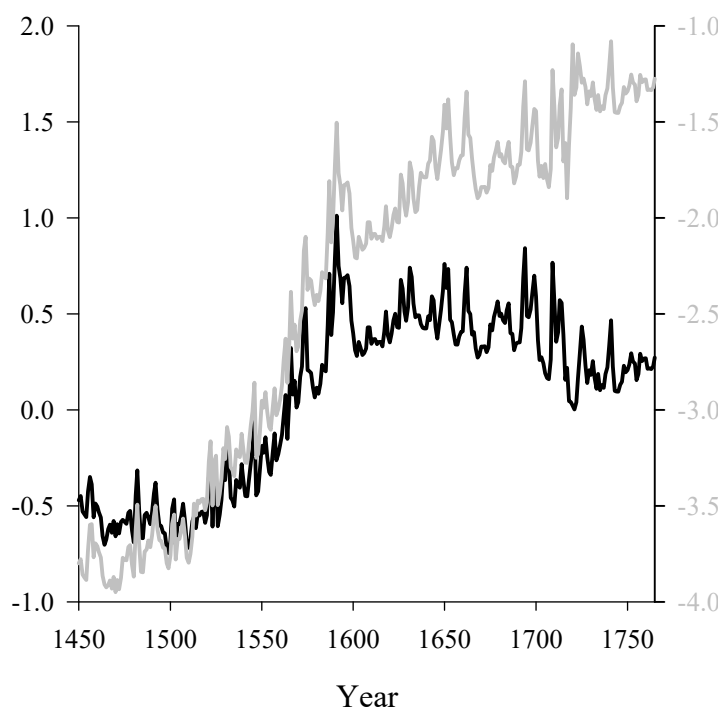
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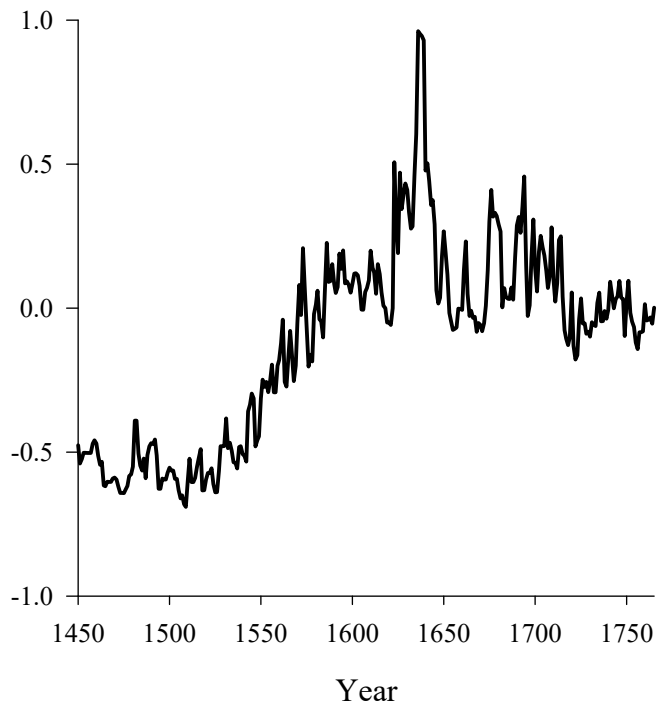
Munich



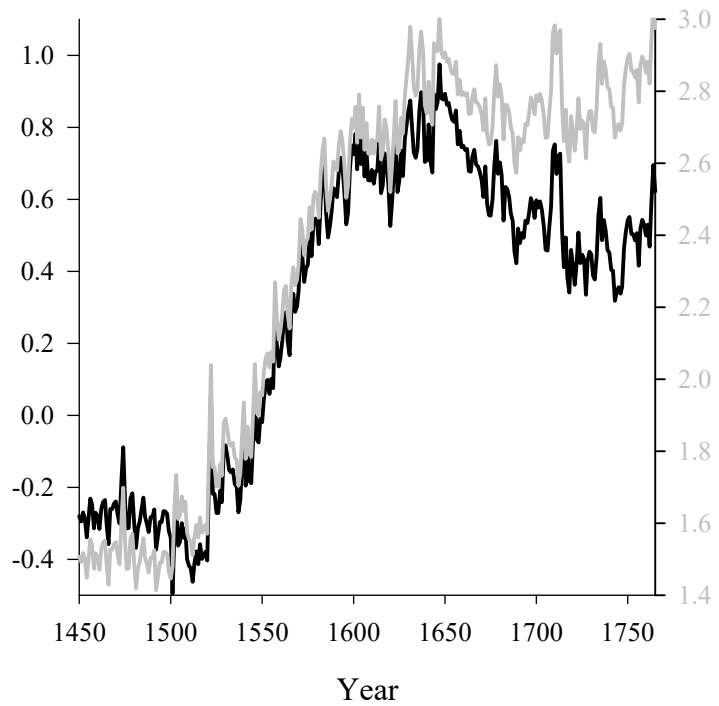
Paris



Strasbourg



Valencia



Vienna

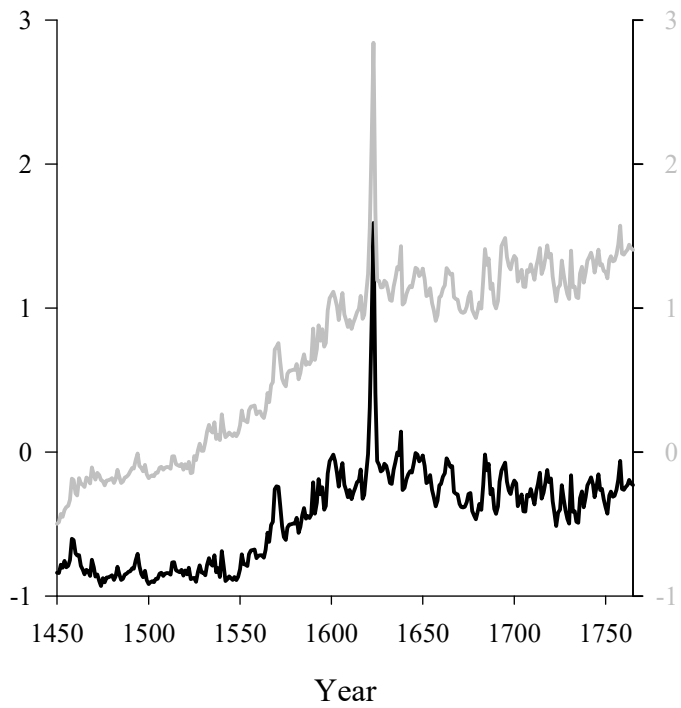
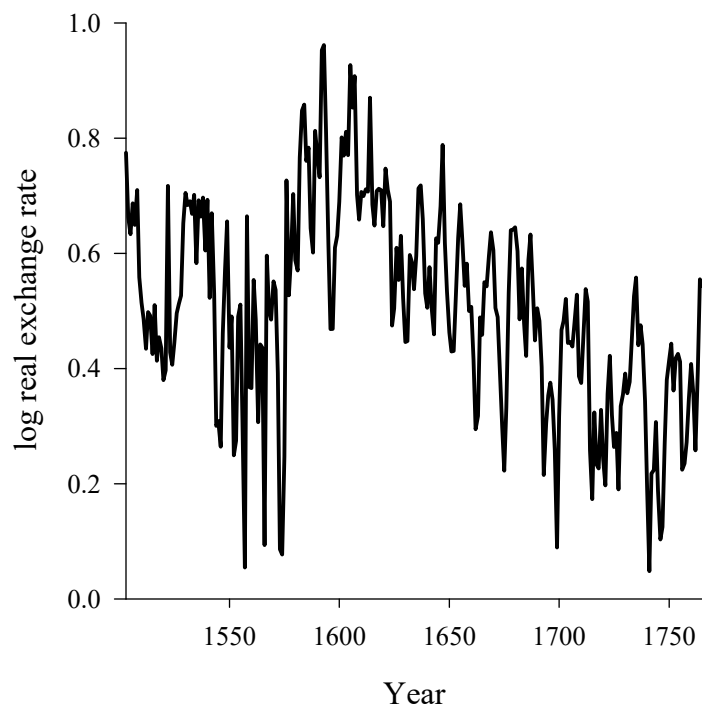
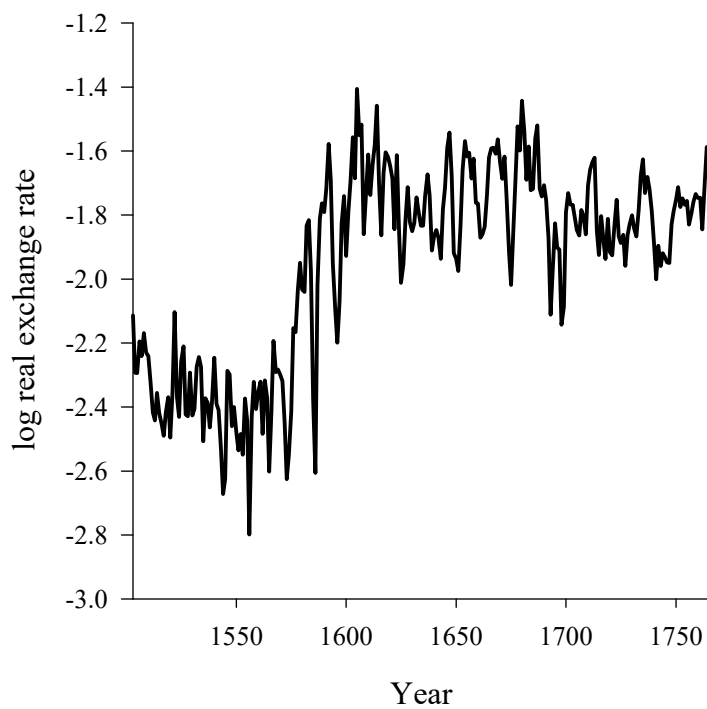


Figure A.2: Log Real Exchange Rates 1503-1765

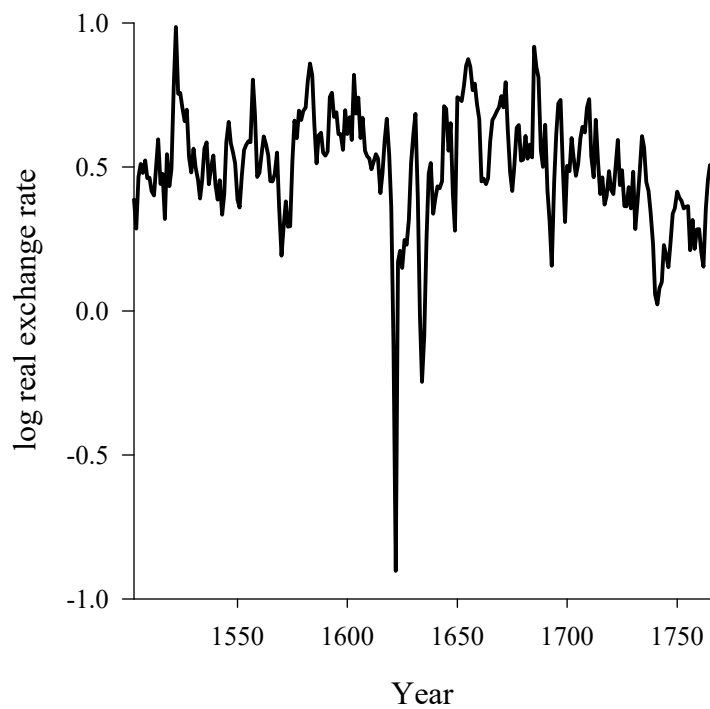
Amsterdam



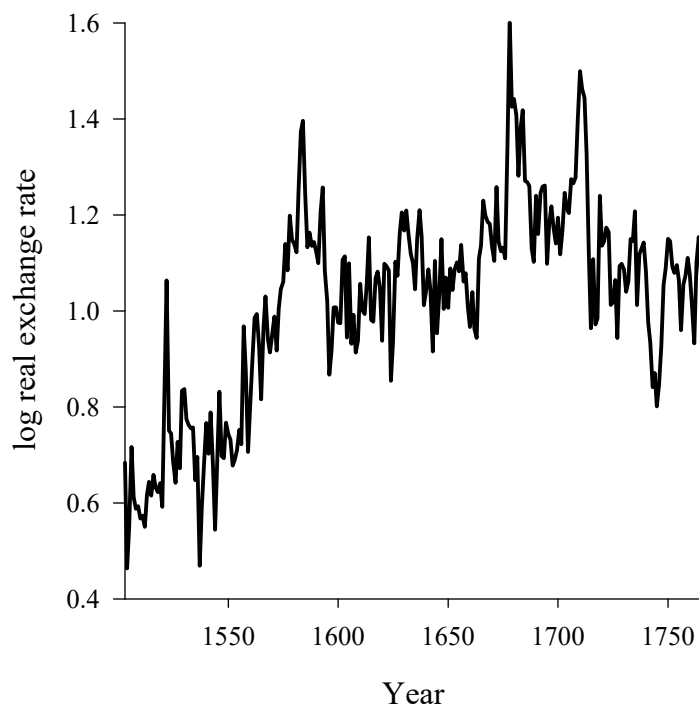
Antwerp



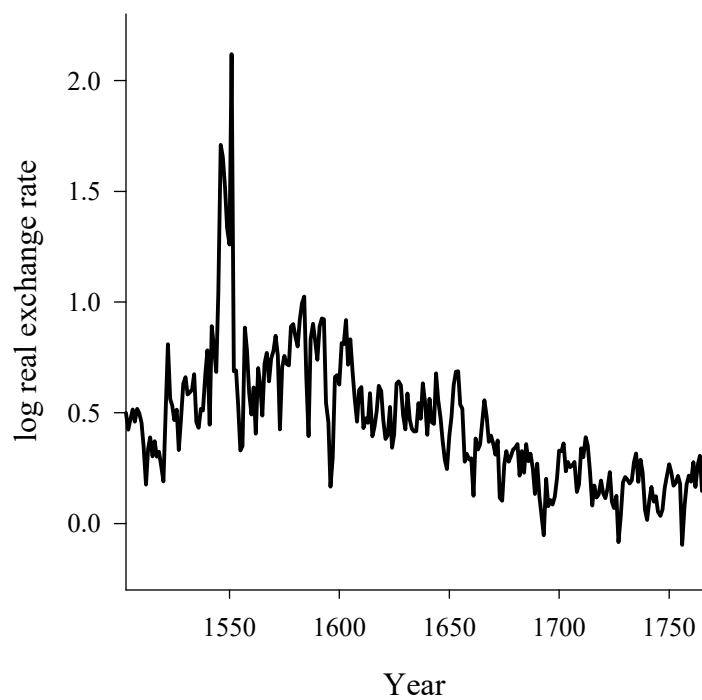
Augsburg



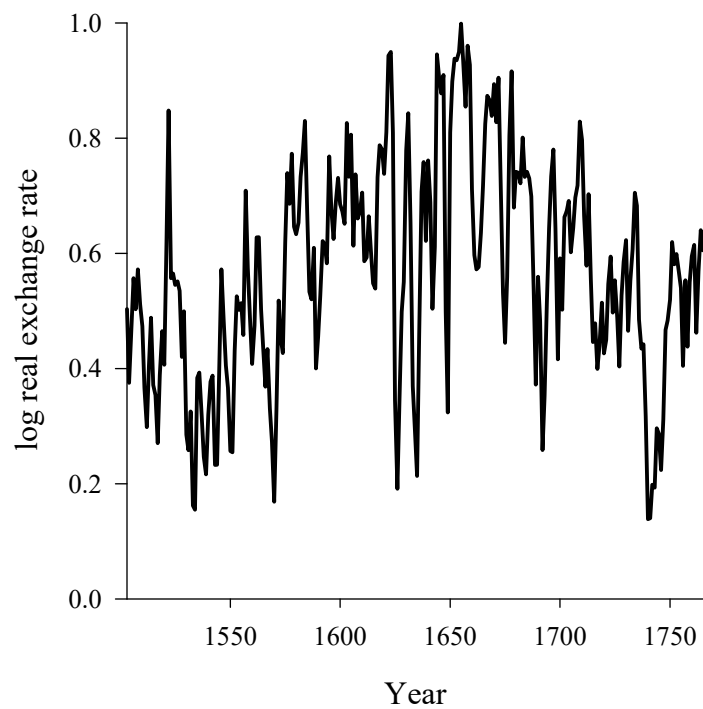
Krakow



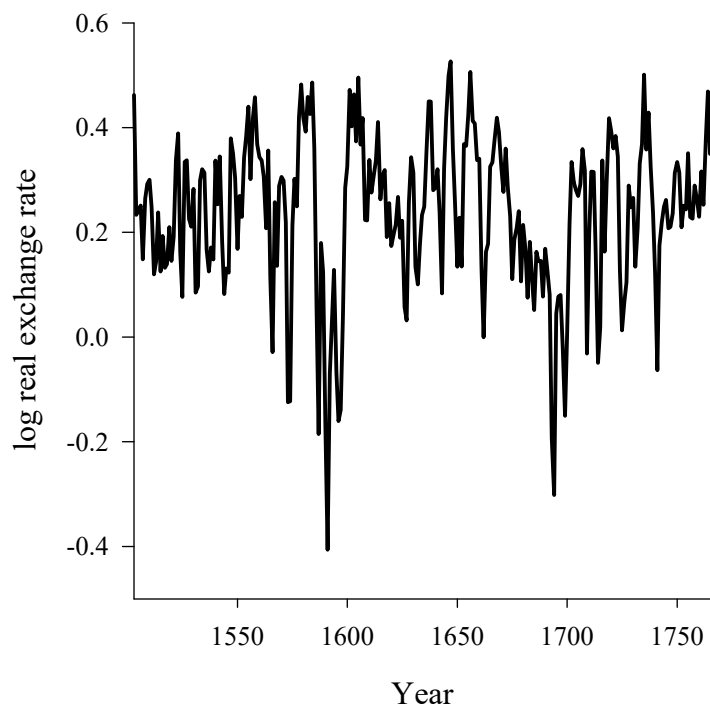
London



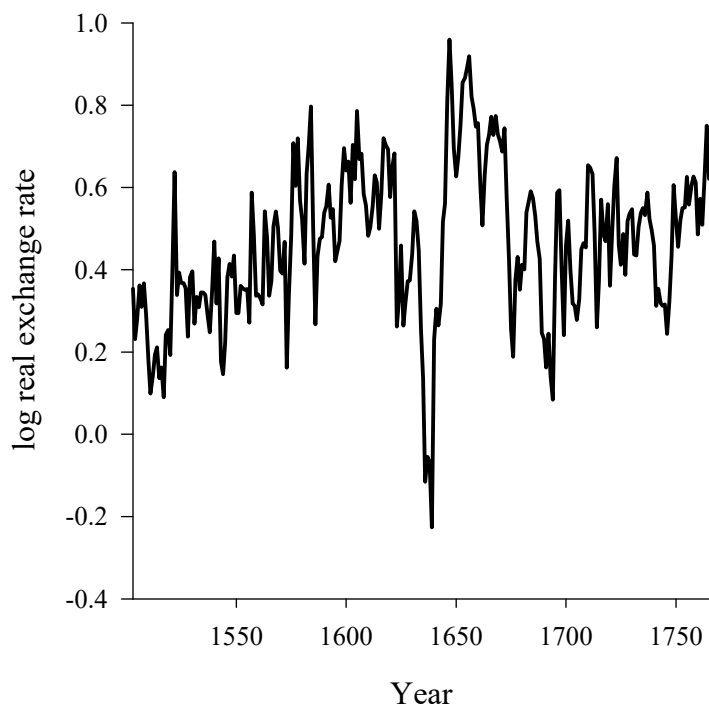
Munich



Paris



Strasbourg



Vienna

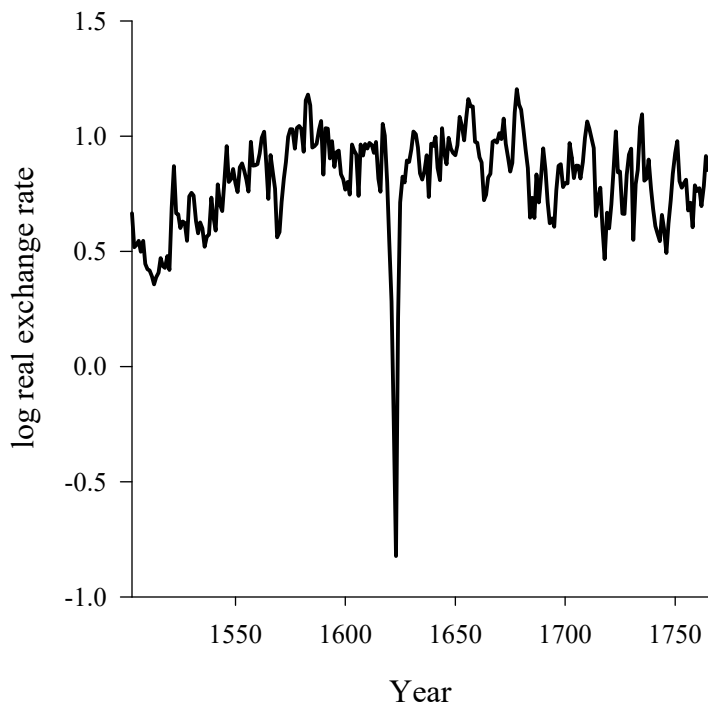


Figure A.3: City Longitudes and Latitudes

