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6 January 2017

The evolution of Ottoman-European market linkages, 1469-1914: evidence from dynamic factor models*

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Abstract

This paper studies the relationship between commodity markets in two key regions of the international economy during the 1469-1914 period: the Ottoman Empire and Europe. By providing evidence on what thus far has been largely a qualitative discussion, we propose the first comprehensive empirical analysis of the process of market integration between Istanbul and 19 European cities, using data on commodity baskets and a set of traded goods. By computing dynamic factor models using Bayesian inference we are able to overcome a series of data constraints, such as missing observations and small sample size. The results point to the existence of broad and persistent market linkages between the two regions throughout four and half centuries. We also find that market integration was negatively impacted by the intensity of Ottoman-European conflicts.

*We acknowledge financial support from the Faculty of Business and Economics, University of Melbourne. We thank the participant at the Brown Bag, Department of Economics, University of Melbourne and at the Fourth EH-Clio Lab Conference, Instituto de Economia of the Pontificia Universidad Catolica de Chile for helpful comments. We are grateful to Jeff Borland, Jeanne Lafortune, and Jeffrey Williamson for useful suggestions that improved earlier versions of this paper. All remaining errors are our own.

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1 Motivation

Europe and the Islamic world constituted two largely separate urban systems, each with a different structure and long-term evolution and with little evidence of significant interaction across religious lines.

Bosker et al. (2012, p.1419)

What makes the Ottomans important from the perspective of European history is that the empire steadily looked westward for expansion [. . .] This is precisely why the Ottomans mattered to Europe's internal developments.

Iyigun (2008, pp.1470-1)

Economic historians have long been engaged in scholarly debates about the origin and evolution of commodity market integration and its implications for economic development. This is because understanding the level of connectedness of global and regional markets allows to gain an understanding on market efficiency, embodied in how quickly price signals are transmitted across borders, and thus to assess the quality of market institutions of allocative efficiency. A recent survey by Federico (2012) provides a comprehensive summary of the literature investigating how market integration evolved over time and across space. Federico (2012) highlights, *iter alia*, our limited knowledge about long-run integration beyond Western Europe and the US, as well as on the period preceding the nineteenth century. This paper aims to bring some new insights on the topic by undertaking an analysis of commodity market integration between two key regions of the international economy, the Ottoman Empire and Europe, during 1469-1914.

The large body of literature on Ottoman-European economic relations considers the developments in the two regions' economic history as deeply entwined and interdependent. Standard historiography accounts identify economic exchange as a major dimension of interaction between the two worlds, despite recurrent military confrontations and political rivalries. A recent paper by Iyigun (2008) provides empirical evidence of the existence of considerable interactions between Europe and the Ottoman Empire, with the latter having a positive impact on the former's political and ecclesiastic history. Specifically, by showing that Ottomans' military expeditions in Europe were associated with a lower number of intra-European conflicts, the paper highlights one of the dimensions in which European history was influenced by its periphery.

This conventional wisdom has recently been challenged by Bosker et al. (2012), who point to the absence of interdependence between the Islamic world (including the Ottoman Empire) and Europe, measured by the lack of integration between Muslim and Christian cities over the 1000-1800 period. Identifying the concept of integration in terms of "urban potential", the authors find that the difference in religious denomination between European and Middle Eastern cities represented a significant barrier between the two regions' economic integration.[1] While being more related to market access than to conventional integration measures, Bosker et al. (2012) use the urban potential index in a set of regressions to test for the existence of economic linkages between Europe and the Islamic world. They interpret the empirical results as evidence of the lack of significant interactions between the two areas (Bosker et al., 2012, p.1427).

Such different perspective on the evolution of Ottoman-European linkages defies traditional historical accounts, which portray the two regions as linked by strong economic ties and significant commercial relations between the fifteenth century and the outbreak of World War One Europe, thus raising some interesting questions: to what degree were Ottoman and European commodity markets influenced by each other's development? How strongly were their markets integrated? Did the two regions interact predominantly in the political and military sphere but not in the economic one?

By answering these questions we provide two types of contributions: one empirical, one methodological. First, we revisit the ongoing debate on the nature of the linkages between Ottoman and European worlds, by providing empirical evidence on a specific dimension of their long-run economic relations: the integration of the two regions' commodity markets. While the relationship between European and Ottoman prices has been previously studied by Pamuk (2001, 2004), we are the first to provide a comprehensive empirical analysis of commodity market integration.[2] Specifically we

[1] Bosker et al. (2012, p.1423) measure the urban potential of a predominantly Muslim (Christian) city as the distance-weighted sum of the population of all other Muslim (Christian) cities.

[2] Pamuk's seminal contributions stem primarily from the collection of Ottoman price data and the construction of an Ottoman CPI (Pamuk, 2001, 2004). The two papers also present a comparison of price trends in the Ottoman Empire and Europe by plotting CPI series; a similar approach is provided by Özmucur and Pamuk (2007), with a focus on real wages. Our analysis complements and improves the existing qualitative literature.

investigate the dynamics of price transmissions between Istanbul and 19 European cities between 1469 and 1914, using data on CPI and on a set of specific traded goods. Following Federico (2012) we consider two markets to be integrated if two conditions are satisfied: the law of one price and market efficiency.[3] By computing rigourous estimates of the dynamics of integration using the *long durée* approach, we are able not only to gain an in-depth understanding of the nature of the historical relationship between two key regions of the international economy, but also to obtain informative insights on their process of long-run growth and development. This is because market integration (or the lack thereof) reflects the existence (absence) of well-functioning institutions of allocative efficiency.[4] Furthermore, analysing the behaviour of commodity markets is indicative not only of the extent to which the European and the Middle Eastern economies were efficiently linked and of the degree of market-orientation of the two regions, but it is also crucial for understanding whether the economic rise of Europe occurred in symbiosis with, or isolation from, one of its closest regional partner.[5] Finally, after computing the degree of Ottoman-European market integration, we use our estimates to test the extent to which military conflicts impacted the process of commodity price transmission. As recurrent wars severed the economic ties between the Ottoman and the European worlds, we assess whether disruptive conflictual confrontations prevented the building of persistent economic relations.

Secondly, we offer a robust methodological solution to a common problem in the measurement of market integration involving datasets with a long time dimension coupled with missing and/or limited overlapping observations across series. Specifically, we propose a dynamic factor model drawing on Beveridge-Nelson decomposition (Beveridge and Nelson, 1981), using Bayesian inference.

[3]The law of one price implies that two distinct markets should exhibit the same equilibrium price when integrated. The market efficiency condition refers to the speed of convergence to equilibrium between two markets after a price shock.

[4]Integrated markets are associated with good institutions, able to allocate resources efficiently; such institutions are in turn considered among the key factors contributing to the creation of the set of incentives which eventually led to the industrial revolution North and Thomas (1973); North (1981).

[5]One of the enduring controversies in economic history is centred around the degree to which Europe's relationship with the rest of the world was significant in her breakthrough as dominant industrial economic power (Findlay and O'Rourke, 2007, pp.330-1).

In this setting, the long run equilibrium between two series is captured by a stochastic trend and, at the same time, each series is allowed to follow its own stationary process, embodying individual dynamics. This method enables us to deal with two key challenges. First, consistent with Bayesian estimation, we handle missing data as parameters, rather than imputing them or truncating the sample, thus handling unobserved individual prices in a realistic and flexible manner.[6] This is particularly important because our analysis uses price data, which are by nature not predictable; hence imputing missing observations by interpolation may seriously distort the behaviour of the series, while using only contiguous observations would lead to the loss of useful information, to the point of undermining the feasibility of the study. Secondly, in order to assess the existence of market integration, instead of testing the null of no co-integration against the alternative (as for example in the Johansen co-integration test), we simultaneously draw inference on three hypotheses: no integration, weak market integration and strong market integration by comparing the posterior probabilities of each model. This strategy provides more robust results compared with standard co-integration approaches which, despite asymptotic validity, may generate conflicting inference when the null and alternative hypotheses are switched, even more so in a small sample setting.

The paper is structured as follows: after providing an overview of Ottoman-European economic linkages (section 2), we describe the data (section 3) and the econometric methodology used to test for market integration (section 4). We then present and discuss the results (sections 5-6) and assess the impact of conflict on integration (section 7). Section 8 concludes.

2 The development of Ottoman-European economic relations

How strong were the linkages between Ottoman and European markets? How did the degree of integration between them evolve and respond to the economic and political changes shaping over 400 years of history of bilateral commercial relations? We start by offering some background information about the evolution of the economic linkages between Europe and the Ottoman Empire, which will help the reader assess the existence of commodity market integration (or lack thereof) between the two regions. Specifically, we focus on the intensity, composition and geographical spread of bilateral commercial relations, as well as on the available evidence on price movements,

[6] Bayesian methods are increasingly been adopted in empirical analysis; see for instance Uebele (2011); Moral-Benito (2012).

which are of key importance to gain insights on the process of price transmission. To be clear, the existence of trade between two countries is a necessary but not sufficient condition for market integration to occur. This is because a change in a country's volume of trade, led by shifts in import demand or export supply, could be driven by a wide variety of factors, such as an expansion in the land frontier, population growth, etc..., which are not necessarily related with commodity market integration. Thus, in order to be able to offer robust evidence on market integration, we need to look at the change in the dispersion of commodity prices between locations: that is, the degree of price convergence, which signals that trade-creating forces have an impact domestic commodity prices.[7] In what follows we illustrate the evidence provided by the literature so far on Ottoman-European price movements.

Exhaustive accounts of the histories of the Middle East and Europe have documented the evolving nature of the economic linkages between the Ottoman Empire and Europe (see among others, Braudel, 1995; Inalcik and Quataert, 1994; Langer, 1935; Pamuk, 1987). These were initially shaped by Ottoman political and military dominance, beginning with the conquest of Istanbul (1453) which gave the Empire an unparalleled strategic base to dominate the Black Sea and the Mediterranean. Mehmet the Conqueror's navy was able to overturn Venice's supremacy in the Eastern Mediterranean at the end of the fifteenth century, thus making Istanbul one of the largest transit centre of the south-north trade artery between the Black Sea and Danubian ports and the main cities of the Eastern Mediterranean, Arabia and India (Cleveland, 2004, p.40). The Empire's presence in the Continent via its territorial expansion in Eastern Europe, reaching the doors of Vienna, and its control of the Balkans reduced the geographic distance between the two regions. This made of Istanbul, the Empire's capital, a powerful economic, political and cultural center; due to its strategic location it was also the principal Ottoman market competing with Europe.[8]

The strength of the commercial and economic relations between Europe and the Ottoman Empire varied throughout the centuries. They were impacted by the evolution in the geographic

[7]Changes in commodity prices in turn lead to a redistribution of resources between economic activities. See O'Rourke and Williamson (2002) for a detailed explanation about the role of prices in measuring commodity market integration.

[8]For example, Inalcik and Quataert (1994, p.182) document the competition between Venice and Istanbul over grain supplies.

location and distribution of bilateral commercial networks, mirroring the decline of the Mediterranean and the rise of the Atlantic as the fulcrum of global trade. A key turning point was the signing of the Treaty of Karlowitz (1699), marking the end of the Empire's territorial expansion and a decline in its political strength. Also its economic structure and trade patterns underwent considerable changes: Ottoman raw materials, normally channeled for internal consumption and industry, started being exchanged, at an increasing rate, for European manufactured products.[9] Moreover, from the 1800s the technological advances brought about by the industrial revolution, which led *inter alia* to a considerable expansion of road, canal and rail networks, as well as to unprecedented reductions in bilateral transportation costs, led to an intensification of the economic interactions. These were coupled by variations over time in the composition and patterns of trade between the two regions, reflecting comparative advantage and specialisation, as the Ottoman Empire transformed from being self-sufficient in manufacturing at the beginning of our data period to a net importer of manufactured goods and an exporter of raw materials by the end of it.

The absence of consistent statistics of trade flows between the Ottoman Empire and Europe does not allow to have a complete picture of the dynamics of commercial exchange. However available studies, most of qualitative nature, document the development of significant trade relations between the fifteenth century and the outbreak of World War One, suggesting the existence of interconnected markets (see for example Berov (1974) and Barkan (1975)).[10]

The historical literature also offers insights about price movements between Europe and the Empire: Berov (1974) suggests that average Ottoman price levels, in silver terms, were comparable to those in Italy, France, England and the Netherlands. Barkan (1975) and Braudel (1995, pp.517-542) argue that the transmission of the wave of inflation from Europe to the Ottoman territory during the

[9] Furthermore, European merchants started playing an increasingly important role in Ottoman commerce. Their penetration in the Ottoman economic sphere was sanctioned by a system of privileges established by a series of commercial treaties, known as Capitulation. The first, negotiated with France, allowed French merchants to be exempt from Ottoman taxes, to import and export goods at low tariff rates and to be under the legal jurisdiction of the French consul in Istanbul.

[10] Barkan (1975) writes extensively about the high level of interdependence between economic and political spheres in Europe and the Near East, associating the decline of the Ottoman Empire with the disruption of its traditional trade routes in the Mediterranean and the related rise of the Atlantic economy.

sixteenth century, due to the large specie inflows from the New World, led to considerable increases in the price level of basic commodities also in the Empire. Thus a large proportion of goods like wheat and other grains, copper and wool, were diverted from the domestic to the European market, leading in turn to shortages and higher prices at home (Barkan, 1975).[11] The increase in commercialisation and monetisation of the Ottoman realm, together with the transmission of inflation from Europe, are held as contributing factors to the average price hike throughout the Empire. Pamuk (2001, p.81) further considers the high level of development in maritime transportation and the sophistication of commercial network in the Mediterranean as signs of the interconnection between Europe and the Empire.

Overall, most of the available literature on the economic relations between Europe and the Empire is of descriptive/qualitative nature. As far as we are aware, only Pamuk (2004) and Özmucur and Pamuk (2007) have examined the behaviour of Ottoman prices and compared them with those in Europe. By plotting data on CPI and wages in Istanbul and various European locations they have provided suggestive evidence on the existence of integration between the two regions in the long-run. However, both authors point to the need of extending their work, by investigating the process of Ottoman-European integration more in depth, and providing a more comprehensive empirical analysis, thus bringing quantitative evidence on what thus far has been largely a qualitative discussion. This would not only provide more rigour to their analysis, but would also offer a better understanding of the variation in the magnitude of integration between the Ottoman and the European markets over time and space. This paper intends to take up this task. Specifically, drawing on the co-integration literature we will provide the first empirical analysis of the dynamics of the process of price transmission between Istanbul and various European cities and of its variation through four and half centuries.

3 Data

We use two types of data, both with yearly frequency, between 1469 and 1914: CPI and the prices of a set of traded goods (wheat, rice, butter, olive oil, honey, soap, charcoal, wood and chickpeas). The Ottoman Empire's data are from Pamuk's extensive collection of Istanbul's prices (Pamuk, 2000). Istanbul's CPI, constructed using constant relative weights reflecting consumption

[11]See also Pamuk (2001).

patterns, includes both food and non-food items (flour, rice, cooking oil, honey, mutton, chickpeas, olive oil, soap, wood, coal, nails).[12] The data for the 19 European cities in our sample are from Allen (2001). The European CPIs are constructed using similar baskets, allowing for differences in national consumption patterns (for example wheat bread prices are used for Spain, while rye bread prices for Poland). Like in the Ottoman case they include both food and non-food items (bread, beans/peas, meat, butter/olive oil, cheese, eggs, beer/wine, soap, linen, candles, lamp oil, fuel).[13] To allow comparability all data have been converted into grams of silver.

Prices constitute the most widespread unit of analysis in the market integration literature, commonly used to test for the Law of One Price. Provided that a good is traded, observing price trends or price gaps between markets and their change over time allows to make inference about the degree to which shocks are transmitted across locations. When using the CPI we are interested in testing for market integration in a broader sense, looking at convergence in the overall price level between markets. Despite not being identical, all items included in the Ottoman and European CPIs are highly comparable and representative of the typical consumption basket of an average income earner.[14] Furthermore, the vast majority of the goods used to construct the indices were traded between the Ottoman Empire and Europe, though not always on a regular basis (Özmucur and Pamuk, 2007, p.60). Thus, while using CPI data allows us to draw a broad brush picture of the Ottoman-European economic linkages, we also focus on the behaviour of specific markets in order to measure the intensity of the linkages between some key traded commodities. We see the two analyses as complementary.

4 Econometric Methodology

There is a rich literature on market integration, both within historical and contemporary settings. The standard methods used to test for market integration range from the simple computation of coefficients of variation, to OLS regressions to the use of more advanced econometric techniques

[12]For details on CPI construction and on the archival sources used see Pamuk (2000).

[13]For details on the CPIs' construction method see Allen (2001, pp.420-22).

[14]The lack of a complete match in the European and Ottoman CPIs may lead us to reject more easily the hypothesis of market integration as the lack of convergence may be driven by the different basket composition rather than by the absence of price transmission.

focusing on co-integration analysis.[15] The co-integration approach has often been coupled with the estimation of error correction models (ECM) and the computation of half-lives.[16] An alternative approach is founded on the study of price co-movement, tested through the computation of dynamic factor models.[17]

We draw on this literature and base our analysis on the computation of dynamic factor models within the state space framework. Specifically, we propose a set of bivariate models to investigate the relationships between Istanbul and other European cities. This approach allows us to identify and isolate the interactions between two cities and potentially provides more robust results in an Occam's razor sense. As anticipated in sections 2 and 3, we measure market integration in terms of price convergence, and this is the approach at the basis of our analytical framework.

This framework includes three models. The first is the most general and represents no market integration. The second one is nested into the first one and referred to as weak market integration. The third one is nested in the second one and is labelled strong market integration.

Before introducing the models, we define some notations. There are two cities, $i = 1, 2$. The data spans from time $t = 1, 2, ..., T$. The log price of city i at time t is denoted by y_{it}. Missing observations are denoted as y^*_{it}.

4.1 Univariate Model

We start by studying each log price series within a univariate framework, then we analyse the connections between two series. If two markets are not integrated, price changes across locations are not transmitted, or are transmitted very slowly, hence there would not be any relationship between two univariate models.

Each city's price series is partitioned into a stochastic trend, a stationary process and a white noise. This subdivision can be viewed as an application of the Beveridge-Nelson decomposition

[15] See for example Shiue and Keller (2007) on market integration between China and Western Europe before the industrial revolution and Özmucur and Pamuk (2007) for a study on European commodity market integration between 1500 and 1800.

[16] See, for example Getnet et al. (2005); Federico (2007); Brunt and Cannon (2014).

[17] See Uebele (2011) for an analysis of wheat market integration between European and US cities and Andersson and Ljungberg (2015) for an investigation of grain market integration in Baltic Sea region in the 19$^{\text{th}}$ century.

(Beveridge and Nelson, 1981). The stochastic trend represents the long-run expectation or a dynamic equilibrium state in a market.

The model is illustrated as follows:

$$y_{it} = \alpha_i + \beta_i f_{it} + \gamma_i g_{it} + e^y_{it} \tag{1}$$

$$f_{it} = f_{i,t-1} + e^f_{it} \tag{2}$$

$$g_{it} = \phi_i g_{i,t-1} + e^g_{it} \tag{3}$$

for $i = 1, 2$ with $e^y_{it} \sim N(0, \sigma_i^2)$. For identification purposes we assume that the innovations $e^f_{it} \sim N(0, 1)$ and $e^g_{it} \sim N(0, 1)$ have standard normal distributions and that $\beta_i > 0$ and $\gamma_i > 0$. All errors $(e^y_{it}, e^f_{it}, e^g_{it})$ are independent across time t and city i.

The intercept α_i incorporates transaction costs. The stochastic trend f_{it} represents the dynamic factor with a constant loading β_i. It embodies the long-run steady state implied by aggregate economic information. We assume that it follows a random walk process. g_{it} is a stationary AR(1) process with $\phi_i \in (0, 1)$ and loading γ_i. It represents city-specific fluctuations related to business cycles or other short-run price changes around $\beta_i f_{it}$. The white noise error term e^y_{it} is associated with measurement error.

The univariate model treats each city separately. If two markets are not integrated they do not have a common f_t or β_i: their log price series dynamics are in line with the prediction from the univariate model.

4.2 Weak Model

When two series share the same stochastic trend f_t but have different loading coefficients β_t, their relationship can be modelled as an ECM. Such approach is commonly used in the market integration literature based on co-integration analysis (see for example Getnet et al., 2005; Brunt and Cannon, 2014).[18]

The common stochastic trend embodies the long-run relationship between prices and can be interpreted as a dynamic equilibrium, as illustrated in the following model $f_{1t} = f_{2t}$:

[18] The absence of a co-integration relationship indicates that each time series has its own stochastic trend, consistent with the prediction of the univariate model.

$$y_{it} = \alpha_i + \beta_i f_t + \gamma_i g_{it} + e^y_{it} \tag{4}$$

$$f_t = f_{t-1} + e^f_t \tag{5}$$

$$g_{it} = \phi_i g_{i,t-1} + e^g_{it} \tag{6}$$

for $i = 1, 2$. With the exception of f_t, this is equivalent to the univariate model. We label this model as weak model of market integration. It is consistent with an ECM because it preserves a long-run relationship between two variables. In fact Equation (4) can be rewritten as

$$\beta_2(y_{1t} - \alpha_1) - \beta_1(y_{2t} - \alpha_2) = \beta_2\gamma_1 g_{1t} - \beta_1\gamma_2 g_{2t} + \beta_2 e^y_{1t} - \beta_1 e^y_{2t} \tag{7}$$

Because the right-hand side of the equation is stationary, then the left-hand side of the equation is also stationary. This ensures that a linear function of y_{1t} and y_{2t} is stationary: such linear relationship represents the long-run equilibrium of the two data series. Any temporary deviation from the long-run equilibrium would cause the data to stochastically adjust and to return to equilibrium.[19]

If the data support the weak model against the univariate model, the two markets share the same stochastic trend and preserve a long-run dynamic equilibrium as in an ECM. However, the existence of such long-run dynamic equilibrium may not necessarily conform with the Law of One Price, as log price levels may still diverge (if $\beta_1 \neq \beta_2$). The left panel of Figure 1 shows two simulated series from a weak model, indicating that it would be inappropriate to conclude that two markets are integrated.[20]

4.3 Strong Model

We propose a strong model to represent the market integration hypothesis, whereby two cities

[19] This is based on the assumption that $\beta_i \neq 0$. In our application, as plotting the data clearly shows that the log price levels have trends, we take such assumption for granted.

[20] When using levels instead of log price data, a divergence between two series may be interpreted as a change in transaction costs. However, if in the presence of a long time series as in our case, using levels is not appropriate due to both the likelihood of finding heteroskedasticity and to the fact that the price dynamics may not fit any simple linear framework. Hence, unless the time series are short, using log price data is preferable.

share both the same stochastic trend and loading coefficients. It is our preferred measure of market integration, as embodied by price convergence and consistent with the prediction of the Law of One Price. This can be represented graphically by the simulated data in the right panel of Figure 1. Structurally, the strong model is nested in the weak model by forcing the stochastic trend loadings β_i to be equal between two cities.

The model is as follows:

$$y_{it} = \alpha_i + \beta f_t + \gamma_i g_{it} + e^y_{it} \tag{8}$$

$$f_t = f_{t-1} + e^f_t \tag{9}$$

$$g_{it} = \phi_i g_{i,t-1} + e^g_{it} \tag{10}$$

for $i = 1, 2$. With the exception of β, this is equivalent to the weak model. The intercept difference $|\alpha_1 - \alpha_2|$ represents trading costs. Hence, as in the right panel of Figure 1, a strong model predicts that two log prices are parallel curves, allowing for temporal deviations and noises. For the strong model to hold, any deviations originated from individual cities, g_{it} or e^y_{it}, would adjusted back to zero.[21]

4.4 Bayesian Estimation

The empirical estimation is based on Bayesian inference. Given the nature of our dataset, the Bayesian method has several advantages. First of all each price series contains some missing observations.[22] Imputing missing data would not be a feasible strategy, as price movements can not be predicted. In contrast, the Bayesian approach treats these missing values as probability distributions in the same way as model parameters, thus allowing to account for uncertainty in imputations. This is of key importance especially within the state space framework: we argue that it would not be suitable to draw reliable inference with a non-Bayesian method in the presence of such a non

[21] Özmucur and Pamuk (2007) applied the same idea to a restricted ECM by forcing the slope coefficient equal to 1. Since the authors used price level data instead of log price data, their approach cannot capture proportional transaction cost.

[22] In the original datasets by Pamuk (2000) and Allen (2001) the share of missing observations ranges between 0.22 per cent (CPI in Antwerp) and 91.14 per cent (rice in Krakow). In our estimation we use only the series with a maximum of 60 per cent missing values.

negligible amount of missing data.

Second, the number of overlapping observations across series is often not large, thus exposing the empirical estimation to small sample problems, often encountered when using historical data.[23] This becomes particularly relevant when we divide the full sample into subperiods to analyse the change in market integration over time. While asymptotic inference is valid theoretically, the minimal number of observations needed to have robust inference is unclear. As small sample properties are exact under the Bayesian framework, this type of estimation is preferable in our context. In the empirical estimation we use only the series with a maximum of 60 per cent non-overlapping values between two cities. This is calculated as the share of non-overlapping observations over t for each commodity and each computational period.[24]

Last but not the least, model selection is not achieved by testing a null hypothesis versus the alternative, but rather by treating each model symmetrically. As the Bayesian framework treats all models equally a priori, the posterior probabilities of the three models reflect evidence provided by the data for or against market integration. Indeed, the application in this paper shows that treating models symmetrically has different implications.

We estimate the models by using the Markov chain Monte Carlo (MCMC) methodologies, explained in detail in the appendix. Suppose that all parameters including the missing data are denoted by Ψ. The posterior distribution is a collection of many draws $\Psi^{(i)}$ for $i = 1, ..., M$, where M is the number of draws that are used for inference in the MCMC. Simulation consistent statistics can be computed from the sample $\{\Psi^{(i)}\}_{i=1}^{M}$. For instance, the posterior mean of the factor f is simply computed as $\widehat{E(f \mid Y)} = \frac{1}{M} \sum_{i=1}^{M} f^{(i)}$, where Y is the data.

An important application is that when forecasting the density at time t by using information up to $t-1$, we need to obtain the posterior draws $\Psi^{(i)}$ by using data only up to $t-1$ to represent the conditional posterior distribution $\Psi \mid Y_{1,t-1}$, where $Y_{1,t-1} = (y_1, ..., y_{t-1})$ and $y_t = (y_{1t}, y_{2t})$. If a certain data point y_{is} is missing, we denote y_{is} as an empty element. The predictive density $p(y_t \mid \Psi, Y_{1,t-1})$ conditional on the parameter Ψ can be computed easily because the model is explicit.

[23] We define overlapping observations as the case in which for both cities have price data for time t

[24] Therefore, by construction, each univariate series can have a maximum of 60 per cent missing values.

For the univariate model, we can derive from Equation (1)-(3) that

$$y_t \mid \Psi, Y_{1,t-1} \sim N\left(\begin{pmatrix} \alpha_1 + \beta_1 f_{1,t-1} + \gamma_1 \phi_1 g_{1,t-1} \\ \alpha_2 + \beta_2 f_{2,t-1} + \gamma_2 \phi_2 g_{2,t-1} \end{pmatrix}, \quad \begin{pmatrix} \sigma^2 + \beta_1^2 + \gamma_1^2 & 0 \\ 0 & \sigma^2 + \beta_2^2 + \gamma_2^2 \end{pmatrix}\right)$$

For the weak model, we can derive from Equation (4)-(6) that

$$y_t \mid \Psi, Y_{1,t-1} \sim N\left(\begin{pmatrix} \alpha_1 + \beta_1 f_{t-1} + \gamma_1 \phi_1 g_{1,t-1} \\ \alpha_2 + \beta_2 f_{t-1} + \gamma_2 \phi_2 g_{2,t-1} \end{pmatrix}, \quad \begin{pmatrix} \sigma^2 + \beta_1^2 + \gamma_1^2 & \beta_1 \beta_2 \\ \beta_1 \beta_2 & \sigma^2 + \beta_2^2 + \gamma_2^2 \end{pmatrix}\right)$$

For the strong model, we can derive from Equation (8)-(10) that

$$y_t \mid \Psi, Y_{1,t-1} \sim N\left(\begin{pmatrix} \alpha_1 + \beta f_{t-1} + \gamma_1 \phi_1 g_{1,t-1} \\ \alpha_2 + \beta f_{t-1} + \gamma_2 \phi_2 g_{2,t-1} \end{pmatrix}, \quad \begin{pmatrix} \sigma^2 + \beta^2 + \gamma_1^2 & \beta^2 \\ \beta^2 & \sigma^2 + \beta^2 + \gamma_2^2 \end{pmatrix}\right)$$

The conditional predictive density $p(y_t \mid \Psi, Y_{1,t-1})$ for different models can be inferred from the above distributions. Then we can integrate out the parameter estimation uncertainty by taking the sample average to obtain

$$p(\widehat{y_t \mid Y_{1,t-1}}) = \frac{1}{M} \sum_{i=1}^{M} p(y_t \mid \Psi^{(i)}, Y_{1,t-1}) \tag{11}$$

When we use the data, the value of $p(\widehat{y_t \mid Y_{1,t-1}})$ is called the predictive likelihood. As the conditional posterior sample $\Psi^{(i)}$ is inferred from the subsample $Y_{1,t-1}$, the predictive likelihood is a forecasting-based measure of model fitting.

4.5 Measurement of Market Integration

We report the posterior probabilities of models as a coherent measure of market integration. For each pair of cities, among which Istanbul is always included, the prior probabilities of the univariate, weak and strong model are the same. We denote M_i as model i, where $i = \{uni, weak, strong\}$, and the prior probability is expressed as

$$P(M_{uni}) = P(M_{weak}) = P(M_{strong}) = \frac{1}{3}.$$

The posterior probability of a model is calculated by applying Bayes rule. For example, (recall that Y is the data) the posterior probability of the strong model is

$$
\begin{aligned}
P(M_{strong} \mid Y) &= \frac{P(M_{strong}, Y)}{P(Y)} \\
&= \frac{P(M_{strong})p(Y \mid M_{strong})}{P(M_{uni})p(Y \mid M_{uni}) + P(M_{weak})p(Y \mid M_{weak}) + P(M_{strong})p(Y \mid M_{strong})} \\
&= \frac{p(Y \mid M_{strong})}{p(Y \mid M_{uni}) + p(Y \mid M_{weak}) + p(Y \mid M_{strong})}.
\end{aligned}
$$

The last equation embodies the principle of equality across the three models' prior probabilities. Thus, the interpretation of a posterior model probability is intuitive. For instance, if $P(M_{strong} \mid Y) = 0.9$, we can say that after observing the data, the probability of two markets being integrated is 90%.

The data density for each model i, $p(Y \mid M_i)$, is called the marginal likelihood (Kass and Raftery, 1995). It is a density forecasting based measure for Bayesian model selection. To be clear, suppose that the data $Y = (y_1, y_2, ..., y_T)$ is a time series data as in our application, the marginal likelihood of model M_i can be decomposed as

$$
p(Y \mid M_i) = \prod_{t=1}^{T} p(y_t \mid Y_{1,t-1}, M_i),
$$

where $p(y_t \mid Y_{1,t-1}, M_i)$ is the predictive likelihood of model M_i at time t. When $t = 1$, $Y_{1,t-1}$ is an empty set and the density forecasting are performed on the prior distribution. Such decomposition shows that the marginal likelihood is an out-of-sample forecasting measure, hence ensuring the consistent comparability of models with different number of parameters. An over-parameterised model will be automatically excluded if it does not have a good out-of-sample performance. Observing a comparatively larger marginal likelihood implies that the model receives more support from the data. Because we assume that all models are equally probable in the prior, the posterior probability solely reflects the data evidence.

To explain our methodological choices to readers who are not familiar with Bayesian inference, we provide an *ad hoc* example to clarify its difference with a classical testing approach.[25] Suppose

[25] The Bayesian and classical method have fundamental differences on inference philosophy. However, in

that we test the null hypothesis H_0 of observing the weak model M_{weak} against the alternative H_1 of observing the univariate model M_{uni}, choosing 5% as the significance level to reject the null. While according to this rule the weak model shall be discarded if its probability is below 5%, conflicting conclusions may be reached if the null and alternative hypothesis are switched. For instance, if a hypothesis has probability 30% and the other has probability 70%, neither of them can be rejected.

In this paper, we utilise the posterior probabilities of models as statistical guidance for inference on market integration. A higher probability of a strong model means that the data support market integration. A higher probability of a weak model indicates that two markets have a certain long-run relationship but do not obey to the law of one price. A higher probability of a univariate model shows that two markets are independent. Instead of specifying a rejection rule, this method provides a full picture of data evidence for each model. It treats models symmetrically and has no inferential conflict.

4.6 Half-lives

In all our models the city-specific fluctuations g_{it} has a stationary AR(1) representation. Hence it also has a well-defined half-life, calculated as the posterior mean of $\ln(0.5)/\ln(|\phi_i|)$. For a city i, it represents how long it takes to halve the gap between its current price level and the equilibrium price. Its interpretation is similar to that of an half-life in an ECM, which measures the speed of convergence, and hence can be interpreted as market efficiency. Half-lives with small values represent more efficient markets, as they embody a faster speed of price convergence.

Calculating half-lives when the data frequency is annual can be challenging, as normally commodity prices do not take years but weeks or months to adjust to equilibrium. This applies also to our historical setting. Specifically, Taylor (2001) shows that half-life estimates based on yearly data are upward biased. A parsimonious way to tackle this problem would be to replace the low frequency data with the high frequency ones, but this is not feasible in our case. Alternatively, the underlying basis of the yearly data can be corrected using Taylor (2001)'s suggested strategy. Let $\hat{H}$ be the half-life estimates using yearly data and L be the period over which the "averaging"

practice, we could always find some numerical similarities such as a density interval and a confidence interval. Although they have different interpretations, the results are comparable and usually point to similar conclusions.

applies;[26] We can compute the true half-life H by solving

$$\hat{H} = \frac{L\ln(2)}{\ln\left(\frac{L(1-2^{-2/H})-2^{1-1/H}(1-2^{-L/H})}{2^{-1/H}(1-2^{-L/H})^2}\right)}.$$

Following the above mechanism, we have adjusted the predictive half-life accordingly, on a monthly basis.

5 Results

We start by presenting the results on market integration between Istanbul and each European city for the full period, 1469-1914. Then, in order to investigate the change in the patterns of integration over time, we split the sample into five sub-periods (the log marginal likelihoods are reported in Tables A1 to A76). The choice of dividing the data into sub-samples has been guided by the way in which the CPI has been constructed, in turn motivated by underlying economic and monetary trends in the Ottoman Empire.[27] Such division is in line with Stoianovich's periodisation of Ottoman European commercial relations (Stoianovich, 1974, p.62). In each table column 2 indicates the number of overlapping observations between city-pairs; columns 3 to 5 report the log marginal likelihoods for our three measures of market integration: no integration, weak and strong integration. A complementary and intuitive way of looking at the results is provided by the posterior probability of models in Figures 2 to 7. The bars in each figure represent the posterior probability of observing each model; they also report the number of overlapping to total observations.[28] For conciseness we plot the posterior probabilities only for a selected number of goods, for the full results see Figures A1-A5 in the Appendix. Because the number of non-overlapping observation always exceeds 60 percent during the first sub-period (1469-1585), we do not report these results. As mentioned in the previous section, in order to interpret our findings we use the posterior probabilities as statistical guidance; while not specifying a strict rejection criterion, we use the following rule of thumb as indicative of a strong model's dominance over the others: $P(M_{strong}|Y) = 80\%$. If this rule is satisfied we consider two markets to be integrated. To be clear, here the results are only able to identify the existence of market integration (or lack thereof). The degree of market integration

[26]If the averaging of annual data is achieved over the monthly (weekly) data, then L equals to 12 (52).

[27]For details see Pamuk (2004, p.468).

[28]For example in Figure 2 Amsterdam's CPI has 101 over 105 overlapping observations with Istanbul's CPI.

will be discussed in section 5.1.

Generally, our findings favour the strong integration hypothesis for most time periods, and for a large number of commodities and cities. Hence, overall our analysis provides support to the existence of broad and persistent market linkages between the Ottoman and European economies over the centuries, highlighting a long lasting relationship of mutual influence. At the same time, we observe a degree of heterogeneity along the dimensions of time, geography and commodity types.

First of all, the empirical analysis based on commodity prices offers stronger evidence of price pass-through, relative to using CPI data. This is not surprising as the CPIs are not constructed using identical baskets across countries, and intend to capture the transmission of price changes across markets at the aggregate level. Nevertheless, we still find some support for integration using CPI data: for example, the full sample findings point to the existence of integrated markets over the very long run between Istanbul and two important trade partners in the Mediterranean region, Napoli and Madrid, as well as with Leipzig and Lwow, linked to the Ottoman capital via the land route (Figure 3). Observing the existence of a process of long-run price transmission with cities along both commercial routes is indicative of the significance and complementarity of these alternative ways of exchanging goods between the two regions. The CPI findings also indicate that the period in which price transmission was most widespread was 1691-1768 (Figure 2): the data support the existence of market integration, in the strong form, between Istanbul and five cities lying both on the sea and the land route: Augsburg, Lwow, Munich, Napoli and Northern Italy. In the precedent (1586-1690) and successive (1769-1843) sub-periods, we observe strong market integration with Napoli and Madrid, respectively. This reflects the fact that the Mediterranean had been the most widely used route to exchange goods between the Ottoman Empire and Southern Europe for centuries. It also signals that trade between Europe and the Levant was able to resist the opening of the Cape route and even expand at the end of the 16^{th} century (Davis, 1970, p.202).

Similarly, the analysis based on commodity markets offers widespread support to the strong integration models; in what follows we summarise the results according to historical periods, the type of commodities traded and location, whereby we divide Europe in four macro-regions. Broadly speaking, these regions reflect a division along the major trade routes: North-Western Europe (Amsterdam, Antwerp, London, Paris) linked to Istanbul via the Mediterranean and the Atlantic; Central Europe (Augsburg, Munich, Leipzig, Strasbourg) and Eastern Europe (Gdansk, Krakow, Lwow, Warsaw) connected to the Ottoman Empire via the land route; Southern Europe (Florence, Milan, Madrid, Northern Italy, Naples, Valencia) trading predominantly via the Mediterranean.[29]

Focusing on the time dimension, we find that commodity market integration was persistent over the centuries. The historical phase which witnessed the most widespread economic linkages spanned from 1586 to 1843 (sub-periods 2 to 4), as during these years the strong integration model is favoured over the others for most of commodities/cities in the sample. However, we also observe that the share of integrated cities relative to the non-integrated ones declines over time: from 72 percent in 1586-1690 to 61 percent in 1691-1768 to 59 percent 1769-1843.[30] While this share declines further (to 40 percent) in the last sub-period, 1844-1914, it is important to highlight that for this time span we have data only for four commodities and two cities, of which 2 are integrated.[31] As such, the results may not necessarily mirror a weakening of the linkages between the Ottoman Empire and Europe during the second half of the nineteenth century, but may rather reflect the lack of a comparatively exhaustive sample relative to the earlier periods.

The results on the spatial patterns of integration are summarised in Figure 8. In North-Western Europe we find evidence of price convergence between 1586 and 1843 for a variety of commodities: chickpeas, butter, wheat, soap, charcoal, olive oil and wood.[32] We find similar patterns in Central Europe: our results point to the existence of price transmission with Ottoman markets between 1586 and 1843 for a wide set of commodities. We identify the largest number of integrated markets in Augsburg, Munich and Leipzig during the third sub-period (1691-1768), and in Strasbourg integration increased in the following sub-period (1769-1843). For the Eastern European cities we find the largest share of integrated markets in the period from 1586 to 1690.[33] Turning to Southern

[29]Northern Italy is a composite of average prices in Venice, Milan and Florence.

[30]The shares are calculated as follows: in 1586-1690 we have price data for 25 commodities/cities, of which 18 are integrated with Istanbul. The correspondent numbers for 1691-1768 are 33 over 54; and for 1769-1843 22 over 37.

[31]Specifically we have data for Milan's olive oil, rice, soap and wheat markets and Strasbourg's rice market.

[32]While in Antwerp the share of integrated markets did not change during this period, for Amsterdam and Paris the periods with the largest number of linked markets were 1691-1768 and 1769-1843, with integration increasing over time. All London's markets for which data are available (butter, wheat, olive oil) were integrated with Istanbul in the third subperiod (1691-1768).

[33]This region exhibits some heterogeneity: only Gdansk's markets were integrated for three consecutive

Europe, we find clear evidence in support for the strong model in both sub-periods 2 and 3, with Napoli exhibiting the strongest linkages in the region. At the same time we observe a decline in the average share of integrated markets in the following century (1691-1843).[34]

When looking at specific commodities, we find that grains and particularly wheat (Figure 7), had strong and geographically widespread patterns of integration. Wheat price data are available for the 1691-1843 period for 13 cities. In 1691-1768 10 of them and in 1769-1843 13 of them are integrated with the Ottoman capital. In the rice market (Figure 5) price convergence took place between Augsburg and Istanbul (but not in Milan and Valencia) in 1585-1690, but then spread to all cities for which we have data between 1769 and 1914 (Milan, Strasbourg and Warsaw). Also the olive oil market linkages were strong for a wide set of cities, which were all integrated with Istanbul between 1585 and 1843, with the exception of Milan in the second sub-period (Figure 4). The soap data are less abundant: they start in 1691 and are available only for four cities (Milan, Amsterdam, Paris, Leipzig), but still exhibit strong integration patterns between 1691 and 1843 (Figure 6). Wood prices cover only the 1691-1768 period (Figure A5), in which the strong model always dominates the others, in all cities (Augsburg, Gdansk, Madrid, Northern Italy, Paris, Warsaw). Istanbul's chickpea markets are integrated with all cities in 1586-1690, but this declines rapidly in the following periods (Figure A3). Finally, we find less robust evidence for integration in the butter and charcoal markets (Figures A1, A2).

5.1 Half-lives

The findings presented in section 5 allowed us to understand whether two markets were integrated, and how this changed over time. In this section we assess the efficiency of integrated markets by looking at half-lives, indicating how fast price deviations from equilibrium, caused by short-run shocks, were cleared. Figures 9 to 11 illustrate the half-lives of all integrated commodities between

sub-periods (1586 to 1843), behaving similarly to most Central and North-Western European cities, with the largest share in 1769-1843. Furthermore, we find evidence of price pass-through between Lwow and Istanbul's butter and chickpeas markets in 1586-1690, and for all available Krakow's markets (chickpeas and olive oil) between 1586 and 1768. Warsaw's price data are available only for 1691-1843, during which the majority of the commodities support the strong integration hypothesis.

[34] We do not find any evidence of integration in Napoli's and Northern Italy's markets in this period.

1586 and 1843 (see Tables A77-A86 in the appendix for the full results).[35] In both figures and tables, we report two half-lives, representing the speed of convergence to equilibrium of Istanbul's prices as well as those of the paired European city. Looking at both half-lives allows us to identify the leading city within each market, by looking at which location reached faster the equilibrium path. Thus, observing a quicker speed of adjustment in a specific Istanbul market relative to that of its European counterpart (that is, if Istanbul had a smaller half-life), is indicative of its higher efficiency and lower degree of price dispersion.

Overall, the estimates show that the speed of convergence ranged from quickly adjusting markets, such as Istanbul-Augsburg rice (sub-sample 2) and Napoli-Istanbul wheat (sub-sample 3) to slower ones, such as Istanbul-Antwerp charcoal (sub-sample 3) and Augsburg-Istanbul wood (sub-sample 3). Furthermore, the results indicate that the speed of price pass-through was quicker than one month for 27% of the commodities, it ranged between one and two months for 22% of them, it was between three and six months for 25% of the markets, while the remaining 27% took more than 6 months to return to equilibrium. We can also observe that there was not a clear leading market: Istanbul's speed of convergence was quicker for 59.1% of the sample (across time and goods), specifically for wood, butter, olive oil, honey and rice and in sub-samples 2 and 3.[36] Finally on average Istanbul's half-lives were smaller than those of Valencia, Amsterdam, Napoli, Krakow, Lwow, Munich, Milano, Augsburg, London, Warsaw and Madrid, but larger than those of Gdansk, Leipzig, Vienna, Paris, Antwerp and Firenze. Thus, the half-life estimates reinforce our market integration findings, providing a more detailed picture of the relationship of mutual influence between European and Ottoman markets. They also suggest that they were both market-oriented economies, with similarly good institutions of allocative efficiency.[37]

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[35] We computed also the half-lives of non-integrated markets. As expected, such half-lives have much larger values relative to those of the integrated ones, reflecting a lower efficiency. While we do not report them, they are available upon request.

[36] In the chickpeas and soap markets the speed of convergence was similar between Istanbul and the respective European city-pair, while the latter had more efficient wheat and charcoal markets. The results from the full sample point to similar half-lives, while in sub-samples 4 and 5 the European cities had on average a faster speed of convergence.

[37] Our finding are in line with those of Shiue and Keller (2007), who compare market integration in China

5.2 Robustness checks

To verify the validity of our results we perform a set of robustness checks. First we propose an alternative specification for the city-specific factor g_{it}. Following Uebele (2011) we model g_{it} as an AR(8) process (instead of AR(1)) in order to account for potential fluctuations arising from the business cycle. This strategy is also consistent with Burns and Mitchell (1946), who suggest the use of 8 lags to adjust for business cycles when using yearly data. All results are reported in the last three columns of the appendix tables (A1-A76). They are qualitatively similar to our baseline specification, supporting the strong model from most goods, periods and locations.

Second, we perform the empirical analysis with any number of missing or non-overlapping observations. Again, all the baseline results continue to hold.[38] Finally, we use different thresholds to accept the dominance of the strong model over the others. Specifically, we choose a stricter criterion as guideline to consider two markets to be integrated: $P(M_{strong}|Y) = 90\%$. While using this rule leads to a reduction in the number of integrated commodities, we do not observe any period- or city-specific pattern. For example, in subsample 2 the goods for which the probability of the strong model is between 80% and 89% vary from butter in London, Lwow and Napoli to chickpeas in Antwerp and Krakow to honey in Valencia, thus not involving a particular traded item or geographic location. In some cases the results are identical, such as CPI and rice in subperiod 2, chickpeas in subperiod 3 and in the full sample and soap in subperiods 3 and 4. Hence, generally, using the 90% rule would not change our overall conclusions on integration. Obviously, adopting a less strict criterion such as $P(M_{strong}|Y) = 70\%$ would lead to an even more widespread acceptance of the strong integration hypothesis.

6 Discussion

Three key findings emerge from our empirical analysis, which can be framed by looking at market integration along the dimensions of time, geography and commodity types. First, the historical period in which the strong model of integration was most widely supported by the data stretched from the seventeenth to mid-nineteenth century. Second, during these two and half centuries we observe an evolution in the patterns of integration across locations, based on a gradual and partial

and Western Europe and support the argument that both regions had good allocative institutions.

[38] The results are available on request.

shift from the dominant role played by Southern and Eastern European markets in their connection with Istanbul to that of Central and North-Western European markets. Third, we find evidence of price convergence for most commodities in our sample; this was persistent over time and had a wide geographic spread especially for the wheat, olive oil and soap markets.

How can we explain such findings? We believe that our results are likely to reflect both the patterns and intensity of commercial exchange between Europe and Istanbul. Unfortunately, we are not able to document the volume of trade flows between Europe and the Ottoman Empire, as aggregate trade statistics are not available for the 1450-1800 period and overall information about trade transactions of specific commodities and/or years is fragmentary. Instead, we turn to the large body of historical literature describing the intensity of commercial interconnectedness between the two regions.[39] Most importantly, such literature provides evidence that the commodities in our sample were import competing, a necessary condition for the transmission of price changes across locations.[40] Berov (1974), among others, reports a list of traded items between the Balkans, the Empire and Europe between the sixteenth and the nineteenth century, documenting the active competition between Istanbul and various European cities for basic food items and raw materials. McGowan (1981, pp.1-3) explains how between the sixteenth and the eighteenth century the patterns of trade between Europe and the Ottoman Empire mirrored regional specialisation in production, hence differences in relative factor prices. Europe was able to share cheaper Ottoman factor supplies during the pre-industrial era of high population growth. Such demographic pressures, particularly strong in North-Western Europe, altered land to labour ratios (and prices), increasing the need for unprocessed commodities, usually food and fiber.[41] This represented the key linkage in the Ottoman-European trade, whereby land-intensive Ottoman commodities, were exported in copious quantities to Europe in exchange for processed goods or coin, following comparative advantage.

[39] See for example Barkan (1975); Çizakça (1985); Berov (1974); Wallerstein (1979); Bulut (2001); McGowan (1981).

[40] For example, McGowan (1981, pp. 3-5) explains that population pressures in Europe led to an increase in the demand for primary goods which could not be satisfied by domestic supply, thus leading to an increase in imports from the Ottoman Empire. See also Stoianovich (1974).

[41] The conditions of increased population growth in Europe in the sixteenth century meant that there was not enough land to sustain prevailing consumption patterns, thus leading to a rise in imports from the Levant.

Indeed, there is extensive evidence that between 1500 and 1800 trade between Europe and the Ottoman Empire, despite subject to fluctuations, was active and heterogenous, reflecting higher levels of commercialisation in both regions.[42] Trade transactions were regulated by the principle of capitulation (*ahidname*) since 1500. This represented a form of amnesty formally granted by the head of the Islamic community to non-Muslim nations (Inalcik and Quataert, 1994, p.189). In practice, the capitulations guaranteed foreigners the possibility to travel and trade freely throughout the Empire and in return the Ottomans expected a similar treatment for their own traders abroad, that is a *quid pro quo* bargaining for mutual advantage.[43] Another important factor facilitating trade with Europe was the de facto minimal degree of tariffs and overall protectionist measures applied by the Empire (Inalcik and Quataert, 1994).

The Ottoman Empire exported to Europe primarily agricultural produce (wheat, rice, olive oil) and raw materials (silk, wool and mohair) as well as a limited number of manufactures, while importing mainly cloth and raw materials, such as tin and lead.[44] European traders competed with Ottoman merchant networks for the exports of manufactured goods, especially textiles (Inalcik and Quataert, 1994, p. 480). The competition for the control of the Mediterranean was quite lively, even more so the rivalry between English and Venetians merchants in the sixteenth century and between English, Dutch and French traders in the seventeenth century. The existence of such competitive environment, in conjunction with the capitulation agreements, facilitated the process of price transmission between Ottoman and European markets (Inalcik and Quataert, 1994, p. 482).[45]

As emerged from the empirical analysis, the share of integrated commodity markets exhibited some geographic variation. This is because the weight and relative importance of the Ottoman Empire's main trading partners, the Italian city states, France, England, the Netherlands and the

[42]See for example Inalcik and Quataert (1994) and Stoianovich (1974).

[43]Ottoman traders belonging to non-Muslim minorities (Jews, Greeks and Armenians) thrived in many European cities such as Venice, Ancona and Lwow. Ottoman Muslim merchants in Venice were given their own *fondaco dei Turci* in 1592.

[44]For instance, between 1621 and 1721 Middle Eastern raw silk exports to England increased by 275%; silk exports to the Low Countries rose considerably, too (Çizakça, 1985, 357). Between 1621-1634 and 1663-1669 exports of mohair yarn to England rose by 400% (Davis, 1970).

[45]See Çizakça (1985, p. 364) for Ottoman-European competition in the textile sector.

Habsburg Empire, varied throughout the centuries, reflecting changes in economic and geopolitical supremacy. At the beginning of our period the most active trade relationship occurred with the Italian city of Venice, followed by Genoa and Florence. The Venetian and the Genoese were also the main middlemen for Levantine products in North-Western Europe and Spain, which may help explain the market integration findings for these parts of Europe (see Map 1 for an illustration of the sea routes connecting the Ottoman Empire to Europe). The rise and fall from prominence of the Italian traders, substituted first by the Dutch and English and then by the French, as discussed in McGowan (1981, p.15), is broadly captured by our results. The Mediterranean was not always the preferred choice of transportation and was often complemented by the land route, which connected the Empire to Eastern and Central Europe, via the Danube and Transylvania (see Map 2). These roads were actively used in the seventeenth century by Rumelian traders to buy and sell Ottoman and European goods. Land-based trade thrived during this period thanks to the spread of large trade fairs in the Balkans, such as those of Uzundjova and Plovdiv (Stoianovich, 1974; McGowan, 1981). In fact our results show that the majority of Eastern European markets were integrated with the Ottoman capital during the seventeenth and eighteenth centuries.

Beyond Transylvania, the caravan routes that connected the Empire to the Austrian border flourished particularly during the eighteenth century, when the decrease in mercantile activities in the Mediterranean shifted the commercial exchange of Ottoman-British goods by the way of Vienna (Inalcik and Quataert, 1994, p.486). This was further facilitated by the growing importance of the fairs of Leipzig, particularly active from the early 1700s, of those Komorn and Rusciuk on the Danube (Stoianovich, 1974, p.98). An alternative way to exchange goods with Europe was via Dubrovnik, used as a hub for both maritime trade via the Adriatic and overland trade via the Balkans (Inalcik and Quataert, 1994, pp. 510-1).[46] The active use of overland transit and the alternative via Dubrovnik are at the bases of our broad findings of integration in Central European cities of Leipzig, Augsburg, Strasbourg and Vienna, which were particularly strong in the 1691-1768 period.

Our results also show that London, Antwerp, and Amsterdam's commodity market linkages with Istanbul strengthened between the late seventeenth and the first decades of the nineteenth

[46]Dubrovnik was a tributary state of the Ottoman Empire, whereby trade was controlled by Italian-speaking merchants of Slav background, who enjoyed special privileges within the Ottoman territory.

century.[47] England's direct contact with the Empire started at the time of the Ottoman-Venetian war (1570-3) and it was strengthened by the provision of full capitulatory privileges in May 1580 (Inalcik and Quataert, 1994) and the foundation of the Levant Company in 1581 (Willan, 1955). Displacing the Venetians from the Mediterranean in the early seventeenth century, English trade relations with the *Porte* remained intense until the first half of the eighteenth century.[48] Trade with the Dutch also strengthened from the 1570, spurred by the creation of a Turkish "nation" of merchants in Antwerp in 1582 and the granting of capitulations in 1612. The consolidation of the Dutch commercial position in the Levant continued until the late 1700s (Van der Wee, 2013, p.257).[49] The eighteenth century saw a shift in the Empire's trade partners, as England was replaced by France as major destination of Ottoman exports, and supplier of textiles.[50] Our results capture the increased importance of the French markets by showing a strengthening of integration between Paris and Istanbul between 1691-1760 and 1761-1843.[51]

Turning commodities, finding evidence of price convergence for a wide range of goods reflects the active competition between European and Ottoman markets. While various foodstuffs were exported from the Ottoman territories, wheat deserves special attention, since it was the main traded foodstuff in terms of value and quantity, over long periods of time (Braudel, 1995; McGowan, 1981, pp.32-38). While it not possible to make generalisations about the levels of European-Ottoman wheat trade, as these were not regularly recorded, we know that English and Dutch ships were used to import Ottoman wheat and rice throughout the seventeenth and eighteenth centuries and that the land route was also often used to trade grains, sometimes defying the Sultan's interdiction

[47]On average the share of commodities integrated between these North-Western European cities and Istanbul was 72% during 1691-1760.

[48]Ottoman-British trade was based on the English exporting woollen cloth, tin and lead and importing spices, raw materials and various foodstuff, particularly currants, olive oil and wine (Brenner, 1972).

[49]The Ottomans supplied the Dutch with cotton, yarn, leather, honey and beeswax in exchange for lead, tin, iron and steel.

[50]France's status as leading trade partner was facilitated by the 1740 trade agreement which allowed French goods to be imported at 3 percent custom rate, the lowest applicable to foreigners (Inalcik and Quataert, 1994, p.728).

[51]The integrated commodities are wood (1691-1760), soap and wheat (1761-1843).

to export outside the Empire (Fekete and Káldy-Nagy, 1962). Together with cereals, olive oil, and its byproduct soap, were other important Ottoman exports to Europe between 1500 and 1800 (Stoianovich, 1974). The supply of Ottoman oil was in fact connected not only with European demand for direct consumption, but also with the production needs of soap factories.[52] That oil and soap were import competing emerges, for example, from a series of records of the French consuls in the Levant, who often opposed the establishment of Ottoman soap manufacturing, fearing a decline in domestic production and export (Grenville, 1965).

7 The impact of conflict on integration

While our empirical analysis points to the existence of persistent economic ties between Europe and the Ottoman Empire during 1469-1914, their relations were also shaped by conflict during this time. The Empire looked westwards for territorial expansion, especially during its period of military dominance (until the signing of the Treaty of Karlowitz, 1699) and made extensive territorial gains in the Continent. The Ottoman-European wars were not only a matter of geopolitical supremacy, but also a struggle between two rival faiths. Indeed, the religious divide between the two regions was often at the basis of violent confrontations and it is regarded as a major barrier to their interaction (Bosker et al., 2012, p.1423).

To what extent did conflict disrupt market integration between Europe and Istanbul? To measure the impact of war on commodity price transmission we use the following regression:

$$P(strong)_{itc} = \alpha_1 + \beta\, OE - EUwar_{it} + \gamma\, OEwar_t + \Psi X_i + \delta_i + \delta_t + \delta_c + \epsilon_{itc} \qquad (12)$$

where $P(strong)_{itc}$ represents the posterior probability of the strong model for commodity c in city i at time t; $OE-EUwar$ denotes the number of wars between city i and the Ottoman Empire; $OE\ war$ takes the value of 1 if the Ottoman Empire was engaged in a non-European war; δ_i, δ_t and δ_c are city, time and commodity-specific effects, respectively. The vector X_i contains a set of control variables: *sea route*, which equals 1 if the main trade route between Istanbul and city i was via the Mediterranean or the Atlantic and zero otherwise; *distance* is the geographic distance from Istanbul

[52]For example, the decline in labour employed in Marseille soap factories in 1788, led to a decline in Ottoman oil exports in 1789.

and city i;[53] *OE−EU casualties* and *OE casualties* represent the number of casualties in European-Ottoman wars and non-European Ottoman wars, respectively. The estimates of coefficient β are our main point of interest.

To identify the number of wars between between each city in our sample and the Ottoman Empire we utilise Brecke's *Conflict Catalog*, a compilation of all violent conflicts that occurred between 1400 and the present. The *Catalog* provides information about the number of wars, their duration and the number of casualties.[54] Figure 12 illustrates that conflicts between the Empire and our sample of cities were frequent throughout the centuries. At the same time it is also important to note that not all cities were directly involved in wars with the Empire.[55]

The results are presented in Table 1: columns I to V report OLS estimates, columns VI to VIII poisson pseudo-maximum likelihood (PPML) estimates; the standard errors are clustered at the city level. The findings show that war *per se* did not have any impact on market integration (columns I-III and VI). However, when controlling for the number of casualties the coefficient of war becomes negative as significant, thus indicating that conflict intensity reduced the extent of price convergence between Istanbul and Europe (columns IV and VII). Specifically, one additional war lowered the posterior probability of the strong model by 1.7-2 per cent.[56] We obtain similar results when interacting war with duration (see coefficients on *Eu − Ottoman war* x *time* and *Ottoman war* x *time* in columns V and VIII), confirming the negative effect of war intensity on price pass-through. The computation of the marginal effects of war of conflict, illustrated in Figure 13, further highlights the increasing impact of war on integration, as represented by the progressively stronger incidence of conflict, as war intensifies.

8 Conclusion

Our investigation of integration between Europe and the Ottoman Empire shows that the linkages between the two regions' markets had different intensities, varying across the multiple dimensions

[53]The distance data are from geobytes, accessible at `http://geobytes.com/get-city-details-api/`

[54]The *Catalog* records all violent conflicts with at least 32 battle deaths. It is accessible at `http://www.cgeh.nl/data`.

[55]For example Valencia, Augsburg and Leipzig never engaged in conflict with the Porte between 1469 and 1914.

[56]For the PPML regressions the formula to compute the effect of a coefficient is $(e^{\beta} - 1)x100$.

of time, space and commodity type. By exploiting a rich dataset covering 20 cities, 9 commodities and four and half centuries, we have provided new empirical evidence on the nature and degree of market connections between two key regions of the international economy. Our findings also pointed to comparable levels of allocative efficiency between Ottoman and European market institutions, as measured by similar speeds of price pass-through embodied by the half-lives. The implementation of a methodology based on dynamic factor models, using Bayesian inference, enabled us to overcome some key challenges linked to the type of historical data we used and thus to offer the first comprehensive empirical study of price transmission between Istanbul and a large set of European cities.

While our findings stand in contrast with Bosker et al. (2012) key arguments on the lack of interdependence between the Islamic world and Europe, they sit well with the predominantly qualitative historical literature on the economic relations between the two regions. As emphasised by Ottoman-European historiography, we believe that the strong and long lasting integration patterns between Europe and the Ottoman Empire emerging from our analysis reflected a continuous, but at the same time evolving relationship of commercial exchange, resisting the disrupting forces of political antagonism and conflict. Such exchange was predominantly shaped by an East to West flow of primary goods, stimulated by an increase in European demand, especially Western European, from the 16th century. Europe's rising needs started attracting considerable quantities of agricultural exports, dominated by food and fiber, part of which came from the Levant.[57] Despite fluctuating over time, in terms of volume and content, Ottoman products continued to penetrate and influence pre-industrial European markets, due to their import-competing nature. Their possibility to compete with European prices reflected the Empire's relative factor endowment, where a relatively more extensive land frontier offered a cost advantage compared with European limited availability of marginal lands and growing population. Such patterns of specialisation linked Ottoman and European markets and enabled price transmission to take place and persist over the centuries.

[57]The Baltic shores were also key supplier of grain, mainly rye to Western Europe between the 16th and the 18th centuries.

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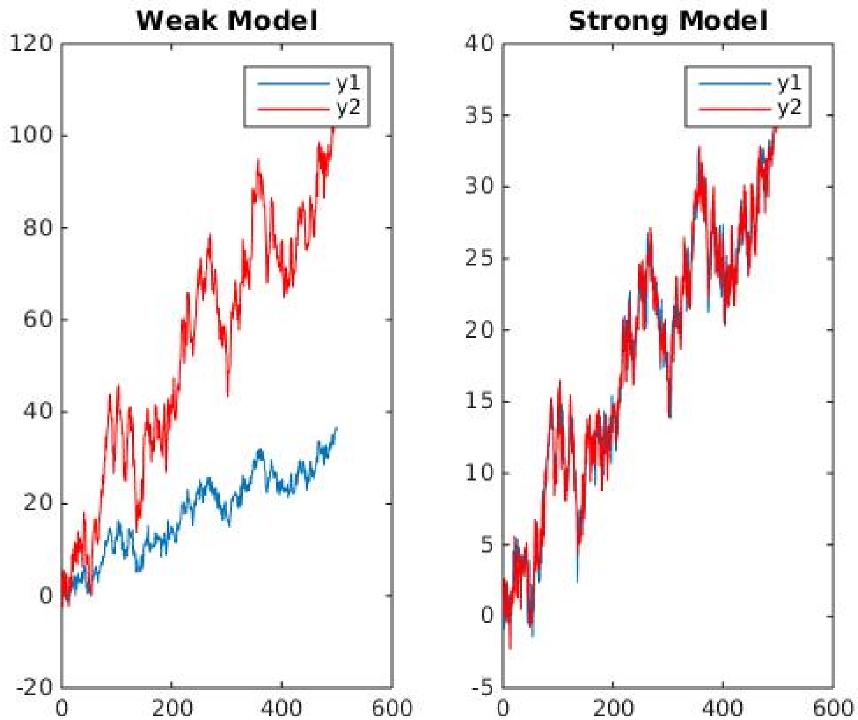
Table 1: The impact of war on integration

	OLS					PPML		
	I	II	III	IV	V	VI	VII	VIII
N. Eu-Ottoman	0.008	0.003	0.002	-0.017*		0.003	-0.021**	
wars	(0.009)	(0.009)	(0.008)	(0.006)		(0.010)	(0.007)	
N. Ottoman	-0.001	-0.001	-0.000	0.001		0.000	0.001	
wars	(0.001)	(0.001)	(0.001)	(0.002)		(0.001)	(0.002)	
Eu-Ottoman					-0.008*			-0.011*
war x time					(0.004)			(0.004)
Ottoman					0.000			0.000
war x tine					(0.000)			(0.000)
Eu-Ottoman				0.000	0.001		0.000	0.001*
war casualties				(0.000)	(0.000)		(0.000)	(0.000)
Ottoman				-0.000**	-0.000*		-0.000***	-0.001***
war casualities				(0.000)	(0.000)		(0.000)	(0.000)
Distance	0.000***	0.000***	-0.000	0.000	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sea route	0.005	0.014	-0.009	-0.066	-0.318***	-0.011	-0.085	-0.457***
	(0.009)	(0.010)	(0.008)	(0.046)	(0.060)	(0.011)	(0.044)	(0.063)
City FE	Y	Y	Y	Y	Y	Y	Y	Y
Time FE	N	Y	Y	Y	Y	Y	Y	Y
Commodity FE	N	N	Y	Y	Y	Y	Y	Y
N	431	431	431	130	116	431	130	116
$R2^+$	0.048	0.202	0.261	0.403	0.434	0.250	0.384	0.421

Notes: * p<0.05, ** p<0.01, *** p<0.001.
Columns I-V report OLS estimates, columns VI-VIII report poisson pseudo maximum likelihood (PPML) estimates. Standard errors are clustered at the city level.
$^+$ Pseudo R2 for PPML regressions

Figure 1: Simulated data from a weak and a strong model



Note: The left panel is simulated from a simplified weak model

$$y_{1t} = f_t + e_{1t}$$
$$y_{2t} = 3f_t + e_{2t},$$

where e_{1t} and e_{2t} are independent standard normal random variables and $T = 500$. The right panel is simulated from a simplified strong model

$$y_{1t} = f_t + e_{1t}$$
$$y_{2t} = f_t + e_{2t},$$

where e_{1t} and e_{2t} are independent standard normal random variables and $T = 500$.

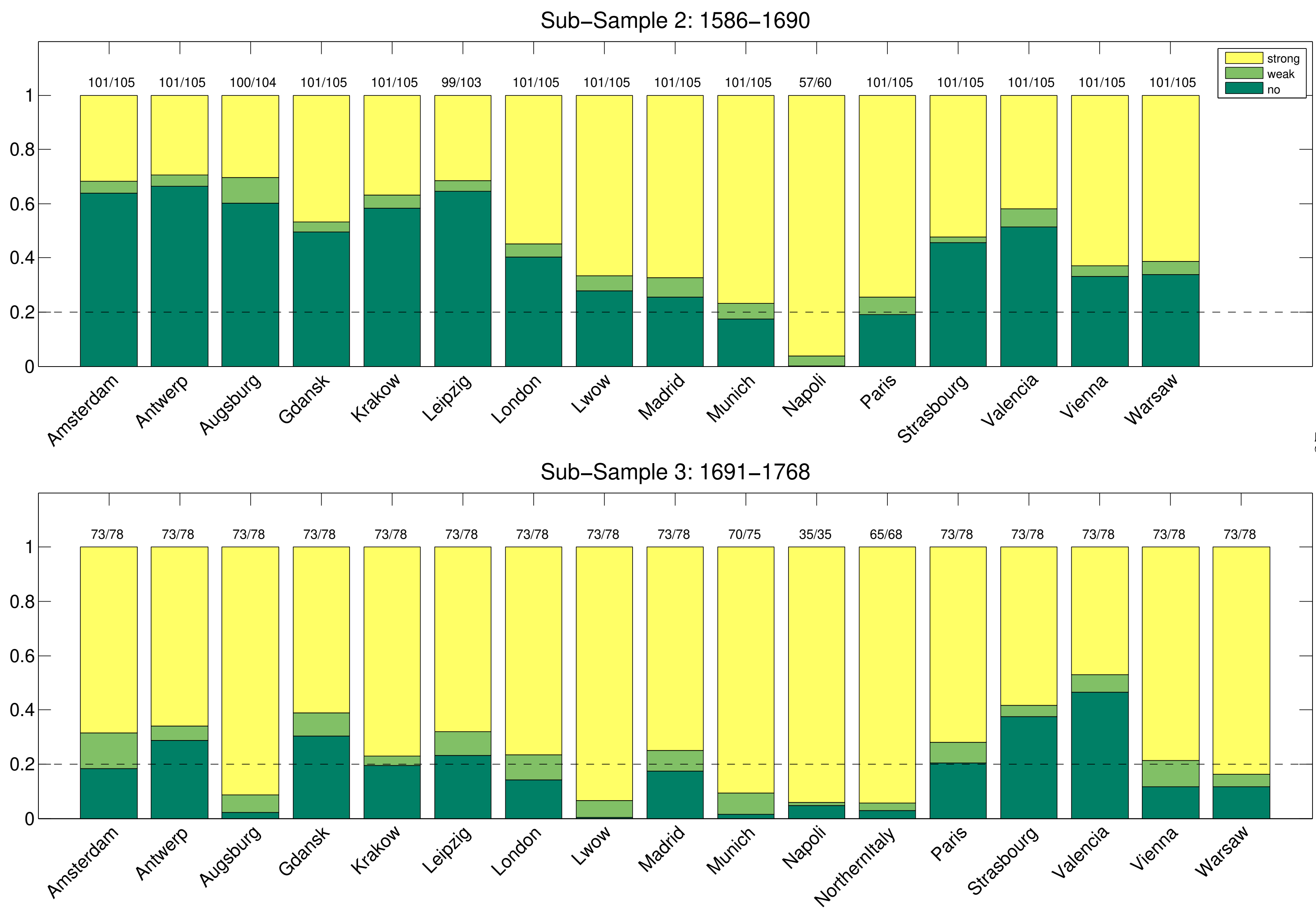


Figure 2: Posterior probabilities of strong, weak and no integration models: CPI, 1586-1690 and 1691-1768

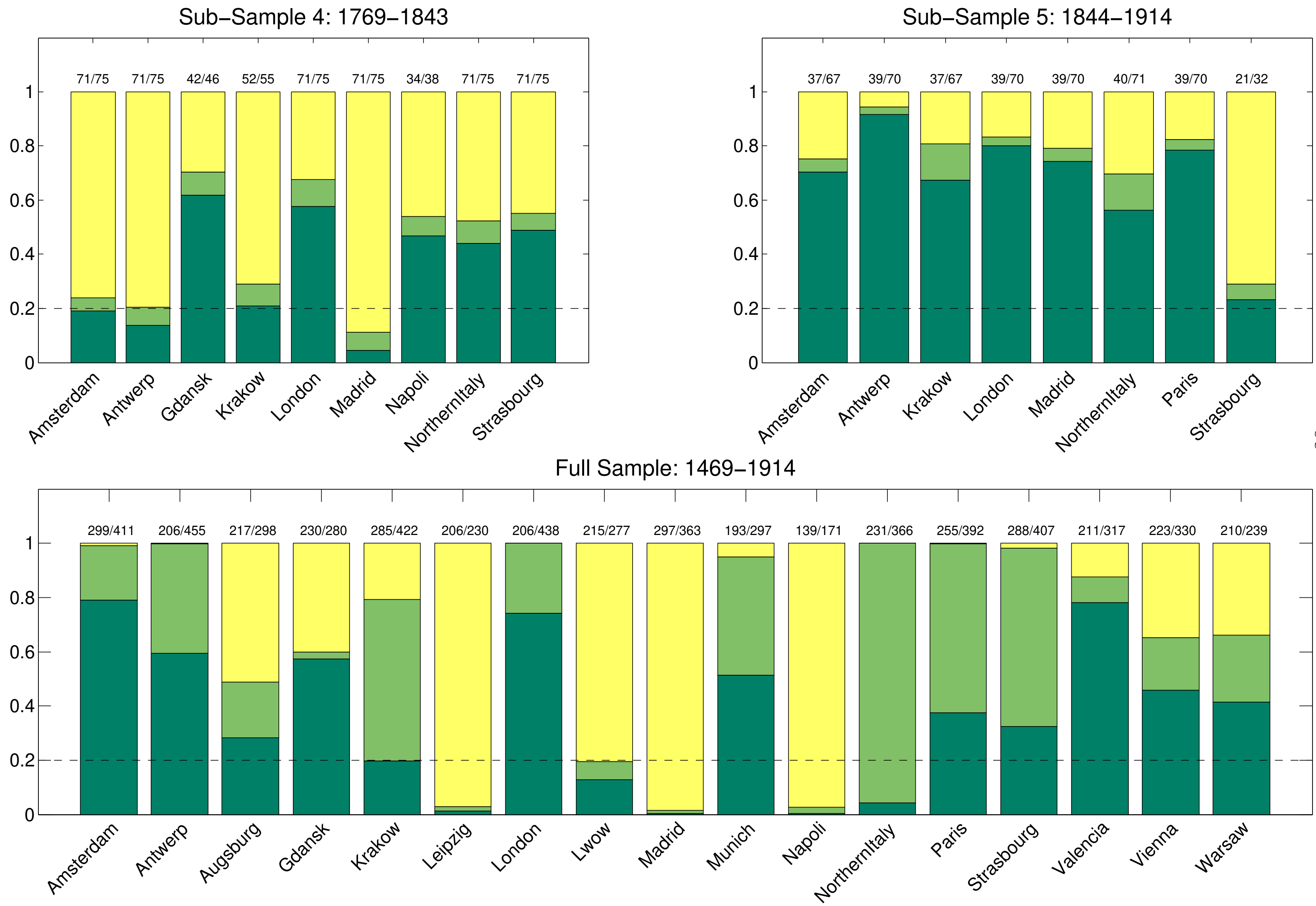


Figure 3: Posterior probabilities of strong, weak and no integration models: CPI, 1769-1843, 1844-1914, 1569-1914

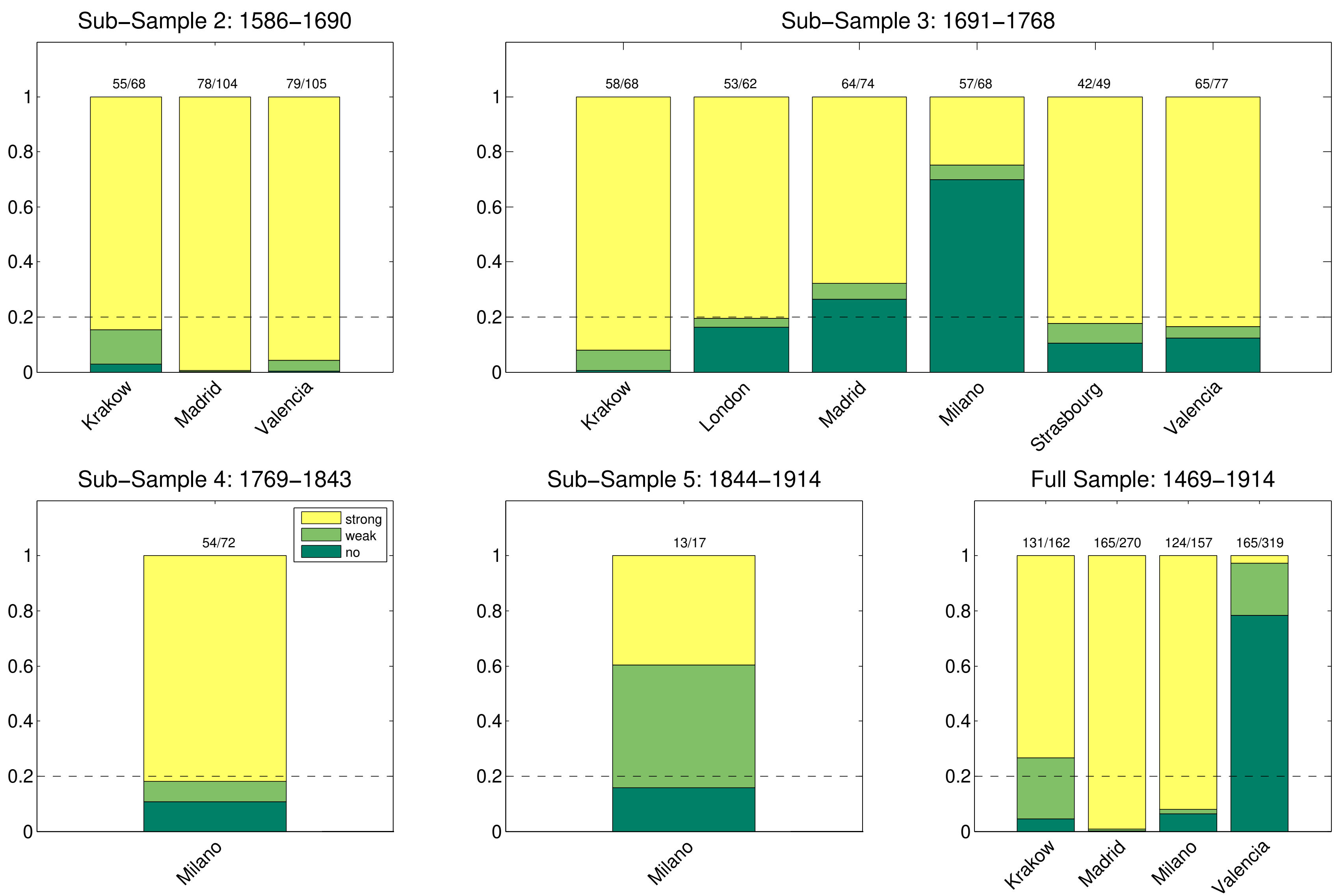


Figure 4: Posterior probabilities of strong, weak and no integration models: olive oil

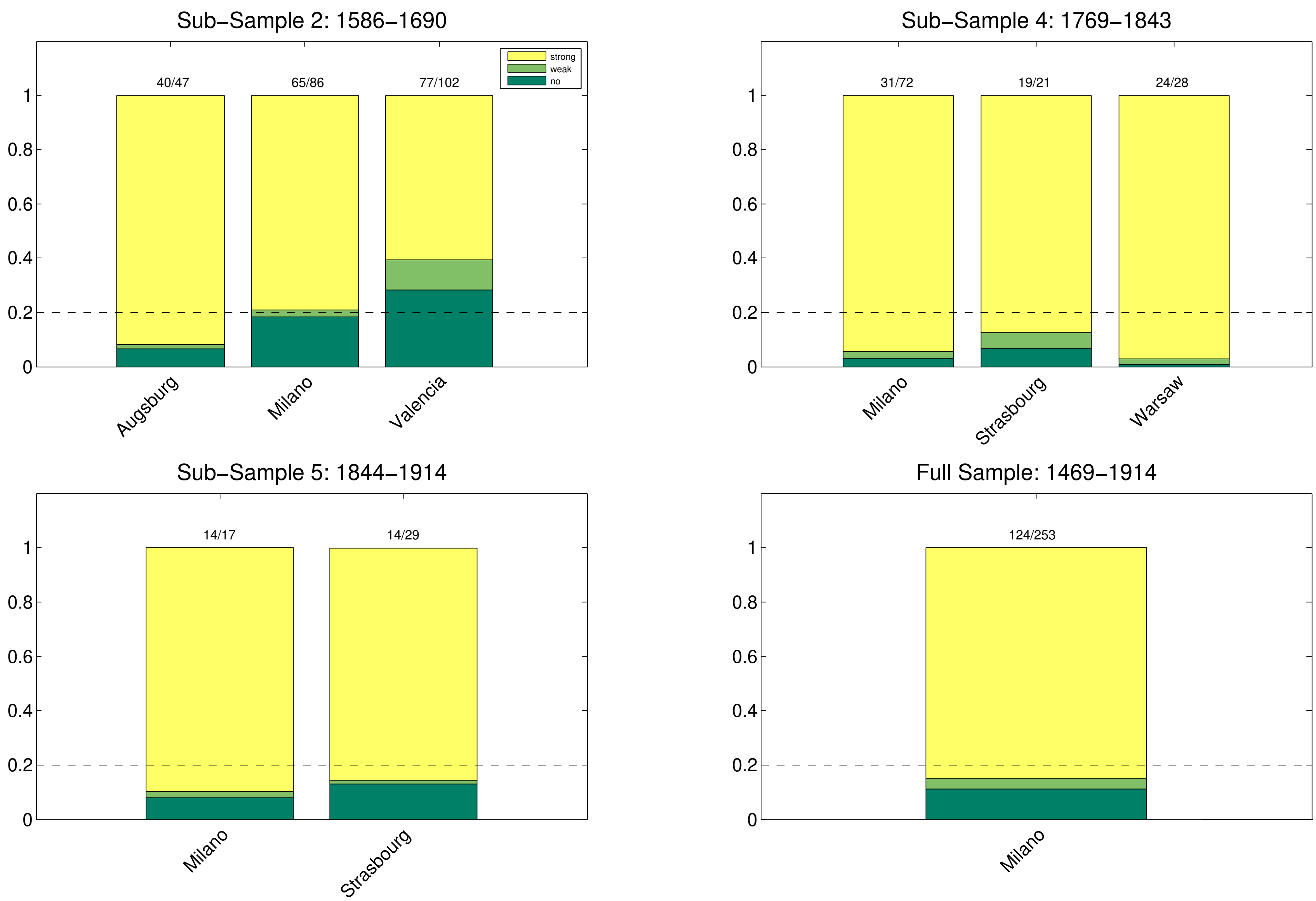


Figure 5: Posterior probabilities of strong, weak and no integration models: rice

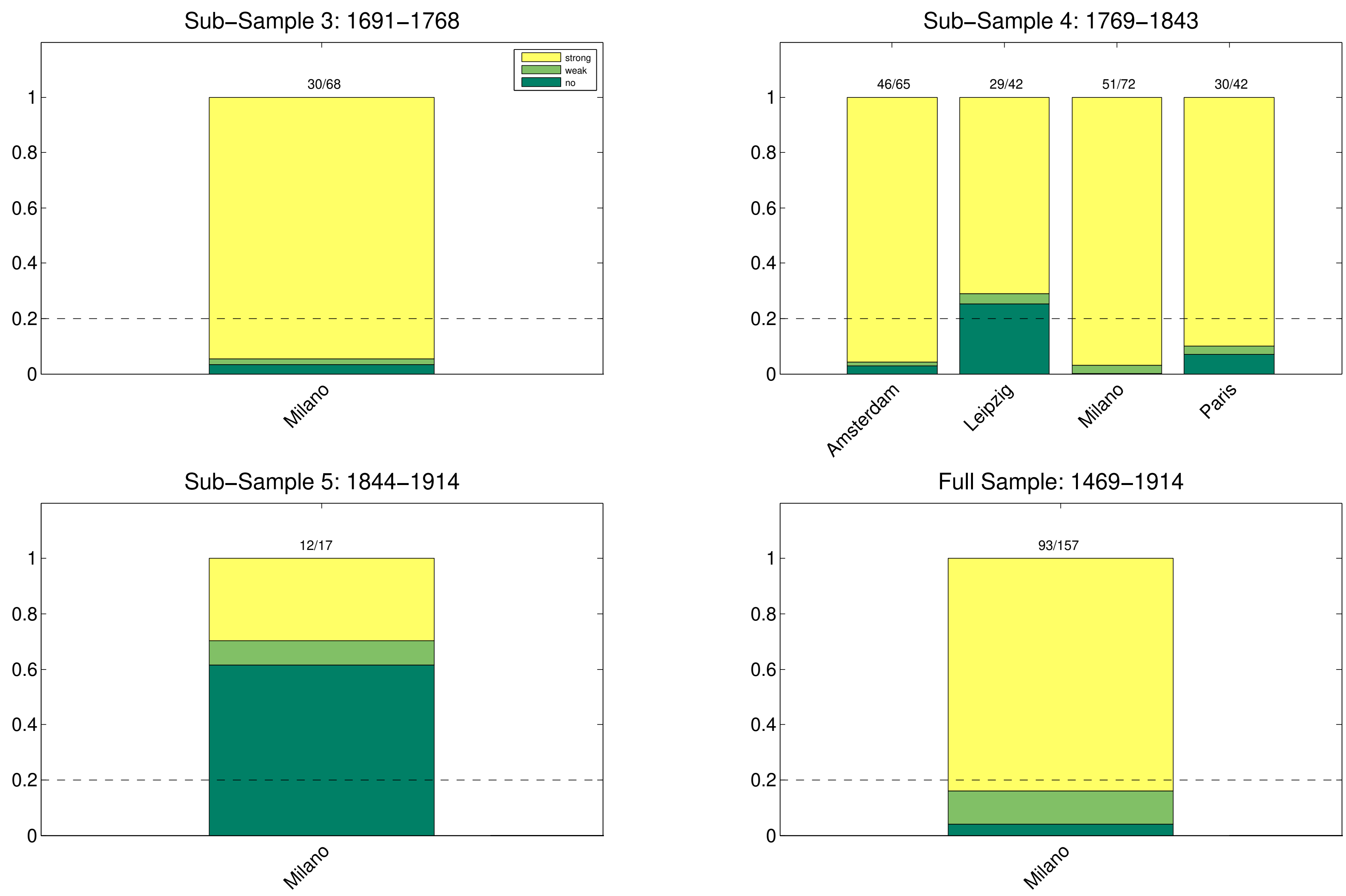


Figure 6: Posterior probabilities of strong, weak and no integration models: soap

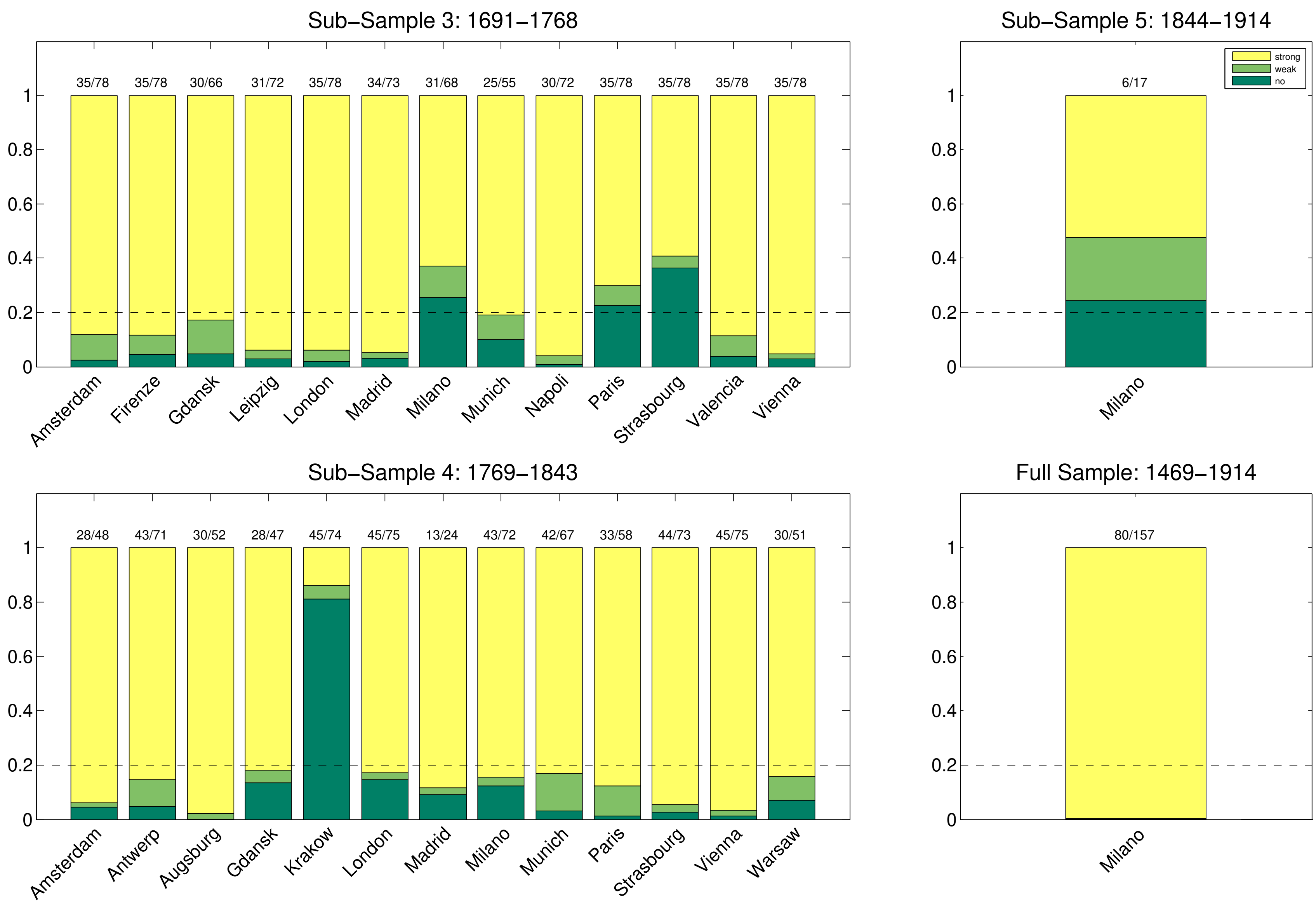
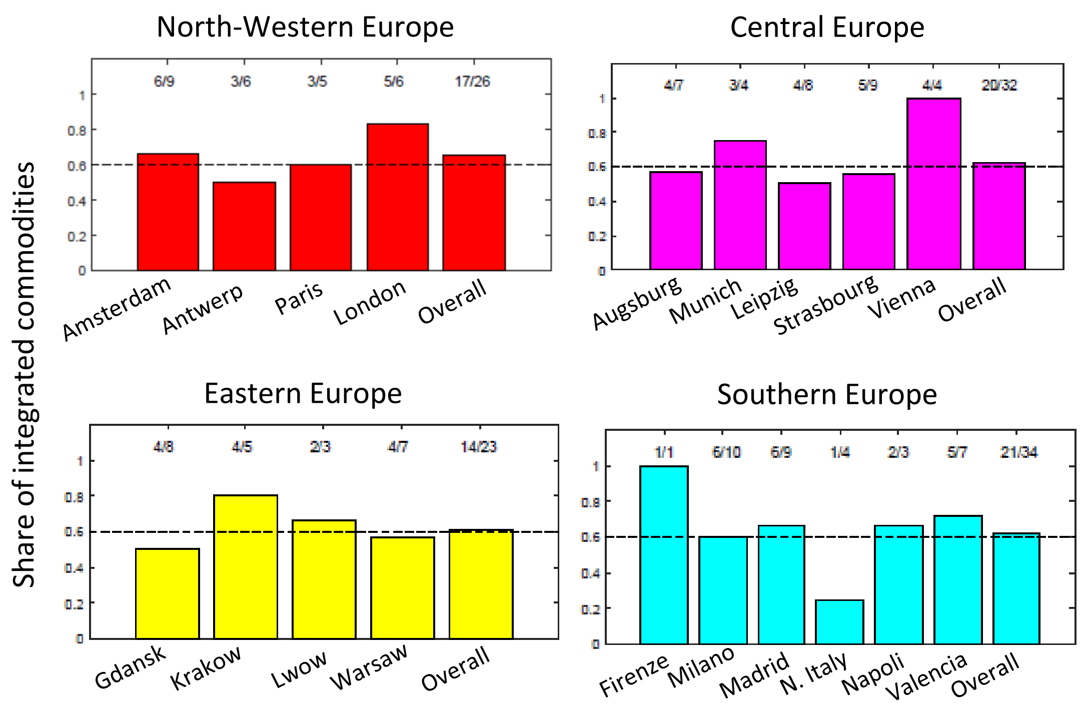


Figure 7: Posterior probabilities of strong, weak and no integration models: wheat

Figure 8: Share of integrated commodity markets across regions



Note: Each panel illustrates the share of commodities in which the strong model of integration is selected in each city. The values on top of each column indicate the number of integrated commodities over total available markets in a specific location.

Figure 9: Half-lives, 1586-1690

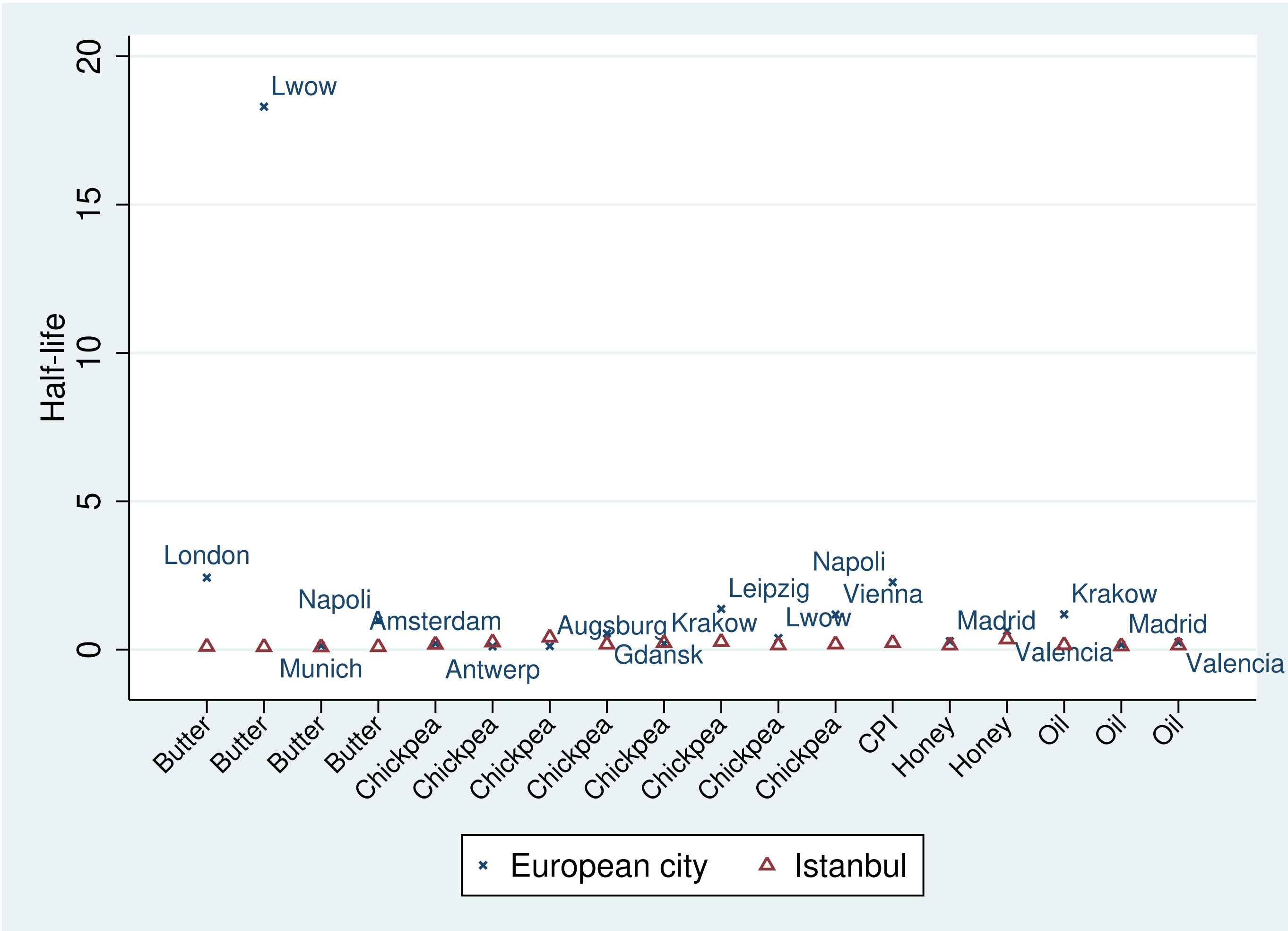


Figure 10: Half-lives, 1691-1768

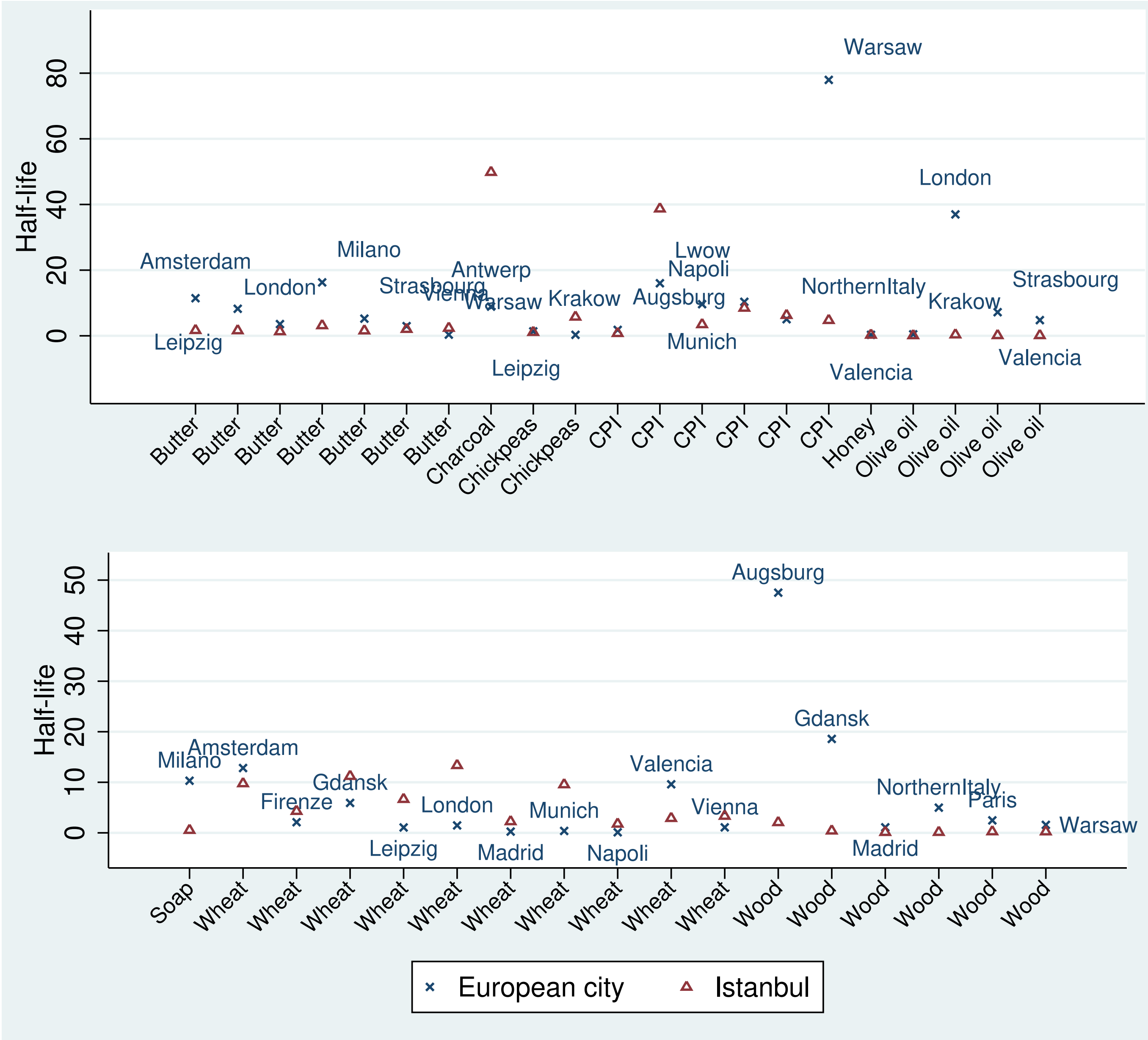


Figure 11: Half-lives, 1769-1843

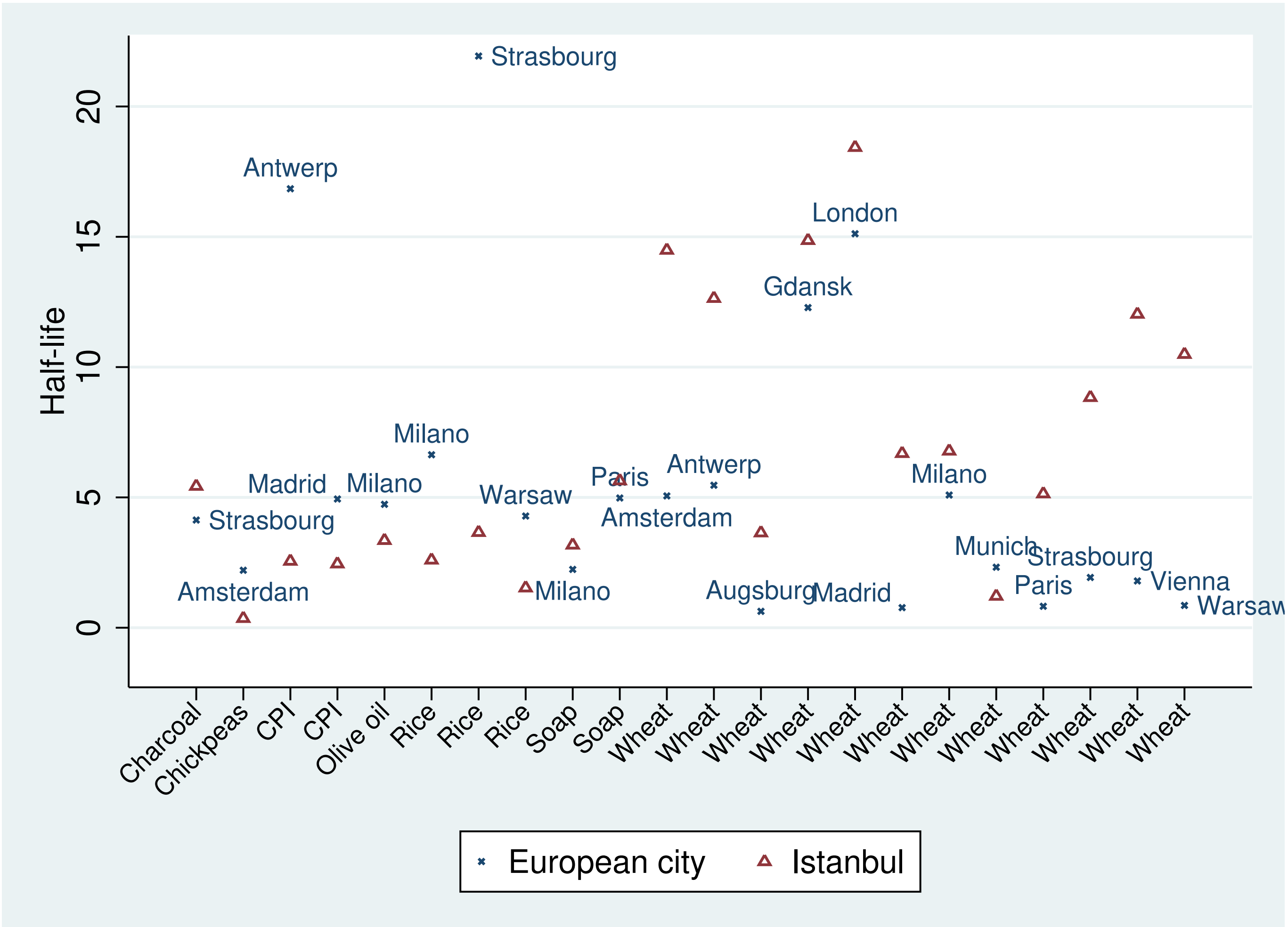
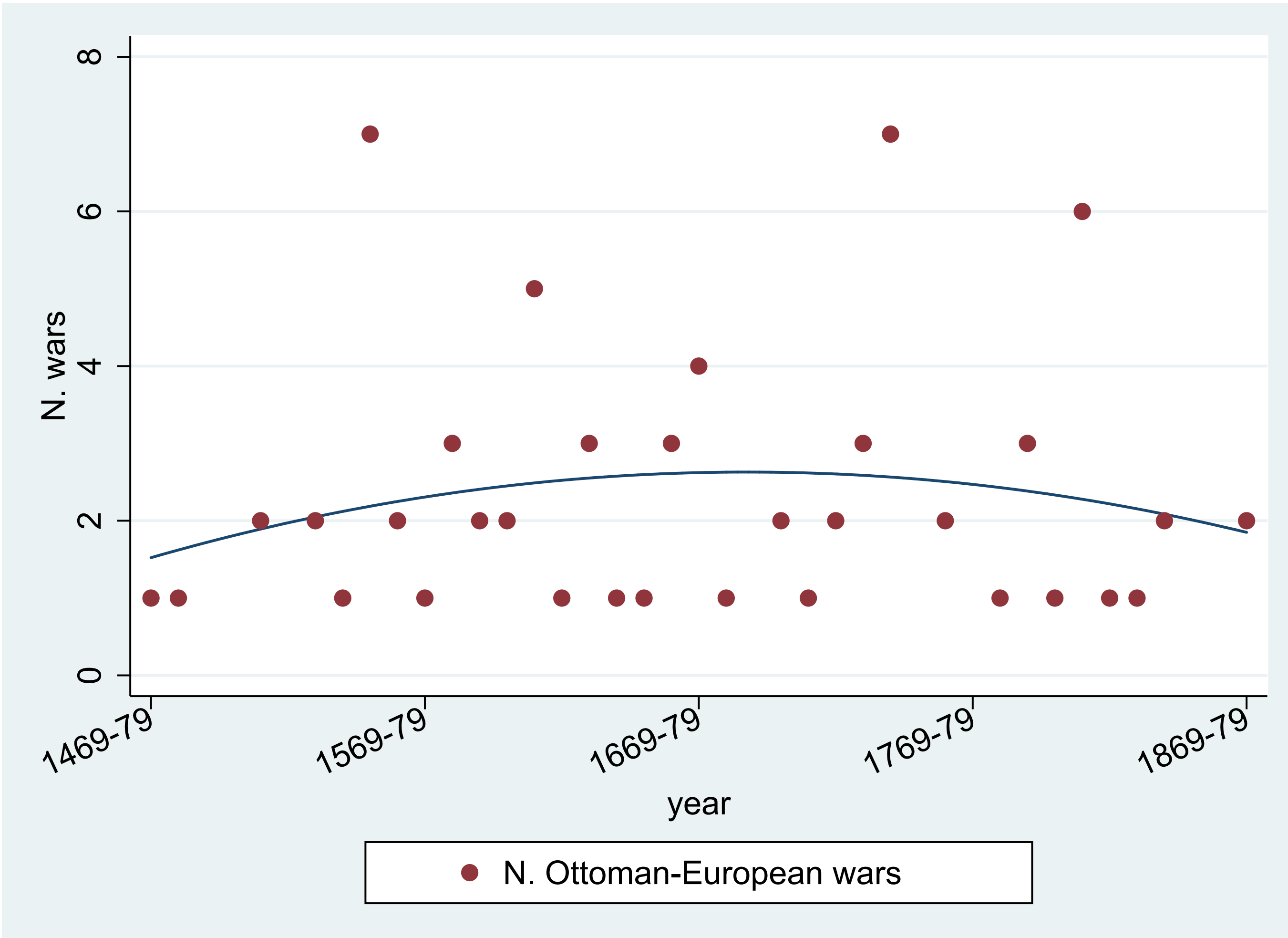
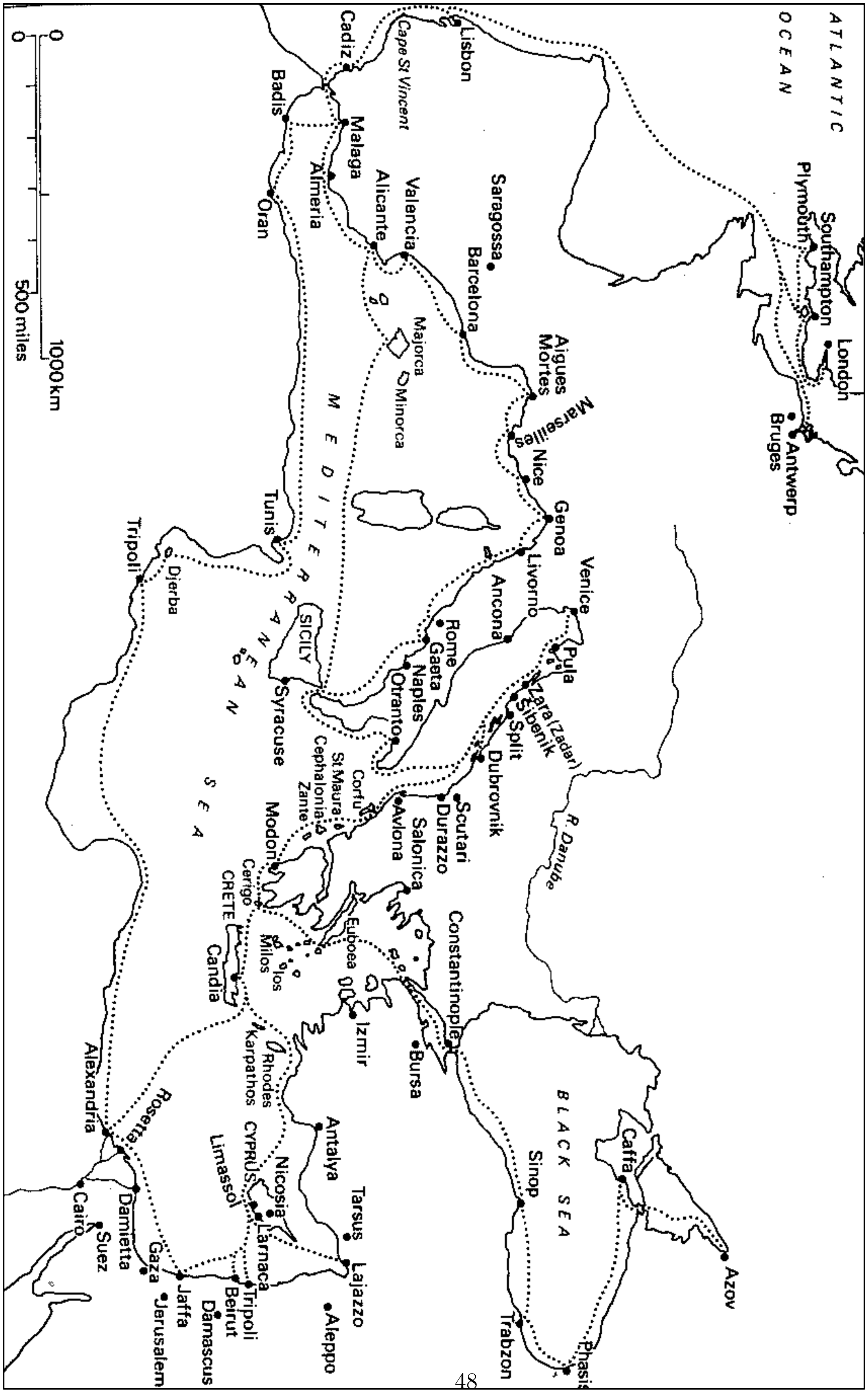


Figure 12: Ottoman-European conflicts, 1469-1914



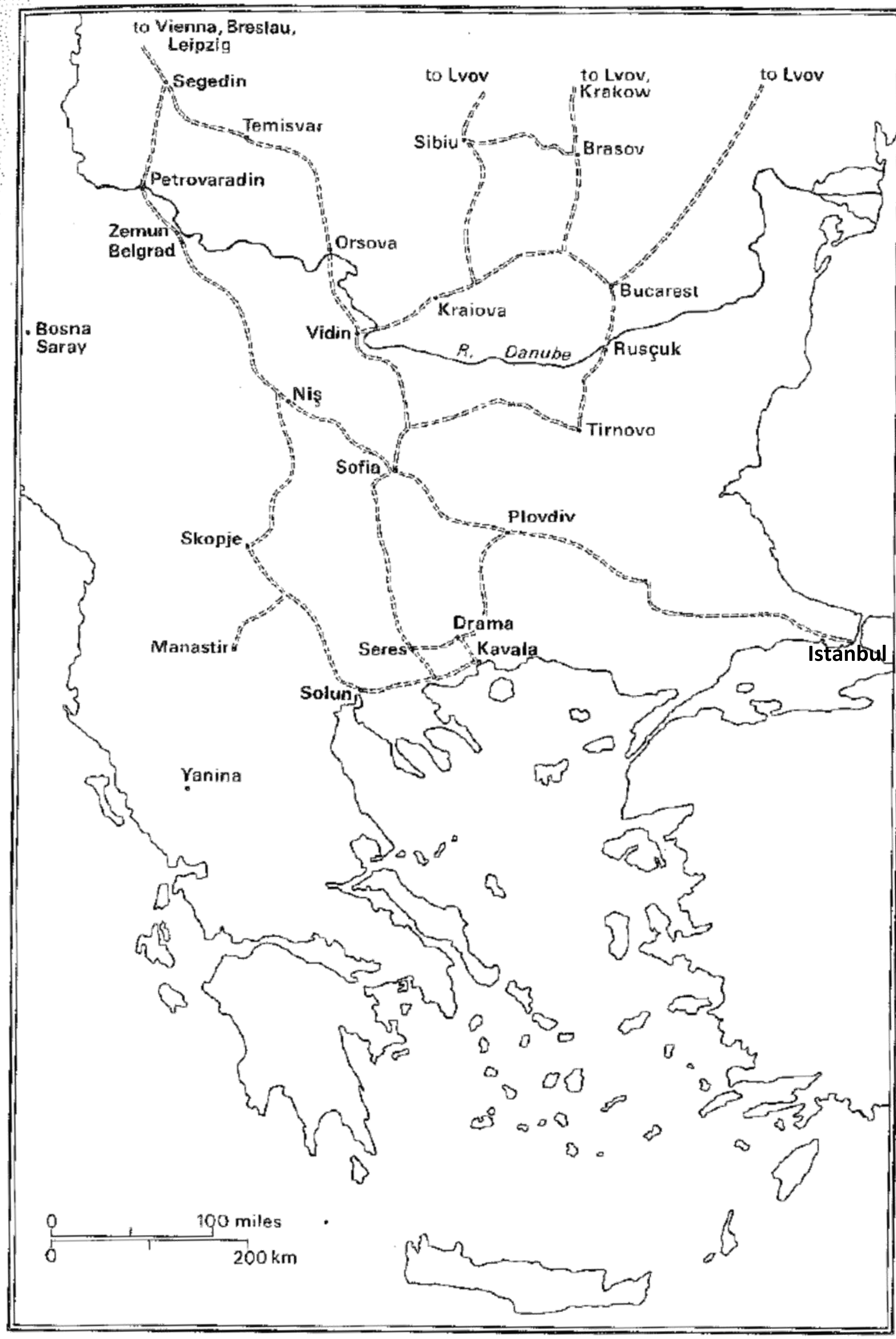
Source: Brecke's *Conflict Catalog*, `http://www.cgeh.nl/data`.

Map 1: Sea routes between the Levant and Europe



Source: Inalcik and Quataert (1994, p. 318)

Map 2: Land routes between Istanbul and Europe



Source: McGowan (1981)

Appendix

Appendix to the article: The evolution of Ottoman-European market linkages, 1469-1914: evidence from dynamic factor models

A Univariate Model

A.1 Parameter Space

The parameters include α, β, ϕ and σ^2. The collection of state variables $f = (f_1, f_2, ..., f_T)'$, $g_1 = (g_{11}, g_{12}, ..., g_{1T})'$ and $g_2 = (g_{21}, g_{22}, ..., g_{2T})'$ are also part of the parameter space. If some data in y are missing, we also call them parameters because they are unknown.

Define $y = (y_1, y_2, ..., y_T)'$ as the collection of all y_t including the imputed missing values.

A.2 Prior

1. $$\alpha \sim N(\underline{m}_\alpha, \underline{h}_\alpha^{-1}), \quad \beta \sim N(\underline{m}_\beta, \underline{h}_\beta^{-1})\mathbf{1}(\beta > 0), \quad \gamma \sim N(\underline{m}_\gamma, \underline{h}_\gamma^{-1})\mathbf{1}(\gamma > 0).$$

   We assume independence between these parameters.

2. $$\sigma^2 \sim IG(\underline{v}/2, \underline{s}/2)$$

3. $$\phi \sim N(\underline{m}_\phi, \underline{h}_\phi^{-1})\mathbf{1}(0 < \phi < 1)$$

4. The first value of f:
   $$f_1 \sim N(0, \sigma^2_{f_1})$$

5. The first value of g
   $$g_1 \sim N(0, \sigma^2_{g_1})$$

A.3 MCMC

1. Write $x_t = (f_t, g_t)'$. We apply the Chan and Jeliazkov's(2009) method to write

$$x_t = Ax_{t-1} + e_t,$$

where $A = \begin{pmatrix} 1 & 0 \\ 0 & \phi \end{pmatrix}$ and $e_t = \begin{pmatrix} e_{ft} \\ u_t \end{pmatrix} \sim N(0, I_2)$. Stacking x_t to obtain $x = (x_1', x_2', ..., x_T')'$, so we have

$$Hx = e_x,$$

where $H = \begin{pmatrix} I_2 & 0 & 0 & ... & 0 & 0 \\ -A & I_2 & 0 & ... & 0 & 0 \\ 0 & -A & I_2 & ... & 0 & 0 \\ \vdots & \vdots & \vdots & ... & \vdots & \vdots \\ 0 & 0 & 0 & ... & I_2 & 0 \\ 0 & 0 & 0 & ... & -A & I_2 \end{pmatrix}$ and $e_x \sim N(0, \Omega)$ with $\Omega = \begin{pmatrix} diag(\sigma^2_{f_1}, \sigma^2_{g_1}) & 0 \\ 0 & I_{2(T-1)} \end{pmatrix}$.

Hence the prior of x is

$$x \sim N(0, K^{-1}),$$

where $K = H'\Omega^{-1}H$.

Clearly

$$y = 1_T\alpha + Bx + e,$$

where $B = I_T \otimes (\beta, \gamma)$. Hence,

$$y \mid x \sim N(1_T\alpha + Bx, \sigma^2 I_T).$$

The conditional posterior is

$$x \mid y \sim N(\hat{x}, K_x^{-1}),$$

where $K_x = K + \sigma^{-2}B'B$ and $\hat{x} = K_x^{-1}\left(\sigma^{-2}B'(y - 1_T\alpha)\right)$.

2. ϕ:

$$\phi \sim N(m, h^{-1})\mathbf{1}(0 < \phi < 1),$$

where $h = \underline{h}_\phi + \sum_{t=2}^{T} g_{t-1}^2$ and $m = h^{-1}(\underline{h}_\phi \underline{m}_\phi + \sum_{t=2}^{T} g_{t-1} g_t)$.

3. α, β and γ are drawn conditionally

   (a) Draw α from $N(\overline{m}, \overline{h}^{-1})$, where $\overline{h} = \underline{h}_\alpha + \sigma^{-2} T$ and $\overline{m} = \overline{h}^{-1}(\underline{h}_\alpha \underline{m}_\alpha + \sigma^{-2} \sum_{t=1}^{T} (y_t - \beta f_t - \gamma g_t))$.

   (b) Draw γ from $N(\overline{m}, \overline{h}^{-1}) \mathbf{1}(\gamma > 0)$, where $\overline{h} = \underline{h}_\gamma + \sigma^{-2} \sum_{t=1}^{T} g_t^2$ and $\overline{m} = \overline{h}^{-1}(\underline{h}_\gamma \underline{m}_\gamma + \sigma^{-2} \sum_{t=1}^{T} g_t (y_t - \alpha - \beta f_t))$.

   (c) Draw β from $N(\overline{m}, \overline{h}^{-1}) \mathbf{1}(\beta > 0)$, where $\overline{h} = \underline{h}_\beta + \sigma^{-2} \sum_{t=1}^{T} f_t^2$ and $\overline{m} = \overline{h}^{-1}(\underline{h}_\beta \underline{m}_\beta + \sigma^{-2} \sum_{t=1}^{T} f_t (y_t - \alpha - \gamma g_t))$.

4. Simulate σ^2 from

$$\sigma^2 \sim IG(\overline{v}/2, \overline{s}/2),$$

   where

$$\overline{v} = \underline{v} + T$$

   and

$$\overline{s} = \underline{s} + \hat{e}'\hat{e}.$$

   The error $\hat{e}$ is defined as $y - X(\alpha, \beta, \gamma)'$ with $X = (1_T, f, g)$.

5. Missing data. If y_t is missing, we impute it by

$$y_t \sim N(\alpha + \beta f_t + \gamma g_t, \sigma^2).$$

B Weak Model

B.1 Parameter Space

The parameters include $\alpha_i, \beta_i, \phi_i, \sigma_i^2$ for $i = 1, 2$. The collection of state variables $f = (f_1, f_2, ..., f_T)'$, $g_1 = (g_{11}, g_{12}, ..., g_{1T})'$ and $g_2 = (g_{21}, g_{22}, ..., g_{2T})'$ are also part of the parameter space. If some data in y are missing, we also call them parameters because they are unknown.

We denote $\alpha = (\alpha_1, \alpha_2)'$ and $\beta = (\beta_1, \beta_2)'$. Define $y_i = (y_{i1}, y_{i2}, ..., y_{iT})'$ as the collection of all y_{it} for country i including the imputed missing values.

B.2 Prior

1. For $i = 1, 2$,

$$(\alpha_i, \beta_i, \gamma_i)' \sim N(\underline{m}, \underline{H}^{-1})\mathbf{1}(\beta_i > 0 \ \& \ \gamma_i > 0).$$

   We assume independent priors, so it can also be written as

$$\alpha_i \sim N(\underline{m}_\alpha, \underline{h}_\alpha^{-1}), \quad \beta_i \sim N(\underline{m}_\beta, \underline{h}_\beta^{-1})\mathbf{1}(\beta_i > 0), \quad \gamma_i \sim N(\underline{m}_\gamma, \underline{h}_\gamma^{-1})\mathbf{1}(\gamma_i > 0).$$

2. For $i = 1, 2$,

$$\sigma_i^2 \sim IG(\underline{v}/2, \underline{s}/2)$$

3. For $i = 1, 2$,

$$\phi_i \sim N(\underline{m}_\phi, \underline{h}_\phi^{-1})\mathbf{1}(0 < \phi_i < 1),$$

   where ϕ_1 and ϕ_2 are independent.

4. The first value of f:

$$f_1 \sim N(0, \sigma_{f_1}^2)$$

5. For $i = 1, 2$, the first value of g_i

$$g_{i1} \sim N(0, \sigma_{g_1}^2)$$

B.3 MCMC

1. Write $x_t = (f_t, g_{1t}, g_{2t})'$. We apply the Chan and Jeliazkov's(2009) method to write

$$x_t = Ax_{t-1} + e_t,$$

where $A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \phi_1 & 0 \\ 0 & 0 & \phi_2 \end{pmatrix}$ and $e_t = \begin{pmatrix} e_{ft} \\ u_{1t} \\ u_{2t} \end{pmatrix} \sim N(0, I_3)$. Stacking x_t to obtain $x = (x_1', x_2', ..., x_T')'$, so we have

$$Hx = e_x,$$

where $H = \begin{pmatrix} I_3 & 0 & 0 & ... & 0 & 0 \\ -A & I_3 & 0 & ... & 0 & 0 \\ 0 & -A & I_3 & ... & 0 & 0 \\ \vdots & \vdots & \vdots & ... & \vdots & \vdots \\ 0 & 0 & 0 & ... & I_3 & 0 \\ 0 & 0 & 0 & ... & -A & I_3 \end{pmatrix}$ and $e_x \sim N(0, \Omega)$ with $\Omega = \begin{pmatrix} diag(\sigma_{f_1}^2, \sigma_{g_1}^2, \sigma_{g_1}^2) & 0 \\ 0 & I_{3(T-1)} \end{pmatrix}$.

Hence the prior of x is

$$x \sim N(0, K^{-1}),$$

where $K = H'\Omega^{-1}H$.

Stack data $y = (y_{11}, y_{21}, y_{12}, y_{22}, ..., y_{1T}, y_{2T})'$ to have

$$y = C\alpha + Bx + e,$$

where $C = 1_T \otimes I_2$, $\alpha = (\alpha_1, \alpha_2)'$, $B = I_T \otimes \begin{pmatrix} \beta_1 & \gamma_1 & 0 \\ \beta_2 & 0 & \gamma_2 \end{pmatrix}$ and $e = (e_{11}, e_{21}, e_{12}, e_{22}, ..., e_{1T}, e_{2T})'$.

Hence,

$$y \mid x \sim N(C\alpha + Bx, \Sigma),$$

where $\Sigma = I_T \otimes \begin{pmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{pmatrix}$. The conditional posterior is

$$x \mid y \sim N(\hat{x}, K_x^{-1}),$$

where $K_x = K + B'\Sigma^{-1}B$ and $\hat{x} = K_x^{-1}\left(B'\Sigma^{-1}(y - C\alpha)\right)$

2. ϕ_i:

$$\phi_i \sim N(m_i, h_i^{-1})\mathbf{1}(0 < \phi_i < 1),$$

where $h_i = \underline{h}_\phi + \sum_{t=2}^{T} g_{i,t-1}^2$ and $m_i = h_i^{-1}(\underline{h}_\phi \underline{m}_\phi + \sum_{t=2}^{T} g_{i,t-1} g_{it})$ for $i = 1, 2$.

3. $(\alpha_i, \beta_i, \gamma_i)$ is drawn from

$$(\alpha_i, \beta_i, \gamma_i)' \sim N(\overline{m}_i, \overline{H}_i^{-1})\mathbf{1}(\beta_i > 0 \ \& \ \gamma_i > 0),$$

where

$$\overline{H}_i = \underline{H} + \sigma_i^{-2} X_i' X_i$$

and

$$\overline{m}_i = \overline{H}_i^{-1}(\underline{H}\underline{m} + \sigma_i^{-2} X_i' y_i),$$

where $X_i = (\mathbf{1}, f, g_i)$ is the regressor of y_i.

Simulating from a joint truncated normal distribution is tricky, especially under multiple restrictions. So a simple but inefficient way is to simulate α_i, β_i and γ_i separately as follows:

(a) Draw α_i from $N(\overline{m}_i, \overline{h}_i^{-1})$, where $\overline{h}_i = \underline{h}_\alpha + \sigma_i^{-2} T$ and $\overline{m}_i = \overline{h}_i^{-1}(\underline{h}_\alpha \underline{m}_\alpha + \sigma_i^{-2} \sum_{t=1}^{T} (y_{it} - \beta_i f_t - \gamma_i g_{it}))$.

(b) Draw β_i from $N(\overline{m}_i, \overline{h}_i^{-1})\mathbf{1}(\beta_i > 0)$, where $\overline{h}_i = \underline{h}_\beta + \sigma_i^{-2} \sum_{t=1}^{T} f_t^2$ and $\overline{m}_i = \overline{h}_i^{-1}(\underline{h}_\beta \underline{m}_\beta + \sigma_i^{-2} \sum_{t=1}^{T} f_t (y_{it} - \alpha_i - \gamma_i g_{it}))$.

(c) Draw γ_i from $N(\overline{m}_i, \overline{h}_i^{-1})\mathbf{1}(\gamma_i > 0)$, where $\overline{h}_i = \underline{h}_\gamma + \sigma_i^{-2} \sum_{t=1}^{T} g_{it}^2$ and $\overline{m}_i = \overline{h}_i^{-1}(\underline{h}_\gamma \underline{m}_\gamma + \sigma_i^{-2} \sum_{t=1}^{T} g_{it} (y_{it} - \alpha_i - \beta_i f_t))$.

4. Simulate σ_i^2 from

$$\sigma_i^2 \sim IG(\overline{v}/2, \overline{s}/2),$$

where

$$\overline{v} = \underline{v} + T$$

and

$$\overline{s} = \underline{s} + \hat{e}_i' \hat{e}_i$$

with $\hat{e}_i = y_i - X_i(\alpha_i, \beta_i, \gamma_i)'$.

5. Missing data. If $y_{i,t}$ is missing, we impute it by

$$y_{i,t} \sim N(\alpha_i + \beta_i f_t + \gamma_i g_{it}, \sigma_i^2).$$

C Strong Model

C.1 Parameter Space

The parameters include $\alpha_i, \phi_i, \sigma_i^2$ for $i = 1, 2$ and β (common parameter). The collection of state variables $f = (f_1, f_2, ..., f_T)'$, $g_1 = (g_{11}, g_{12}, ..., g_{1T})'$ and $g_2 = (g_{21}, g_{22}, ..., g_{2T})'$ are also part of the parameter space. If some data in y are missing, we also call them parameters because they are unknown.

We denote $\alpha = (\alpha_1, \alpha_2)'$ and $\beta = (\beta_1, \beta_2)'$. Define $y_i = (y_{i1}, y_{i2}, ..., y_{iT})'$ as the collection of all y_{it} for country i including the imputed missing values.

C.2 Prior

1. For $i = 1, 2$,

   $$\alpha_i \sim N(\underline{m}_\alpha, \underline{h}_\alpha^{-1}), \quad \gamma_i \sim N(\underline{m}_\gamma, \underline{h}_\gamma^{-1})\mathbf{1}(\gamma_i > 0)$$

   and

   $$\beta \sim N(\underline{m}_\beta, \underline{h}_\beta^{-1})\mathbf{1}(\beta > 0).$$

   We assume independence between these parameters.

2. For $i = 1, 2$,

   $$\sigma_i^2 \sim IG(\underline{v}/2, \underline{s}/2)$$

3. For $i = 1, 2$,

   $$\phi_i \sim N(\underline{m}_\phi, \underline{h}_\phi^{-1})\mathbf{1}(0 < \phi_i < 1),$$

   where ϕ_1 and ϕ_2 are independent.

4. The first value of f:

   $$f_1 \sim N(0, \sigma_{f_1}^2)$$

5. For $i = 1, 2$, the first value of g_i

$$g_{i1} \sim N(0, \sigma_{g_1}^2)$$

C.3 MCMC

1. Write $x_t = (f_t, g_{1t}, g_{2t})'$. We apply the Chan and Jeliazkov's(2009) method to write

$$x_t = Ax_{t-1} + e_t,$$

where $A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \phi_1 & 0 \\ 0 & 0 & \phi_2 \end{pmatrix}$ and $e_t = \begin{pmatrix} e_{ft} \\ u_{1t} \\ u_{2t} \end{pmatrix} \sim N(0, I_3)$. Stacking x_t to obtain $x = (x_1', x_2', ..., x_T')'$, so we have

$$Hx = e_x,$$

where $H = \begin{pmatrix} I_3 & 0 & 0 & ... & 0 & 0 \\ -A & I_3 & 0 & ... & 0 & 0 \\ 0 & -A & I_3 & ... & 0 & 0 \\ \vdots & \vdots & \vdots & ... & \vdots & \vdots \\ 0 & 0 & 0 & ... & I_3 & 0 \\ 0 & 0 & 0 & ... & -A & I_3 \end{pmatrix}$ and $e_x \sim N(0, \Omega)$ with $\Omega = \begin{pmatrix} diag(\sigma_{f_1}^2, \sigma_{g_1}^2, \sigma_{g_1}^2) & 0 \\ 0 & I_{3(T-1)} \end{pmatrix}$.

Hence the prior of x is

$$x \sim N(0, K^{-1}),$$

where $K = H'\Omega^{-1}H$.

Stack data $y = (y_{11}, y_{21}, y_{12}, y_{22}, ..., y_{1T}, y_{2T})'$ to have

$$y = C\alpha + Bx + e,$$

where $C = 1_T \otimes I_2$, $\alpha = (\alpha_1, \alpha_2)'$, $B = I_T \otimes \begin{pmatrix} \beta & \gamma_1 & 0 \\ \beta & 0 & \gamma_2 \end{pmatrix}$ and $e = (e_{11}, e_{21}, e_{12}, e_{22}, ..., e_{1T}, e_{2T})'$.

Hence,

$$y \mid x \sim N(C\alpha + Bx, \Sigma),$$

where $\Sigma = I_T \otimes \begin{pmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{pmatrix}$. The conditional posterior is

$$x \mid y \sim N(\hat{x}, K_x^{-1}),$$

where $K_x = K + B'\Sigma^{-1}B$ and $\hat{x} = K_x^{-1}\left(B'\Sigma^{-1}(y - C\alpha)\right)$

2. ϕ_i:

$$\phi_i \sim N(m_i, h_i^{-1})\mathbf{1}(0 < \phi_i < 1),$$

where $h_i = \underline{h}_\phi + \sum_{t=2}^{T} g_{i,t-1}^2$ and $m_i = h_i^{-1}(\underline{h}_\phi \underline{m}_\phi + \sum_{t=2}^{T} g_{i,t-1} g_{it})$ for $i = 1, 2$.

3. α_i, β and γ_i are drawn conditionally

   (a) Draw α_i from $N(\overline{m}_i, \overline{h}_i^{-1})$, where $\overline{h}_i = \underline{h}_\alpha + \sigma_i^{-2}T$ and $\overline{m}_i = \overline{h}_i^{-1}(\underline{h}_\alpha \underline{m}_\alpha + \sigma_i^{-2}\sum_{t=1}^{T}(y_{it} - \beta f_t - \gamma_i g_{it}))$.

   (b) Draw γ_i from $N(\overline{m}_i, \overline{h}_i^{-1})\mathbf{1}(\gamma_i > 0)$, where $\overline{h}_i = \underline{h}_\gamma + \sigma_i^{-2}\sum_{t=1}^{T} g_{it}^2$ and $\overline{m}_i = \overline{h}_i^{-1}(\underline{h}_\gamma \underline{m}_\gamma + \sigma_i^{-2}\sum_{t=1}^{T} g_{it}(y_{it} - \alpha_i - \beta f_t))$.

   (c) Draw β from $N(\overline{m}, \overline{h}^{-1})\mathbf{1}(\beta > 0)$, where $\overline{h} = \underline{h}_\beta + (\sigma_1^{-2} + \sigma_2^{-2})\sum_{t=1}^{T} f_t^2$ and $\overline{m} = \overline{h}^{-1}\Big(\underline{h}_\beta \underline{m}_\beta + \sigma_1^{-2}\sum_{t=1}^{T} f_t(y_{1t}$

4. Simulate σ_i^2 from

$$\sigma_i^2 \sim IG(\overline{v}/2, \overline{s}/2),$$

where

$$\overline{v} = \underline{v} + T$$

and

$$\overline{s} = \underline{s} + \hat{e}_i'\hat{e}_i.$$

The error $\hat{e}_i$ is defined as $y_i - X_i(\alpha_i, \beta, \gamma_i)'$ with $X_i = (1_T, f, g_i)$.

5. Missing data. If $y_{i,t}$ is missing, we impute it by

$$y_{i,t} \sim N(\alpha_i + \beta f_t + \gamma_i g_{it}, \sigma_i^2).$$

Table A1: Marginal likelihood of CPI, 1586-1690

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	101/105	133.31	130.65	132.60	132.08	130.07	132.88
Antwerp	101/105	97.69	94.93	96.87	95.64	91.40	91.97
Augsburg	100/104	91.32	89.47	90.63	94.29	91.54	92.90
Gdansk	101/105	125.13	122.57	125.07	127.10	124.85	126.46
Krakow	101/105	156.90	154.42	156.44	155.21	151.79	153.11
Leipzig	99/103	120.70	117.95	119.98	118.59	114.39	115.64
London	101/105	104.03	101.88	104.34	102.05	99.45	101.83
Lwow	101/105	162.41	160.83	163.29	160.70	157.53	159.67
Madrid	101/105	92.56	91.28	93.53	90.98	88.54	91.73
Munich	101/105	93.01	91.88	94.49	94.83	92.09	94.31
Napoli	57/60	68.44	71.25	74.57	65.78	69.48	72.99
Paris	101/105	111.43	110.35	112.79	108.31	105.88	106.73
Strasbourg	101/105	98.91	95.85	99.04	97.85	93.08	95.45
Valencia	101/105	151.31	149.25	151.11	149.51	146.47	148.07
Vienna	101/105	100.62	98.48	101.26	99.36	95.79	98.19
Warsaw	101/105	127.74	125.80	128.34	126.02	122.67	123.27

Table A2: Posterior probability of CPI, 1586-1690

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	101/105	64%	4%	32%	30%	4%	66%
Antwerp	101/105	66%	4%	29%	96%	1%	2%
Augsburg	100/104	60%	9%	30%	76%	5%	19%
Gdansk	101/105	50%	4%	47%	61%	6%	32%
Krakow	101/105	58%	5%	37%	87%	3%	11%
Leipzig	99/103	65%	4%	31%	94%	1%	5%
London	101/105	40%	5%	55%	53%	4%	43%
Lwow	101/105	28%	6%	67%	71%	3%	26%
Madrid	101/105	26%	7%	67%	31%	3%	66%
Munich	101/105	18%	6%	77%	60%	4%	36%
Napoli	57/60	0%	3%	96%	0%	3%	97%
Paris	101/105	19%	6%	74%	77%	7%	16%
Strasbourg	101/105	46%	2%	52%	91%	1%	8%
Valencia	101/105	52%	7%	42%	78%	4%	19%
Vienna	101/105	33%	4%	63%	75%	2%	23%
Warsaw	101/105	34%	5%	61%	91%	3%	6%

Table A3: Marginal likelihood of CPI,1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	73/78	104.61	104.28	105.93	106.03	103.69	106.24
Antwerp	73/78	112.58	110.88	113.41	110.66	107.82	110.45
Augsburg	73/78	97.37	98.42	101.07	95.23	94.00	96.66
Gdansk	73/78	104.52	103.27	105.22	104.61	101.13	103.66
Krakow	73/78	127.65	125.90	129.02	126.17	122.74	125.87
Leipzig	73/78	72.43	71.44	73.51	75.58	73.80	74.23
London	73/78	110.97	110.55	112.66	109.74	108.40	110.25
Lwow	73/78	90.67	93.89	96.58	90.19	93.45	96.70
Madrid	73/78	88.27	87.43	89.73	87.68	83.51	85.57
Munich	70/75	101.63	103.24	105.68	99.78	99.88	102.30
Napoli	35/35	58.46	57.01	61.46	57.54	55.38	58.99
NorthernItaly	65/68	73.30	73.31	76.82	71.87	71.63	73.91
Paris	73/78	75.40	74.41	76.65	74.50	71.46	73.71
Strasbourg	73/78	98.00	95.80	98.44	97.52	93.58	96.07
Valencia	73/78	116.71	114.77	116.73	115.84	112.37	113.73
Vienna	73/78	98.17	97.99	100.09	96.95	95.93	98.16
Warsaw	73/78	98.12	97.19	100.09	97.54	95.34	98.91

Table A4: Posterior probability of CPI, 1691-1768

Posterior Probability							
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	73/78	18%	13%	68%	43%	4%	53%
Antwerp	73/78	29%	5%	66%	54%	3%	43%
Augsburg	73/78	2%	6%	91%	18%	5%	76%
Gdansk	73/78	30%	9%	61%	70%	2%	27%
Krakow	73/78	20%	3%	77%	56%	2%	42%
Leipzig	73/78	23%	9%	68%	70%	12%	18%
London	73/78	14%	9%	77%	34%	9%	57%
Lwow	73/78	0%	6%	93%	0%	4%	96%
Madrid	73/78	17%	8%	75%	88%	1%	11%
Munich	70/75	2%	8%	91%	7%	8%	86%
Napoli	35/35	5%	1%	94%	19%	2%	79%
NorthernItaly	65/68	3%	3%	94%	11%	8%	81%
Paris	73/78	20%	8%	72%	66%	3%	30%
Strasbourg	73/78	38%	4%	58%	80%	2%	19%
Valencia	73/78	46%	7%	47%	87%	3%	10%
Vienna	73/78	12%	10%	79%	21%	8%	71%
Warsaw	73/78	12%	5%	84%	20%	2%	78%

Table A5: Marginal likelihood of CPI, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	71/75	72.38	71.00	73.75	70.88	67.76	71.03
Antwerp	71/75	54.94	54.21	56.69	52.82	49.53	53.01
Gdansk	42/46	14.14	12.18	13.40	18.91	21.57	18.26
Krakow	52/55	38.44	37.50	39.67	36.92	33.55	36.44
London	71/75	65.84	64.08	65.26	65.50	61.55	63.15
Madrid	71/75	11.91	12.29	14.89	17.31	16.35	19.33
Napoli	34/38	31.62	29.74	31.60	29.90	26.93	28.41
NorthernItaly	71/75	39.61	37.96	39.69	39.76	35.53	39.11
Strasbourg	71/75	70.21	68.14	70.13	68.89	65.03	67.37

Table A6: Posterior probability of CPI, 1769-1843

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	71/75	19%	5%	76%	46%	2%	52%
Antwerp	71/75	14%	7%	80%	45%	2%	53%
Gdansk	42/46	62%	9%	29%	6%	90%	3%
Krakow	52/55	21%	8%	71%	61%	2%	37%
London	71/75	58%	10%	32%	90%	2%	8%
Madrid	71/75	5%	7%	89%	11%	4%	84%
Napoli	34/38	47%	7%	46%	79%	4%	17%
NorthernItaly	71/75	44%	8%	48%	66%	1%	34%
Strasbourg	71/75	49%	6%	45%	81%	2%	17%

Table A7: Marginal likelihood of CPI, 1844-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	37/67	88.29	85.63	87.24	87.40	83.34	85.58
Antwerp	39/70	69.47	65.99	66.68	68.59	63.53	64.14
Krakow	37/67	60.53	58.92	59.26	59.37	56.36	56.49
London	39/70	82.75	79.55	81.18	81.94	77.30	79.62
Madrid	39/70	72.36	69.63	71.08	71.17	67.28	68.61
NorthernItaly	40/71	71.71	70.29	71.09	70.83	68.69	70.52
Paris	39/70	83.26	80.29	81.76	82.29	77.78	79.65
Strasbourg	21/32	41.89	40.46	43.00	40.65	37.73	39.86

Table A8: Posterior probability of CPI, 1844-1914

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	37/67	70%	5%	25%	85%	1%	14%
Antwerp	39/70	92%	3%	6%	98%	1%	1%
Krakow	37/67	67%	14%	19%	90%	4%	5%
London	39/70	80%	3%	17%	90%	1%	9%
Madrid	39/70	74%	5%	21%	91%	2%	7%
NorthernItaly	40/71	56%	14%	30%	54%	6%	40%
Paris	39/70	78%	4%	17%	92%	1%	7%
Strasbourg	21/32	23%	6%	71%	66%	4%	30%

Table A9: Marginal likelihood of CPI, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	299/411	461.93	460.56	457.48	462.50	461.59	460.51
Antwerp	206/455	439.65	439.27	433.11	441.15	441.60	438.85
Augsburg	217/298	342.81	342.49	343.40	347.34	344.58	343.10
Gdansk	230/280	347.85	344.74	347.49	361.39	362.74	361.19
Krakow	285/422	587.85	588.95	587.89	582.66	586.27	579.57
Leipzig	206/230	280.26	280.43	284.52	289.85	285.74	290.66
London	206/438	509.81	508.75	499.98	512.50	511.50	508.16
Lwow	215/277	407.27	406.66	409.11	403.77	405.23	401.99
Madrid	297/363	330.83	332.52	336.82	338.42	339.28	340.76
Munich	193/297	345.69	345.53	343.37	348.04	345.75	344.33
Napoli	139/171	235.37	237.15	240.94	232.31	236.17	240.02
NorthernItaly	231/366	273.93	277.03	268.14	273.14	277.32	272.04
Paris	255/392	413.58	414.10	408.55	413.45	413.95	408.91
Strasbourg	288/407	488.74	489.45	485.91	489.08	488.53	484.17
Valencia	211/317	470.79	468.69	468.95	464.32	463.31	462.28
Vienna	223/330	428.22	427.37	427.94	427.01	422.71	423.45
Warsaw	210/239	340.57	340.05	340.37	333.50	335.21	336.41

Table A10: Posterior probability of CPI, 1469-1914

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	299/411	79%	20%	1%	65%	26%	9%
Antwerp	206/455	59%	41%	0%	38%	59%	4%
Augsburg	217/298	28%	21%	51%	93%	6%	1%
Gdansk	230/280	57%	3%	40%	18%	68%	14%
Krakow	285/422	20%	59%	21%	3%	97%	0%
Leipzig	206/230	1%	2%	97%	31%	1%	69%
London	206/438	74%	26%	0%	72%	27%	**1%**
Lwow	215/277	13%	7%	80%	18%	79%	3%
Madrid	297/363	0%	1%	98%	7%	17%	75%
Munich	193/297	51%	44%	5%	89%	9%	2%
Napoli	139/171	0%	2%	97%	0%	2%	98%
NorthernItaly	231/366	4%	96%	0%	2%	98%	0%
Paris	255/392	37%	62%	0%	38%	62%	0%
Strasbourg	288/407	32%	66%	2%	63%	36%	0%
Valencia	211/317	78%	10%	12%	67%	24%	9%
Vienna	223/330	46%	20%	35%	96%	1%	3%
Warsaw	210/239	41%	25%	34%	4%	22%	74%

Table A11: Marginal likelihood of butter, 1586-1690

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	74/97	51.30	50.20	51.67	49.37	47.96	48.88
Antwerp	78/102	29.10	27.82	29.38	26.68	25.20	26.20
Gdansk	80/104	-10.57	-11.93	-9.22	-13.87	-15.38	-13.03
Leipzig	38/53	-12.91	-11.74	-10.86	-14.58	-13.52	-12.97
London	81/105	66.38	66.30	68.89	63.46	62.83	64.96
Lwow	45/50	-6.17	-6.68	-4.02	-7.86	-9.23	-5.87
Munich	38/42	-15.62	-16.05	-10.54	-18.11	-18.11	-12.84
Napoli	48/61	-4.59	-4.32	-1.57	-6.83	-6.79	-4.70

Table A12: Posterior probability of butter, 1586-1690

City	Overlap/Total	Posterior Probability AR(1) No			AR(8) No		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	74/97	36%	12%	52%	54%	13%	33%
Antwerp	78/102	38%	11%	51%	54%	12%	34%
Gdansk	80/104	20%	5%	75%	28%	6%	65%
Leipzig	38/53	8%	27%	65%	11%	33%	56%
London	81/105	7%	6%	87%	17%	9%	75%
Lwow	45/50	10%	6%	84%	12%	3%	85%
Munich	38/42	1%	0%	99%	1%	1%	99%
Napoli	48/61	4%	6%	90%	10%	10%	80%

Table A13: Marginal likelihood of butter, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	48/78	62.14	64.71	67.09	60.50	62.52	65.41
Antwerp	44/72	36.31	34.53	36.82	35.33	33.28	35.61
Gdansk	48/78	37.14	35.60	37.81	35.90	33.18	34.48
Leipzig	26/39	0.72	-0.43	3.29	-0.12	-2.65	0.27
London	48/78	75.72	76.23	78.43	74.83	74.60	76.93
Lwow	31/53	-0.76	-1.49	-0.82	-1.42	-2.68	-3.39
Milano	41/68	48.79	49.50	52.85	48.47	48.92	52.01
Munich	31/53	58.61	56.31	59.55	58.08	55.42	58.49
Strasbourg	35/59	13.42	12.12	16.78	16.85	14.07	18.22
Vienna	33/54	25.91	27.78	31.24	24.21	25.70	29.40
Warsaw	37/59	6.25	6.81	10.98	4.55	4.60	8.61

Table A14: Posterior probability of butter, 1691-1768

City	Overlap/Total	Posterior Probability AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	48/78	**1%**	8%	**91%**	1%	5%	94%
Antwerp	44/72	35%	6%	59%	41%	5%	54%
Gdansk	48/78	32%	7%	62%	76%	5%	19%
Leipzig	26/39	7%	2%	91%	39%	3%	58%
London	48/78	6%	9%	85%	10%	8%	82%
Lwow	31/53	41%	20%	39%	70%	20%	10%
Milano	41/68	2%	3%	95%	3%	4%	93%
Munich	31/53	27%	3%	70%	39%	3%	58%
Strasbourg	35/59	3%	1%	96%	20%	1%	79%
Vienna	33/54	0%	3%	96%	1%	2%	97%
Warsaw	37/59	1%	1%	98%	2%	2%	97%

Table A15: Marginal likelihood of butter, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	50/73	67.91	66.36	67.82	66.05	63.47	65.19
Antwerp	28/36	2.10	-0.43	0.58	0.72	-2.81	-2.12
Gdansk	32/47	-14.75	-16.36	-14.89	-16.15	-18.06	-17.12
Leipzig	28/42	3.69	1.28	3.79	1.92	0.09	1.22
London	52/75	22.83	20.15	21.66	21.10	17.11	18.63
Milano	50/72	42.40	40.28	40.77	40.41	37.00	37.00
Strasbourg	33/45	9.66	8.22	9.78	7.60	4.75	6.39

Table A16: Posterior probability of butter, 1769-1843

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	50/73	47%	10%	43%	67%	5%	28%
Antwerp	28/36	77%	6%	17%	92%	3%	5%
Gdansk	32/47	48%	10%	42%	65%	10%	25%
Leipzig	28/42	45%	4%	50%	60%	10%	30%
London	52/75	72%	5%	23%	91%	2%	8%
Milano	50/72	76%	9%	15%	94%	3%	3%
Strasbourg	33/45	42%	10%	48%	74%	4%	22%

Table A17: Marginal likelihood of butter, 1844-1914

City	Overlap/Total	(AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	47/70	64.92	64.00	65.75	63.26	61.20	63.03
Lwow	48/70	50.35	48.18	48.86	48.64	45.29	45.27
Vienna	48/71	51.09	49.35	50.54	49.64	46.84	48.04

Table A18: Posterior probability of butter, 1844-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	47/70	27%	11%	62%	52%	7%	41%
Lwow	48/70	17%	9%	75%	94%	3%	3%
Vienna	48/71	33%	10%	57%	79%	5%	16%

Table A19: Marginal likelihood of butter, 1469-1914

City	Overlap/Total	(AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	227/401	332.44	332.84	332.84	328.04	327.48	325.85
Lwow	143/201	48.40	46.72	49.49	44.63	42.61	42.00

Table A20: Posterior probability of butter, 1469-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	227/401	31%	46%	23%	60%	34%	7%
Lwow	143/201	24%	4%	71%	83%	11%	6%

Table A21: Marginal likelihood of charcoal, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Antwerp	36/78	45.42	43.76	47.01	44.03	41.88	45.17
Madrid	36/78	30.43	27.34	29.62	29.79	25.86	27.86
NorthernItaly	36/68	107.89	105.45	108.91	107.28	103.91	107.61
Paris	34/65	25.27	24.30	26.02	26.13	25.76	26.58
Valencia	36/78	48.64	47.22	49.30	47.25	45.42	48.80
Warsaw	28/52	22.75	20.78	21.40	22.69	20.79	21.61

Table A22: Posterior probability of charcoal, 1691-1768

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Antwerp	36/78	16%	3%	81%	24%	3%	74%
Madrid	36/78	67%	3%	30%	86%	2%	12%
NorthernItaly	36/68	26%	2%	72%	41%	1%	57%
Paris	34/65	29%	11%	60%	31%	21%	48%
Valencia	36/78	31%	8%	61%	17%	3%	80%
Warsaw	28/52	72%	10%	19%	67%	10%	23%

Table A23: Marginal likelihood of charcoal, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Strasbourg	21/40	8.77	8.04	10.59	9.48	8.70	11.01

Table A24: Posterior probability of charcoal, 1769-1843

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Strasbourg	21/40	13%	6%	81%	17%	8%	76%

Table A25: Marginal likelihood of charcoal, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
NorthernItaly	64/160	194.33	188.27	193.58	193.22	185.58	193.13

Table A26: Posterior probability of charcoal, 1469-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR (8)		
		No	Weak	Strong	No	Weak	Strong
NorthernItaly	64/160	68%	0%	32%	52%	0%	48%

Table A27: Marginal likelihood of chickpeas, 1586-1690

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	38/50	-45.24	-44.86	-40.80	-45.47	-45.46	-41.79
Antwerp	70/102	-53.94	-55.13	-52.15	-55.50	-56.33	-52.77
Augsburg	51/74	-69.39	-71.12	-66.38	-68.56	-71.24	-65.77
Gdansk	70/103	-39.57	-39.46	-35.46	-35.10	-35.17	-31.56
Krakow	55/82	-71.34	-72.18	-68.96	-70.10	-71.15	-67.45
Leipzig	55/84	-77.69	-77.74	-74.10	-78.71	-81.36	-76.76
Lwow	38/55	-61.20	-60.30	-57.21	-63.22	-60.26	-59.79
Vienna	72/105	-57.09	-57.67	-53.39	-56.88	-59.63	-55.13

Table A28: Posterior probability of chickpeas, 1586-1690

		Posterior Probability					
City	Overlap/Total	AR(1)			AR (8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	38/50	1%	2%	97%	2%	2%	95%
Antwerp	70/102	14%	4%	82%	6%	3%	91%
Augsburg	51/74	5%	1%	94%	6%	0%	94%
Gdansk	70/103	2%	2%	97%	3%	3%	95%
Krakow	55/82	8%	4%	88%	6%	2%	91%
Leipzig	55/84	3%	3%	95%	12%	1%	87%
Lwow	38/55	2%	4%	94%	2%	38%	61%
Vienna	72/105	2%	1%	96%	15%	1%	84%

Table A29: Marginal likelihood of chickpeas, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	31/55	-42.14	-42.55	-40.81	-44.72	-45.38	-43.61
Augsburg	33/63	-29.95	-29.92	-28.62	-31.93	-31.92	-30.82
Gdansk	38/78	-33.00	-32.75	-31.02	-34.65	-34.89	-33.09
Krakow	35/70	-43.94	-43.50	-40.57	-43.46	-43.37	-40.38
Leipzig	34/62	-49.76	-49.83	-46.88	-51.43	-52.35	-49.65
Madrid	33/70	-45.30	-50.70	-47.00	-46.85	-53.81	-51.31
Strasbourg	33/63	-8.78	-10.29	-7.29	-9.89	-12.17	-9.74

Table A30: Posterior probability of chickpeas, 1691-1768

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	31/55	18%	12%	69%	22%	11%	67%
Augsburg	33/63	17%	18%	65%	20%	20%	60%
Gdansk	38/78	10%	13%	76%	15%	12%	73%
Krakow	35/70	3%	5%	92%	4%	5%	91%
Leipzig	34/62	5%	5%	90%	14%	5%	81%
Madrid	33/70	84%	0%	15%	99%	0%	1%
Strasbourg	33/63	18%	4%	78%	44%	5%	51%

Table A31: Marginal likelihood of chickpeas, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	32/65	-15.54	-15.66	-13.08	-16.93	-17.33	-15.06
Augsburg	20/30	-30.32	-30.30	-29.10	-30.72	-31.59	-31.11
Leipzig	28/42	-28.24	-27.95	-27.20	-29.11	-29.46	-29.75
Napoli	21/32	-13.45	-14.21	-12.67	-13.70	-14.98	-13.68
Strasbourg	36/72	-4.25	-5.36	-3.64	-3.33	-4.75	-3.25
Warsaw	20/31	-35.34	-35.66	-34.19	-35.00	-36.06	-34.58

Table A32: Posterior probability of chickpeas, 1769-1843

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	32/65	7%	7%	86%	12%	8%	79%
Augsburg	20/30	19%	19%	62%	48%	20%	32%
Leipzig	28/42	19%	26%	55%	45%	31%	24%
Napoli	21/32	27%	13%	60%	44%	12%	44%
Strasbourg	36/72	32%	10%	58%	43%	10%	47%
Warsaw	20/31	20%	15%	65%	35%	12%	53%

Table A33: Marginal likelihood of chickpeas, 1844-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	30/65	12.89	9.40	11.62	11.16	7.41	9.06
Krakow	31/70	-4.24	-7.43	-5.74	-6.17	-9.51	-7.35
Lwow	31/71	-17.25	-20.47	-18.73	-18.78	-22.00	-19.21
Vienna	31/71	11.35	8.75	12.07	8.91	6.20	9.04

Table A34: Posterior probability of chickpeas, 1844-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	30/65	76%	2%	21%	87%	2%	11%
Krakow	31/70	79%	3%	18%	75%	3%	23%
Lwow	31/71	79%	3%	18%	59%	2%	39%
Vienna	31/71	32%	2%	66%	45%	3%	52%

Table A35: Marginal likelihood of chickpeas, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	136/285	-71.41	-71.13	-73.39	-77.04	-77.26	-78.47
Gdansk	130/240	-67.95	-66.67	-61.79	-72.50	-70.41	-66.44
Krakow	163/376	-167.75	-167.74	-181.48	-171.21	-170.66	-173.97
Leipzig	119/196	-133.30	-136.54	-133.26	-140.61	-141.92	-138.66
Vienna	150/319	-114.55	-114.13	-121.26	-123.29	-122.29	-123.65

Table A36: Posterior probability of chickpeas, 1469-1914

Posterior Probability							
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	136/285	41%	54%	6%	49%	39%	12%
Gdansk	130/240	0%	2%	98%	0%	2%	98%
Krakow	163/376	50%	50%	0%	36%	62%	2%
Leipzig	119/196	48%	2%	50%	12%	3%	85%
Vienna	150/319	40%	60%	0%	23%	61%	16%

Table A37: Marginal likelihood of honey, 1586-1690

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Augsburg	53/76	10.15	9.08	11.53	6.63	4.87	7.32
Madrid	60/90	0.60	2.57	5.15	-3.12	-2.71	-0.13
Valencia	72/105	27.55	26.91	29.61	22.64	21.50	24.40

Table A38: Posterior probability of honey, 1586-1690

Posterior Probability							
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Augsburg	53/76	19%	6%	75%	32%	5%	63%
Madrid	60/90	1%	7%	92%	4%	7%	89%
Valencia	72/105	11%	6%	84%	14%	4%	82%

Table A39: Marginal likelihood of honey, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Madrid	46/77	7.40	6.62	8.43	4.96	3.30	5.39
NorthernItaly	40/68	34.75	32.18	35.31	33.20	30.95	33.44
Valencia	42/78	3.17	4.95	7.01	1.49	3.30	5.59
Warsaw	39/66	31.69	29.99	31.30	30.12	29.70	30.88

Table A40: Posterior probability of honey, 1691-1768

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Madrid	46/77	24%	11%	66%	37%	7%	56%
NorthernItaly	40/68	35%	3%	62%	42%	4%	53%
Valencia	42/78	2%	11%	87%	1%	9%	89%
Warsaw	39/66	54%	10%	36%	26%	17%	56%

Table A41: Marginal likelihood of honey, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
NorthernItaly	55/72	2.16	1.57	3.49	1.60	-1.09	2.14

Table A42: Posterior probability of honey, 1769-1843

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
NorthernItaly	55/72	19%	10%	71%	36%	2%	62%

Table A43: Marginal likelihood of honey, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Madrid	132/221	32.92	37.27	42.35	26.96	28.93	33.68
NorthernItaly	98/144	51.25	50.98	51.81	50.05	49.10	47.01
Valencia	142/278	62.55	59.57	58.47	56.40	55.21	52.86

Table A44: Posterior probability of honey, 1469-1914

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Madrid	132/221	0%	1%	99%	0%	1%	99%
NorthernItaly	98/144	28%	22%	50%	70%	27%	3%
Valencia	142/278	94%	5%	2%	75%	23%	2%

Table A45: Marginal likelihood of olive oil, 1586-1690

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	55/68	5.50	6.98	8.89	3.95	5.89	8.17
Madrid	78/104	21.79	22.19	28.07	20.80	21.89	27.83
Valencia	79/105	22.81	25.28	28.48	19.98	22.78	25.29

Table A46: Posterior probability of olive oil, 1586-1690

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	55/68	3%	13%	85%	1%	9%	89%
Madrid	78/104	0%	0%	100%	0%	0%	100%
Valencia	79/105	0%	4%	96%	0%	8%	92%

Table A47: Marginal likelihood of olive oil, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	58/68	-7.78	-5.36	-2.82	-9.93	-7.95	-5.85
London	53/62	21.82	20.22	23.41	17.79	17.02	19.62
Madrid	64/74	-13.78	-15.32	-12.84	-16.01	-18.15	-15.78
Milano	57/68	43.64	41.06	42.60	41.59	38.67	40.08
Strasbourg	42/49	-2.34	-2.73	-0.28	-4.67	-6.02	-4.62
Valencia	65/77	7.99	6.93	9.90	5.84	4.28	7.22

Table A48: Posterior probability of olive oil, 1691-1768

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	58/68	1%	7%	92%	1%	11%	88%
London	53/62	16%	3%	80%	13%	6%	81%
Madrid	64/74	26%	6%	68%	42%	5%	53%
Milano	57/68	70%	5%	25%	78%	4%	17%
Strasbourg	42/49	11%	7%	82%	43%	11%	45%
Valencia	65/77	12%	4%	83%	19%	4%	77%

Table A49: Marginal likelihood of olive oil, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	54/72	42.83	42.47	44.86	41.49	40.29	42.45

Table A50: Posterior probability of olive oil, 1769-1843

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	54/72	11%	7%	82%	26%	8%	67%

Table A51: Marginal likelihood of olive oil, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	131/162	25.28	26.84	28.61	23.83	25.82	28.12
Madrid	165/270	36.59	39.08	42.78	34.05	33.99	39.58
Milano	124/157	143.73	143.36	146.23	138.91	138.59	138.03
Valencia	165/319	85.55	89.23	90.95	83.16	78.69	82.23

Table A52: Posterior probability of olive oil, 1469-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	131/162	3%	14%	83%	1%	9%	90%
Madrid	165/270	0%	2%	97%	0%	0%	99%
Milano	124/157	7%	5%	88%	47%	34%	19%
Valencia	165/319	85%	15%	0%	48%	1%	51%

Table A53: Marginal likelihood of rice, 1586-1690

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Augsburg	40/47	-16.34	-17.77	-13.71	-18.97	-20.91	-17.78
Milano	65/86	47.38	45.39	48.84	44.86	42.36	44.45
Valencia	77/102	48.09	47.15	48.85	45.35	44.05	46.05

Table A54: Posterior probability of rice, 1586-1690

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Augsburg	40/47	7%	2%	92%	23%	3%	74%
Milano	65/86	18%	3%	79%	57%	5%	38%
Valencia	77/102	28%	11%	60%	30%	8%	61%

Table A55: Marginal likelihood of rice, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	31/72	12.33	12.11	15.72	15.75	14.27	18.03
Strasbourg	19/21	-0.67	-0.83	1.87	-2.21	-3.43	-0.99
Warsaw	24/28	3.29	4.14	7.94	1.65	1.46	5.15

Table A56: Posterior probability of rice, 1769-1843

		Posterior Probability					
City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	31/72	3%	3%	94%	9%	2%	89%
Strasbourg	19/21	7%	6%	87%	21%	6%	72%
Warsaw	24/28	1%	2%	97%	3%	2%	95%

Table A57: Marginal likelihood of rice, 1844-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Vienna	60/71	75.20	72.70	75.58	74.23	68.96	71.81

Table A58: Posterior probability of rice, 1844-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Vienna	60/71	39%	3%	57%	91%	0%	8%

Table A59: Marginal likelihood of rice, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	124/253	119.2	115.1	118.9	117.91	112.17	114.14

Table A60: Posterior probability of rice, 1469-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	124/253	57%	1%	42%	97%	0%	2%

Table A61: Marginal likelihood of soap, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	30/68	39.80	39.29	43.14	37.85	37.21	41.16

Table A62: Posterior probability of soap, 1691-1768

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	30/68	3%	2%	95%	3%	2%	95%

Table A63: Marginal likelihood of soap, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	46/65	36.35	35.59	39.83	35.62	32.57	36.80
Leipzig	29/42	27.40	25.45	28.43	26.47	24.36	27.31
Milano	51/72	31.73	34.37	37.84	30.55	32.22	34.83
Paris	30/42	23.37	22.57	25.93	21.75	19.19	22.74

Table A64: Posterior probability of soap, 1769-1843

City	Overlap/Total	Posterior Probability AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	46/65	3%	1%	96%	23%	1%	76%
Leipzig	29/42	25%	4%	71%	29%	4%	68%
Milano	51/72	0%	3%	97%	1%	7%	92%
Paris	30/42	7%	3%	90%	27%	2%	71%

Table A65: Marginal likelihood of soap, 1844-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	12/17	-4.75	-6.72	-5.47	-4.88	-7.02	-6.20

Table A66: Posterior probability of soap, 1844-1914

City	Overlap/Total	Posterior Probability AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	12/17	62%	9%	30%	72%	8%	19%

Table A67: Marginal likelihood of soap, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	93/157	96.58	97.70	99.64	91.35	93.16	94.99

Table A68: Posterior probability of soap, 1469-1914

City	Overlap/Total	Posterior Probability AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Milano	93/157	4%	12%	84%	2%	14%	84%

Table A69: Marginal likelihood of wheat, 1691-1768

City	Overlap/Total	AR(1) No	AR(1) Weak	AR(1) Strong	AR(8) No	AR(8) Weak	AR(8) Strong
Amsterdam	35/78	-8.01	-6.68	-4.45	-7.57	-6.79	-3.88
Firenze	35/78	-1.12	-0.63	1.86	3.93	4.37	6.81
Gdansk	30/66	-4.35	-3.40	-1.51	-0.91	-0.82	1.89
Leipzig	31/72	-18.69	-18.52	-15.18	-18.34	-19.44	-16.52
London	35/78	-19.09	-18.32	-15.20	-17.53	-16.00	-11.96
Madrid	34/73	-35.16	-35.47	-31.72	-35.68	-36.56	-33.03
Milano	31/68	11.76	10.98	12.66	17.81	17.61	18.29
Munich	25/55	-29.70	-29.84	-27.63	-30.89	-31.30	-28.93
Napoli	30/72	-15.22	-13.87	-10.46	-13.24	-11.32	-7.93
Paris	35/78	-36.24	-37.36	-35.11	-34.22	-36.35	-33.97
Strasbourg	35/78	-27.01	-29.12	-26.53	-26.20	-29.19	-26.97
Valencia	35/78	26.83	27.51	29.96	28.65	28.20	30.80
Vienna	35/78	-9.85	-10.27	-6.36	-9.74	-10.52	-5.69

Table A70: Posterior probability of wheat, 1691-1768

Posterior Probability

City	Overlap/Total	AR(1) No	AR(1) Weak	AR(1) Strong	AR(8) No	AR(8) Weak	AR(8) Strong
Amsterdam	35/78	3%	9%	88%	2%	5%	93%
Firenze	35/78	4%	7%	88%	5%	8%	87%
Gdansk	30/66	5%	12%	83%	5%	6%	89%
Leipzig	31/72	3%	3%	94%	13%	4%	82%
London	35/78	2%	4%	94%	0%	2%	98%
Madrid	34/73	3%	2%	95%	6%	3%	91%
Milano	31/68	26%	12%	63%	29%	24%	47%
Munich	25/55	10%	9%	81%	11%	8%	81%
Napoli	30/72	1%	3%	96%	0%	3%	96%
Paris	35/78	23%	7%	70%	42%	5%	53%
Strasbourg	35/78	36%	4%	59%	66%	3%	31%
Valencia	35/78	4%	8%	88%	10%	6%	84%
Vienna	35/78	3%	2%	95%	2%	1%	98%

Table A71: Marginal likelihood of wheat, 1769-1843

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	28/48	-19.10	-20.15	-16.07	-12.54	-16.07	-12.57
Antwerp	43/71	-2.14	-1.38	0.77	1.75	0.08	2.41
Augsburg	30/52	-34.36	-31.30	-27.48	-32.98	-30.30	-26.59
Gdansk	28/47	-18.36	-19.40	-16.55	-15.83	-19.08	-16.77
Krakow	45/74	-57.07	-59.83	-58.85	-56.14	-60.35	-58.43
London	45/75	-16.53	-18.23	-14.80	-14.80	-18.38	-15.78
Madrid	13/24	-26.76	-28.06	-24.49	-26.07	-28.41	-25.73
Milano	43/72	-5.52	-6.87	-3.60	1.24	-3.71	1.02
Munich	42/67	-24.87	-23.38	-21.59	-23.22	-22.45	-20.27
Paris	33/58	-11.34	-9.22	-7.15	-7.93	-7.27	-5.71
Strasbourg	44/73	-17.69	-17.72	-14.14	-11.59	-13.56	-10.20
Vienna	45/75	-30.68	-30.19	-26.33	-30.72	-32.17	-28.34
Warsaw	30/51	-32.10	-31.87	-29.61	-31.83	-33.96	-31.65

Table A72: Posterior probability of wheat, 1769-1843

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	28/48	5%	2%	94%	50%	1%	49%
Antwerp	43/71	5%	10%	85%	32%	6%	62%
Augsburg	30/52	0%	2%	98%	0%	2%	97%
Gdansk	28/47	13%	5%	82%	70%	3%	27%
Krakow	45/74	81%	5%	14%	90%	1%	9%
London	45/75	15%	3%	83%	71%	2%	27%
Madrid	13/24	9%	2%	88%	40%	4%	56%
Milano	43/72	12%	3%	84%	55%	0%	44%
Munich	42/67	3%	14%	83%	4%	10%	86%
Paris	33/58	1%	11%	88%	8%	16%	76%
Strasbourg	44/73	3%	3%	95%	19%	3%	78%
Vienna	45/75	1%	2%	97%	8%	2%	90%
Warsaw	30/51	7%	9%	84%	43%	5%	52%

Table A73: Marginal likelihood of wheat, 1844-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	41/47	19.65	19.55	21.57	18.31	16.83	18.84
Antwerp	48/69	22.94	24.52	25.22	20.92	20.98	20.78
Krakow	48/71	9.58	11.31	13.66	8.37	7.78	9.85
London	48/71	26.86	27.52	28.00	27.25	26.03	26.38
Munich	48/70	19.10	18.68	21.36	16.53	13.15	15.53
Paris	48/70	15.80	16.34	18.59	13.82	12.22	13.97
Vienna	48/70	-3.14	-3.77	-2.80	-5.18	-8.81	-9.63
Warsaw	48/71	18.85	21.47	23.04	18.14	18.86	20.35

Table A74: Posterior probability of wheat, 1844-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Amsterdam	41/47	11%	10%	78%	34%	8%	35%
Antwerp	48/69	6%	31%	63%	34%	36%	29%
Krakow	48/71	2%	9%	88%	17%	9%	74%
London	48/71	16%	32%	52%	58%	17%	24%
Munich	48/70	9%	6%	85%	71%	2%	26%
Paris	48/70	5%	9%	86%	43%	8%	48%
Vienna	48/70	34%	18%	48%	96%	3%	1%
Warsaw	48/71	1%	17%	82%	8%	17%	75%

Table A75: Marginal likelihood of wheat, 1469-1914

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	109/236	-82.59	-81.54	-86.92	-82.93	-78.60	-81.02
Vienna	132/328	-87.18	-82.47	-83.92	-86.03	-82.17	-83.94
Warsaw	97/183	-30.66	-25.68	-26.57	-26.60	-23.05	-21.92

Table A76: Posterior probability of wheat, 1469-1914

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Krakow	109/236	26%	74%	0%	1%	91%	8%
Vienna	132/328	1%	80%	19%	2%	84%	14%
Warsaw	97/183	0%	71%	29%	1%	24%	75%

Table A77: Marginal likelihood of wood, 1691-1768

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Augsburg	26/78	51.31	52.06	54.13	55.15	54.47	56.74
Gdansk	26/78	32.30	33.13	35.55	36.40	36.84	40.98
Madrid	36/78	29.65	30.52	33.21	33.66	33.60	36.44
NorthernItaly	36/68	23.78	25.37	29.66	27.45	28.01	31.46
Paris	29/58	24.15	24.70	28.39	27.11	25.89	29.81
Warsaw	35/75	-10.71	-10.19	-6.49	-6.96	-8.59	-6.06

Table A78: Posterior probability of wood, 1691-1768

Posterior Probability

City	Overlap/Total	AR(1)			AR(8)		
		No	Weak	Strong	No	Weak	Strong
Augsburg	26/78	5%	11%	84%	16%	8%	77%
Gdansk	26/78	3%	8%	89%	1%	2%	97%
Madrid	36/78	3%	6%	91%	5%	5%	89%
NorthernItaly	36/68	0%	1%	98%	2%	3%	95%
Paris	29/58	1%	2%	96%	6%	2%	92%
Warsaw	35/75	1%	2%	96%	27%	5%	67%

Table A79: Adjusted Half-life (Monthly), CPI

City	Year	Half Lives (European City)	Half Lives (Istanbul)
Napoli	1586-1690	2.271	0.229
Augsburg	1691-1768	1.793	0.796
Lwow	1691-1768	16.004	38.723
Munich	1691-1768	9.628	3.479
Napoli	1691-1768	10.351	8.493
NorthernItaly	1691-1768	5.044	6.290
Warsaw	1691-1768	77.948	4.751
Antwerp	1691-1768	16.844	2.558
Madrid	1691-1768	4.939	2.454
Leipzig	1469-1914	1.565	3.614
Lwow	1469-1914	1338.227	0.807
Madrid	1469-1914	2.599	1.761
Napoli	1469-1914	29.660	2.163

Table A80: Adjusted Half-life (Monthly), Butter

City	Sample	Half Life (European City)	Half Life (Istanbul)
London	1586-1690	2.428	0.107
Lwow	1586-1690	18.301	0.097
Munich	1586-1690	0.137	0.087
Napoli	1586-1691	0.994	0.098
Amsterdam	1691-1768	11.450	1.706
Leipzig	1691-1768	8.234	1.625
London	1691-1768	3.558	1.334
Milano	1691-1768	16.263	3.161
Strasbourg	1691-1768	5.219	1.576
Vienna	1691-1768	2.934	2.037
Warsaw	1691-1768	0.350	2.381

Table A81: Adjusted Half-life (Monthly), Charcoal

City	Sample	Half Life (European City)	Half Life (Istanbul)
Antwerp	1691-1768	8.885	49.857
Strasbourg	1769-1843	4.132	5.434

Table A82: Adjusted Half-life (Monthly), Chickpeas

City	Sample	Half Life (European City)	Half Life (Istanbul)
Amsterdam	1586-1690	0.211	0.176
Antwerp	1586-1690	0.109	0.254
Augsburg	1586-1690	0.121	0.415
Gdansk	1586-1690	0.545	0.183
Krakow	1586-1690	0.207	0.229
Leipzig	1586-1690	1.372	0.268
Lwow	1586-1690	0.391	0.156
Vienna	1586-1690	1.186	0.187
Krakow	1691-1768	1.342	1.114
Leipzig	1691-1768	0.288	5.772
Amsterdam	1769-1843	2.204	0.361
Gdansk	1469-1914	0.210	0.249

Table A83: Adjusted Half-life (Monthly), Honey

City	Sample	Half Life (European City)	Half Life (Istanbul)
Madrid	1586-1690	0.285	0.154
Valencia	1586-1690	0.630	0.354
Valencia	1691-1768	0.286	0.273
Madrid	1469-1914	0.209	0.288

Table A84: Adjusted Half-life (Monthly), Olive Oil

City	Sample	Half Life (European City)	Half Life (Istanbul)
Krakow	1586-1690	1.191	0.161
Madrid	1586-1690	0.169	0.121
Valencia	1586-1690	0.252	0.153
Krakow	1691-1768	0.441	0.126
London	1691-1768	36.971	0.359
Strasbourg	1691-1768	7.186	0.146
Valencia	1691-1768	4.769	0.141
Milano	1769-1843	4.734	3.354
Krakow	1469-1914	0.269	1.562
Madrid	1469-1914	0.104	0.433
Milano	1469-1914	1987.169	1.331

Table A85: Adjusted Half-life (Monthly), Rice

City	Sample	Half Life (European City)	Half Life (Istanbul)
Augsburg	1586-1690	25.244	0.087
Milano	1769-1843	6.636	2.602
Strasbourg	1769-1843	21.936	3.662
Warsaw	1769-1843	4.285	1.533

Table A86: Adjusted Half-life (Monthly), Soap

City	Sample	Half Life (European City)	Half Life (Istanbul)
Milano	1691-1768	10.310	0.543
Milano	1769-1843	2.237	3.177
Paris	1769-1843	4.977	5.643
Milano	1469-1914	23.502	2.123

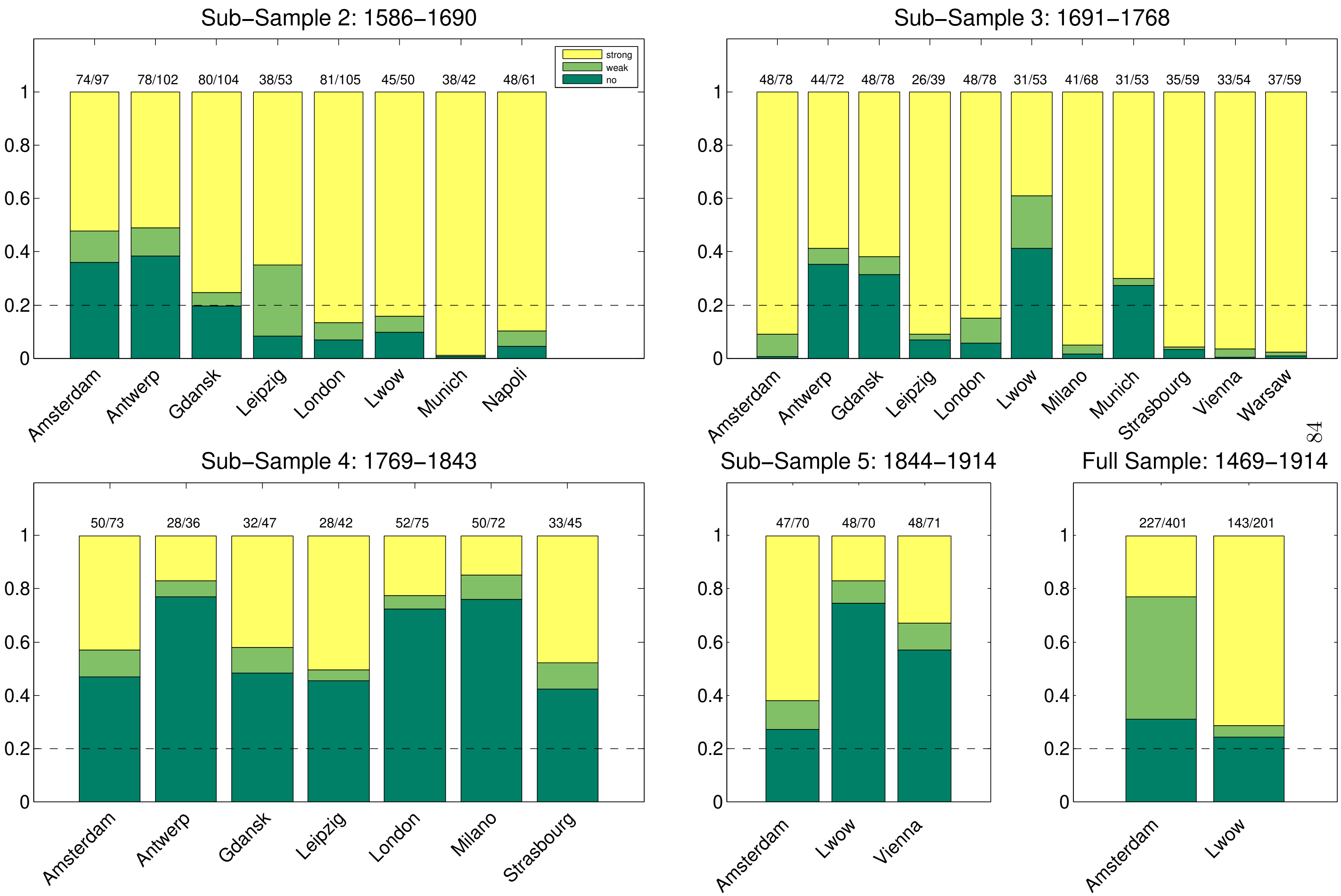
Table A87: Adjusted Half-life (Monthly), Wheat

City	Sample	Half Life (European City)	Half Life (Istanbul)
Amsterdam	1691-1768	12.820	9.776
Firenze	1691-1768	2.102	4.304
Gdansk	1691-1768	5.918	11.227
Leipzig	1691-1768	1.062	6.668
London	1691-1768	1.470	13.375
Madrid	1691-1768	0.250	2.260
Munich	1691-1768	0.375	9.572
Napoli	1691-1768	0.106	1.783
Valencia	1691-1768	9.602	2.903
Vienna	1691-1768	1.086	3.338
Amsterdam	1769-1843	5.057	14.491
Antwerp	1769-1843	5.467	12.643
Augsburg	1769-1843	0.628	3.647
Gdansk	1769-1843	12.283	14.865
London	1769-1843	15.117	18.436
Madrid	1769-1843	0.769	6.692
Milano	1769-1843	5.091	6.783
Munich	1769-1843	2.322	1.213
Paris	1769-1843	0.822	5.143
Strasbourg	1769-1843	1.927	8.840
Vienna	1769-1843	1.794	12.035
Warsaw	1769-1843	0.854	10.494
Krakow	1844-1914	4.744	17.596
Munich	1844-1914	6.481	14.267
Paris	1844-1914	3.253	7.501
Warsaw	1844-1914	4.417	11.642

Table A88: Adjusted Half-life (Monthly), Wood

City	Sample	Half Life (European City)	Half Life (Istanbul)
Augsburg	1691-1768	47.520	2.086
Gdansk	1691-1768	18.582	0.425
Madrid	1691-1768	1.090	0.139
NorthernItaly	1691-1768	4.986	0.147
Paris	1691-1768	2.469	0.265
Warsaw	1691-1768	1.572	0.254

Figure A1



Sub−Sample 2: 1586−1690
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weak
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78/102
80/104
38/53
81/105
45/50
38/42
48/61
Amsterdam
Antwerp
Gdansk
Leipzig
London
Lwow
Munich
Napoli
Sub−Sample 3: 1691−1768
48/78
44/72
48/78
26/39
48/78
31/53
41/68
31/53
35/59
33/54
37/59
Amsterdam
Antwerp
Gdansk
Leipzig
London
Lwow
Milano
Munich
Strasbourg
Vienna
Warsaw
Sub−Sample 4: 1769−1843
50/73
28/36
32/47
28/42
52/75
50/72
33/45
Amsterdam
Antwerp
Gdansk
Leipzig
London
Milano
Strasbourg
Sub−Sample 5: 1844−1914
47/70
48/70
48/71
Amsterdam
Lwow
Vienna
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227/401
143/201
Amsterdam
Lwow
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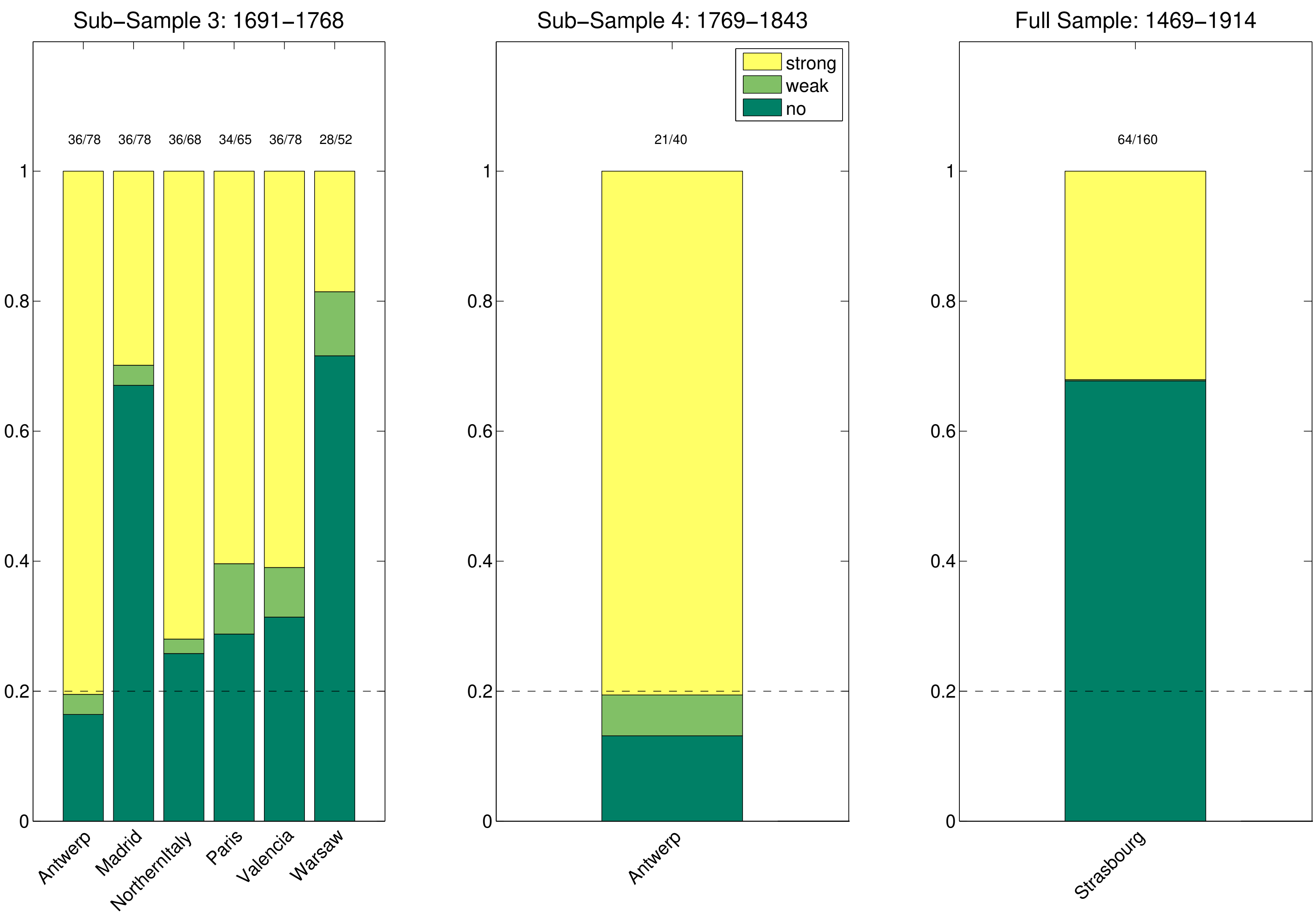
0.4
0.6
0.8
1

Figure A2



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Sub−Sample 4: 1769−1843
Full Sample: 1469−1914
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weak
no
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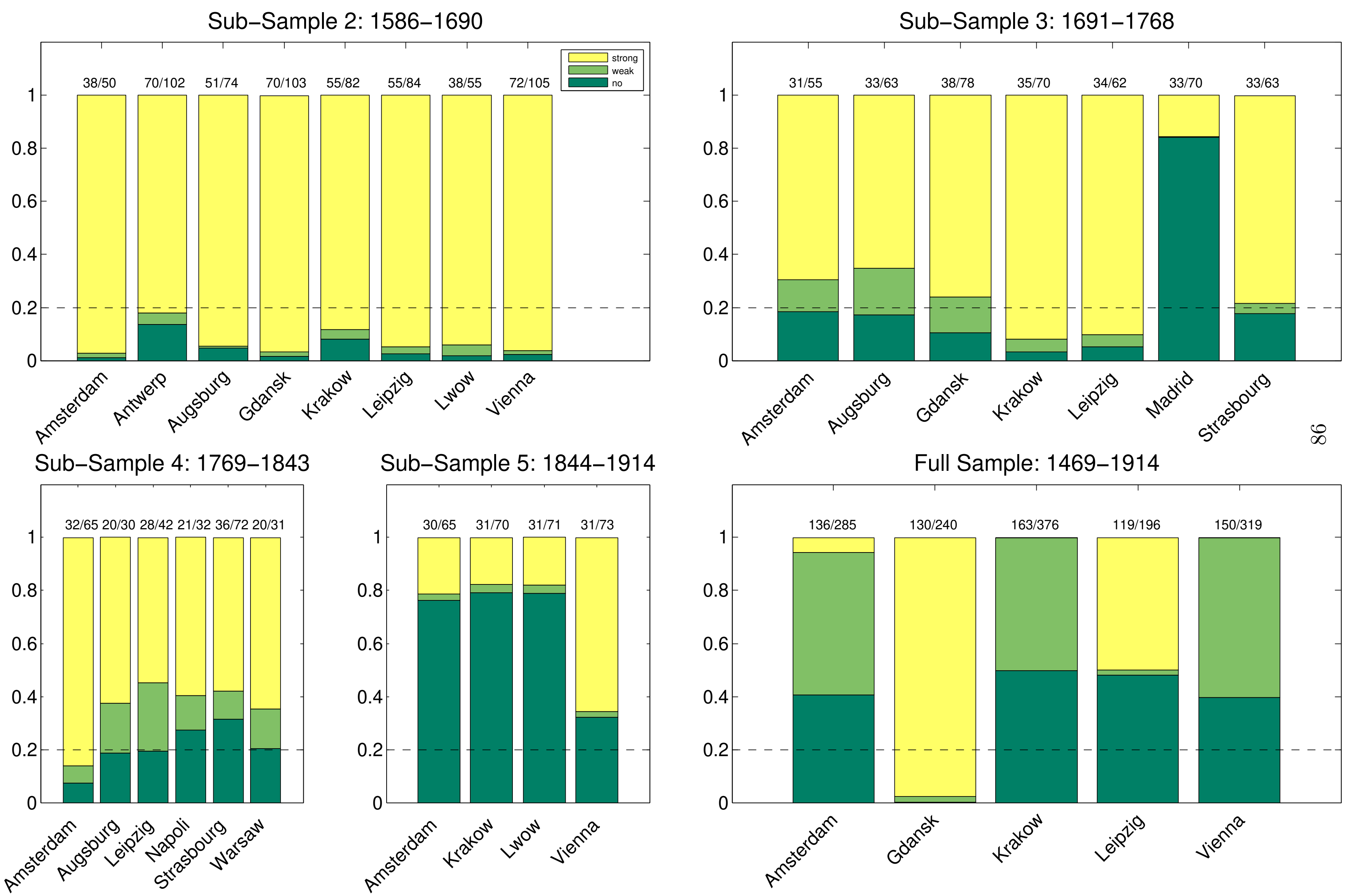
36/78
36/68
34/65
36/78
28/52
21/40
64/160
0
0.2
0.4
0.6
0.8
1
Antwerp
Madrid
NorthernItaly
Paris
Valencia
Warsaw
Antwerp
Strasbourg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weak
no
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Amsterdam Antwerp Augsburg Gdansk Krakow Leipzig Lwow Vienna
Sub−Sample 3: 1691−1768
31/55 33/63 38/78 35/70 34/62 33/70 33/63
Amsterdam Augsburg Gdansk Krakow Leipzig Madrid Strasbourg
Sub−Sample 4: 1769−1843
32/65 20/30 28/42 21/32 36/72 20/31
Amsterdam Augsburg Leipzig Napoli Strasbourg Warsaw
Sub−Sample 5: 1844−1914
30/65 31/70 31/71 31/73
Amsterdam Krakow Lwow Vienna
Full Sample: 1469−1914
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Amsterdam Gdansk Krakow Leipzig Vienna
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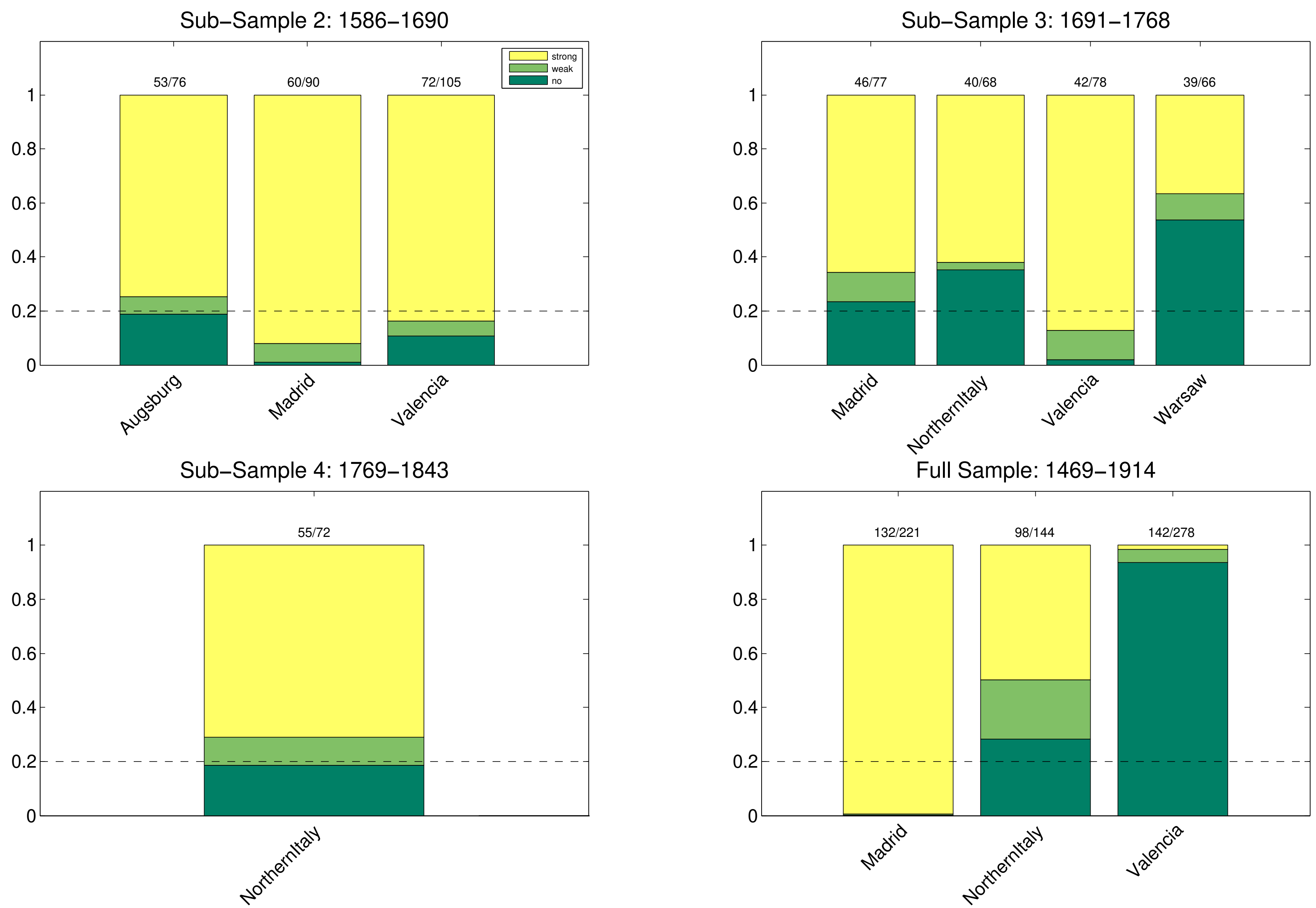
Figure A3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strong
weak
no
53/76
60/90
72/105
Augsburg
Madrid
Valencia
Sub−Sample 3: 1691−1768
46/77
40/68
42/78
39/66
Madrid
NorthernItaly
Valencia
Warsaw
Sub−Sample 4: 1769−1843
55/72
NorthernItaly
Full Sample: 1469−1914
132/221
98/144
142/278
Madrid
NorthernItaly
Valencia
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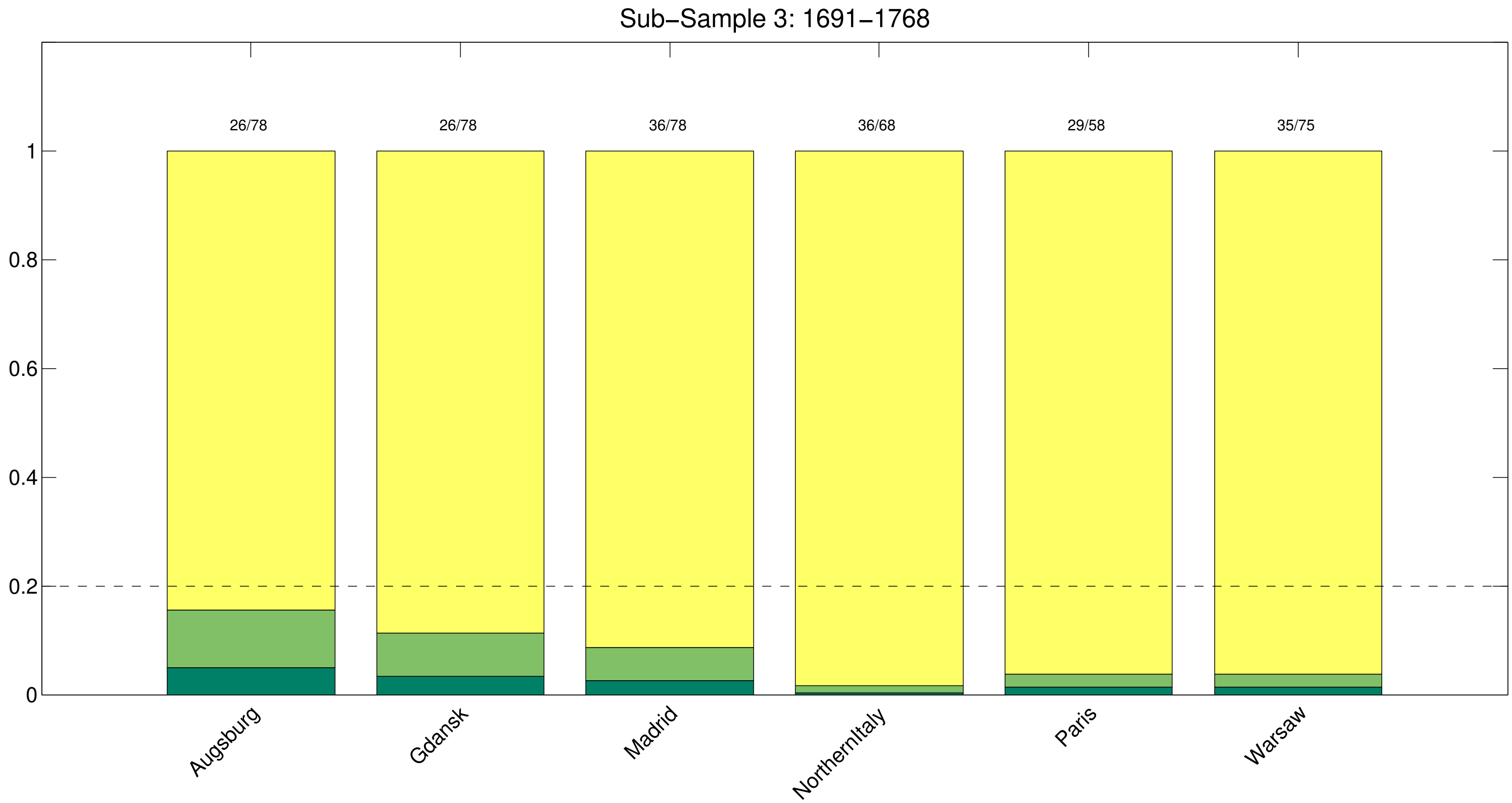
0.6
0.8
1

Figure A4

Figure A5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36/68
29/58
35/75
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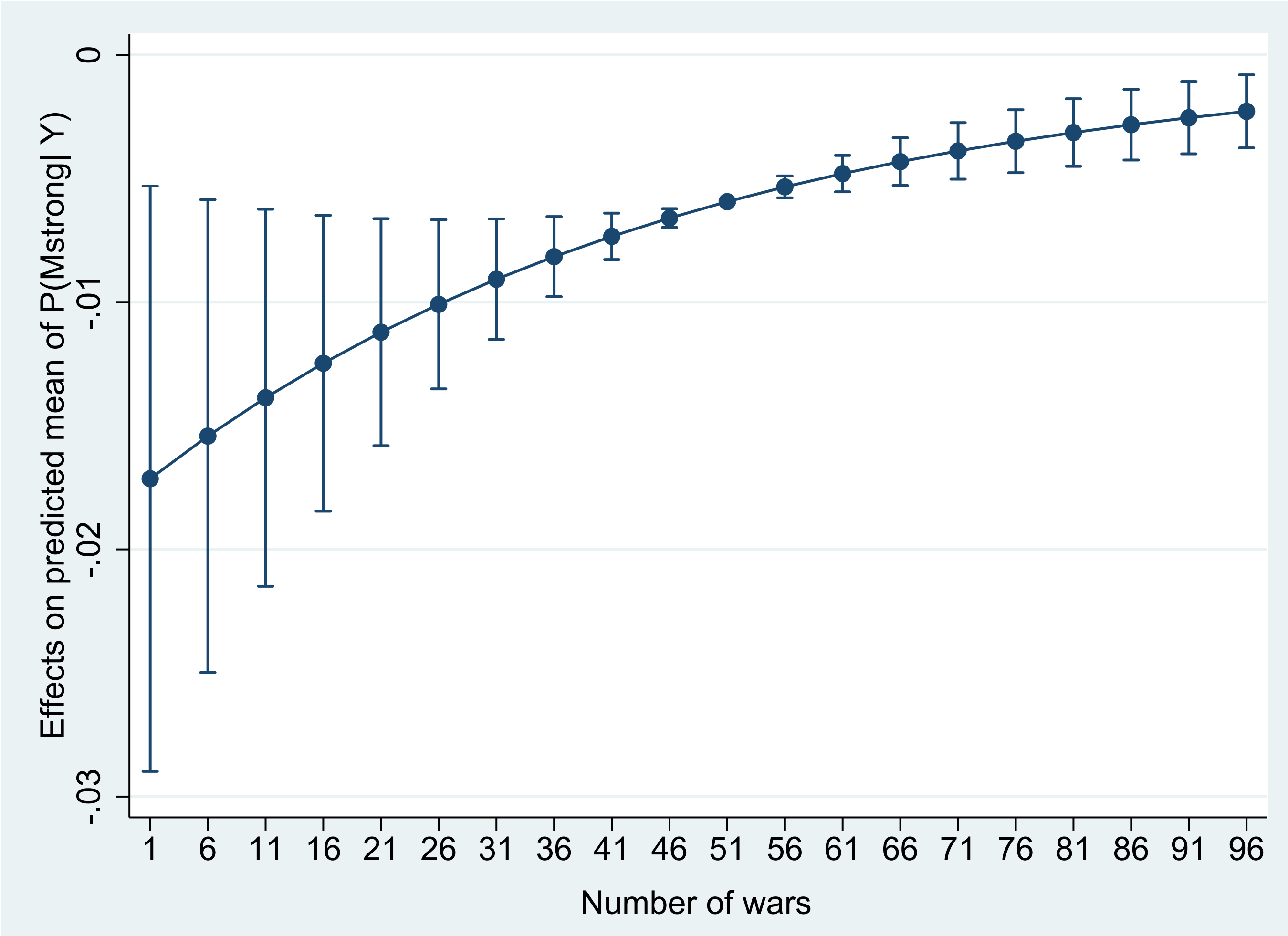
0.8
0.6
0.4
0.2
0
Augsburg
Gdansk
Madrid
NorthernItaly
Paris
Warsaw

Figure A6: Average marginal effects of war on integration



Marginal effects with 95% confidence intervals calculated for the PPML regression specification used in column VII, Table 1.