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**Article**

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# Grain Prices in Pre-industrial Germany, Fifteenth to Nineteenth Centuries

**ABSTRACT:** We present the largest homogenous dataset of grain prices for four major types of grain for pre-industrial Germany covering 70 cities with a total of 259 time series. This article describes the sources and the methodology followed to create calendar-year-based price series in grams of silver per litre. The dataset is organised and documented decentrally by means of one excel file for each city. To aggregate information for all cities in one file, future users can either use spreadsheet software or open-source software code that creates the national-level file. We use the dataset to show how price dispersion developed across more than 300 years. The dataset facilitates future research on market integration, storage, historical demography, and economic impacts of climate change.

*Keywords:* data, grain prices, food prices, pre-industrial, Germany, market integration, storage, historical demography, climate change.

*JEL Codes:* N13, N53, O13

## 1. Introduction

Grain prices are key variables of pre-industrial economies. They form the main basis of Abel's classic study on agrarian crises and long-term cycles.<sup>1</sup> The relevance of grain prices for the analysis of pre-industrial economies stems mainly from the fact that cereals are of great importance for human consumption. The cost of living depended to a large degree on the price of grain. Bread from grain constituted the largest share of expenditure in consumer baskets for the pre-industrial period.<sup>2</sup> In addition, other items in a typical consumption basket were also based on grain inputs. Barley serves for brewing beer; grain and cereal waste is used as animal feed, and animal husbandry produced foods such as meat, eggs, milk and cheese. Given its important role for consumption, grain was a major commodity in pre-industrial economies, it was traded, stored, and used as in-kind payment. The availability of grain was a matter of life and death: Mortality rates

1 Abel (1980).

2 The share was about 30 %, see Allen (2001); Pfister (2017), Supporting information S2, p. 1; Saalfeld (1984), p. 238.

peaked after serious harvest shortfalls, and until the advent of the so-called European grain invasion starting in the late 1860s, decisions of young Germans to marry depended heavily on food prices.<sup>3</sup>

While there is a large body of published grain prices, the available information mostly relates to historical volume units, which varied between individual markets, and to historical currency units. Some series relate to wholesale prices, whereas others relate to prices at markets accessible to individual households. Some prices refer to the calendar year, some to the crop year and others to specific days, such as *Martini* prices, which were collected on an important deadline for peasant dues. The heterogeneity of existing data sources and compilations poses a formidable obstacle to economic historical analysis. To facilitate future research using grain prices, this study constructs the largest homogenous grain price dataset for pre-industrial Germany. Following established practice in recent price history, prices are standardized to calendar year averages in grams of silver per litre. The dataset covers 70 cities with a total of 259 time series relating to all four major types of grain from the 15<sup>th</sup> to the 19<sup>th</sup> centuries. Wherever possible, we present prices at the retail level.

Inspired by the Allen files,<sup>4</sup> the publication of the dataset does not only document the sources but the entire process of constructing the final price series in grams of silver per litre. In this way, the final series can be traced back to the sources with little effort by the researcher, which facilitates alternative uses of the data. In the future, the dataset can be easily improved and extended either by adding new cities or revising existing data files.

Figure 1 summarises the workflow of creating this dataset. This process includes the collection of data from various sources, the preparation of these data for analysis considering several methodological challenges and historical background information, and the organisation of the information in an accessible way.

The remainder of the article is organised as follows: Section 2 introduces the object of our study. The following sections explain the details of the different steps depicted in Figure 1. Section 3 provides a brief overview of the sources used (Figure 1: 'Data collection'). Section 4 discusses how we dealt with challenges facing the construction of a homogenous dataset such as varying currencies, volume units, and time references (Figure 1: 'Data preparation & organisation by city'). Based on the principles established in Section 4, Section 5 explains the structure of the city data files, and how the final series can be merged into an aggregate dataset (Figure 1: 'Organisation by grain type'). Section 6 provides a brief overview of quantitative research based on historical grain prices and demonstrates how the aggregated information from the city files can be used in a quantitative analysis of market integration (Figure 1: 'Statistical analyses'). Section 7 concludes.

3 Alfani/Ó Gráda (2018); Pfister (2021), pp. 105–109, 114 f.

4 Allen (2010); see also Allen (2001). The structure of data organisation is similar to Pfister (2017), Supporting information S1 and S4.

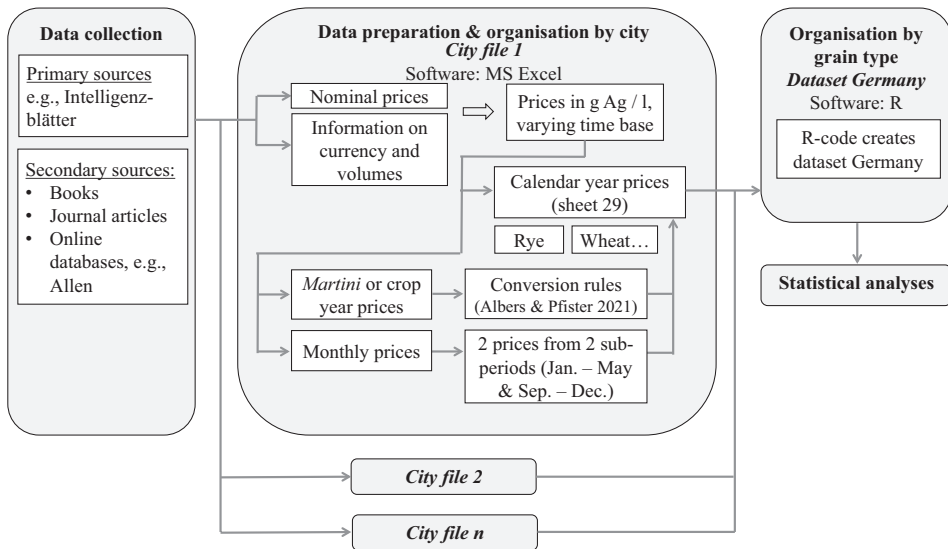


Fig. 1: Workflow of dataset construction and analysis.

Source: own representation.

## 2. Object of study

### 2.1 Stylised facts of the pre-industrial grain economy

Rye was the most important cereal in pre-industrial Germany, which is evident in cropping shares (Table 1). Around 1800, the share of rye in the total acreage sown with the four main types of grain may have been more than 40 % for rye but only about 10 % for wheat (Table 1).<sup>5</sup> Accordingly, a contemporary estimate puts average annual rye consumption per head in the Kingdom of Prussia at 133.6 kilogram in 1833–1855; the equivalent figure for wheat was only 22.3 kilogram.<sup>6</sup>

Rye and wheat were the principal inputs for bread production, the most important vegetable staple food. Nevertheless, the other two types of grain were also used for human consumption to a varying degree. Barley was an input for beer but was also consumed as pearl barley (*Graupen*). Whereas oats served primarily as animal feed, minor quantities were also consumed by humans in the form of porridge; a contemporary estimate places human consumption of oats in Prussia at 6.5 kilogram per year in 1833–1855.<sup>7</sup>

5 van Zanden (1999), p. 368. 15 % of the arable land served the cultivation of other crops. Achilles (1993), p. 198 suggests a broadly similar structure of the sown arable land, but with a slightly smaller weight of rye (33 %) and a somewhat larger portion devoted to other crops than grain (19 %).

6 Meitzen (1871), p. 388.

7 Meitzen (1871), p. 388; see also Göttmann (2006).

Table 1: Shares of main types of grain in cultivated arable land and market turnover (percent)

	barley	oats	rye	wheat
<i>Share in arable land cultivated with four main grain types (c. 1800)</i>				
Achilles		47.5	41	11.5
van Zanden	20	27	45	8
<i>Share in market turnover</i>				
Cologne (1700–1797)	9.7	8.9	68.0	13.4
Cologne (1790–1792)	8.1	7.1	69.4	15.5
Munich (1790–1792)	34.9	8.3	21.9	34.9

*Sources:* Arable land shares: Achilles (1993), p. 198; van Zanden (1999), p. 368. The figure given by Achilles for wheat includes spelt. Information on market turnover in Cologne is based on the aggregation of monthly data regarding traded volumes from Ebeling/Irsigler (1976); see Cologne file of this study. Trade volumes for Munich are from Seuffert (1857), p. 108.

Whereas rye tended to be a subsistence crop, wheat was as a cash crop. The status of wheat as a cash crop is evident from price levels, and the fact that it dominated transaction volumes in at least some markets. In 1767–1791, wheat fetched the highest price, that is, 0.56 grams of silver per litre (g Ag/l), followed by rye (0.40 g Ag/l), barley (0.30 g Ag/l), and oats (0.20 g Ag/l).<sup>8</sup> To contextualize these prices, it is useful to relate them to the cost of living at that time. During the same period, the average value of a typical consumption basket for an adult town dweller was about 396 grams of silver.<sup>9</sup> In 1800, the wheat yield was about 1300 litre per hectare; for rye it was 1200 litre.<sup>10</sup> Multiplying these yields with the corresponding prices indicates that the yield from one hectare of wheat was equivalent to 1.8 consumption baskets, whereas one hectare of rye corresponded to 1.2 baskets. In other words, the economic value of one hectare of wheat was considerably higher and could cover the costs of living for almost 2 persons.

Among the four cereals, the share of wheat in total market turnover was high relative to its comparably low weight in the premodern cropping pattern prevailing in Germany, particularly in comparison with oats (see the contrasting shares in Table 1). From a producer's perspective, the much lower cropping share in combination with a higher economic value and relatively high market turnovers indicate that wheat was as a cash crop and thereby supplemented the core functions of other cereals that contributed the bulk quantities used for consumption (rye, barley) and animal feed (barley, oats).

Some qualifications of these basic facts are in order. At the grain market of Cologne, 69 % of the quantity of cereals traded in 1790–1792 was made up of rye (Table 1). This

8 Figures relate to the 25 years before the beginning of the Revolutionary and Napoleonic Wars, the period with the highest data density before 1800 (cf. Figure 3 below). We use all available prices at the city level in our dataset.

9 Pfister (2017), Supporting information S2 and S3.

10 Troßbach/Kopsidis (2005).

is in line with the importance of rye in cropping and consumption patterns outlined above. Long-run data for Cologne in 1700–1797 show a similar pattern. In Munich, by contrast, market turnover was dominated by wheat and barley in 1790–1792. Because cropping shares in Bavaria were broadly similar to the general pattern for Germany documented in Table 1, the dominance of wheat over rye with respect to market turnover underscores the characterization of wheat as cash crop and rye as subsistence crop. The great weight of barley in market turnover in Munich may be due to the existence of large breweries operated by the king and important clerical institutions in this city.<sup>11</sup>

In addition, cropping shares exhibited regional heterogeneity. In a crescent extending roughly from Swabia (west of the Lech river) in the southeast to Wallonia (southern Belgium) in the northwest, variants of spelt (variably called *Dinkel*, *Fesen*, *Kern*, and *Spelz*) were also a highly relevant grain for nutrition.<sup>12</sup> Around 1853, 28 % of the cultivated arable land in Bavarian Swabia was sown with spelt but only 18 % with rye. In the Bavarian Palatinate, the corresponding shares were 19 % and 32 %.<sup>13</sup>

## 2.2 Area and time period studied

We systematically searched for sources on grain prices in an area defined by the overlap between the Holy Roman Empire of 1791 and the nation state formed in 1871 (see Figure 2). Compared to Germany in the borders of 1990, this includes Silesia and the parts of Brandenburg and Pomerania situated east of the Oder river and excludes southern Schleswig. It also excludes most territories of the Habsburg monarchy located in the Holy Roman Empire, in particular present-day Austria and Czechia.

The same definition of the territorial frame of reference has been used in previous research on urban and total population spanning both the early modern period and the 19<sup>th</sup> century.<sup>14</sup> In addition we include information on three cities outside the boundaries thus defined for which there are good data and which had close relationships to politics in the German lands: Strasbourg was an important Imperial city until 1681, when it was incorporated into France. Gdansk (Danzig) was an important member of the Hanseatic League until the 17<sup>th</sup> century, but became an autonomous community within the Kingdom of Poland from the middle of the 15<sup>th</sup> century. In 1793, it was integrated into the Prussian state that had acquired the town's hinterland in successive steps from the early 16<sup>th</sup> century. Finally, Kaliningrad (Königsberg) was the seat of the Diet of Prussia, which became one of the core territories of the Kingdom of Prussia.

11 Denzel (1998), p. 346, especially footnote 1142. In 1853 cropping shares in Bavaria (excluding Swabia and the territory left of the Rhine) were as follows (small acreages cultivated with spelt excluded; see below): barley 16.4 %, oats 29.1 %, rye 38.3 %, and wheat 16.2 %; own calculation based on Seuffert (1857), pp. 15, 135, 159, 170, 192, and 210.

12 Göttmann (2006); on spelt and its role as an anchor for grain prices in Wallonia, see Pieyns/Tijms (1993), pp. 95 f.

13 Seuffert (1857), pp. 222, 299; shares refer to the arable land sown with grain.

14 Fertig et al. (2018), p. 8; Pfister (2020); Pfister/Fertig (2020), p. 1151.

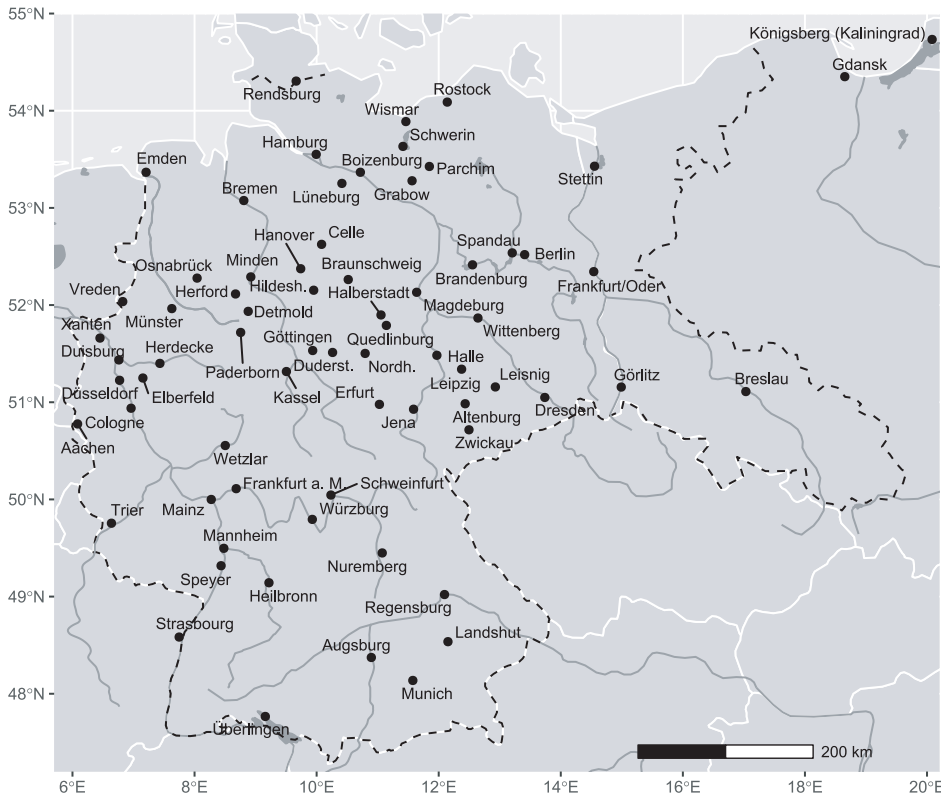


Fig. 2: Cities in the dataset.

Note: Dark grey lines depict major rivers. Black dashed line refers to overlap of the territories of the Holy Roman Empire and the nation state of 1871. Abbreviations: Duderst. Duderstadt, Hildesh. Hildesheim, Nordh. Nordhausen.

Source: own representation based on map of Europe from [www.naturalearthdata.com](http://www.naturalearthdata.com).

The time period covered by our dataset ends in 1871 for three reasons. First, the foundation of the *Reich* in 1871 marks a turning point in the history of state formation in the German lands. This political event went together with a marked expansion of the topics covered by statistical reporting schemes. Specifically, large states began collecting and publishing information on grain prices in the late 1860s. Against this background, our study is devoted to the pre-statistical era of the societal observation of grain markets. Second, the marriage rate reacted to food prices until the late 1860s. From 1870, it shows a similar cyclical movement as a stock market index, which was essentially driven by business cycles of the modern sector.<sup>15</sup> Hence, our research contributes to the study of the pre-industrial era when the economy was dominated by the agricultural sector.

15 Pfister (2018), pp. 589–594, (2021), pp. 105–109, 114 f.

Finally, the introduction of a metric system that started in the *Norddeutsche Bund* in 1868 has a profound implication on the study of grain prices in that it shifted the measurement of grain quantities from volume units to weight units. Since humidity impacts on the weight of grain and because we do not know well the reduction factors applied by contemporaries in each region, grain prices before and after about 1870 are not easily comparable.<sup>16</sup>

The publications of the statistical offices of Bavaria and Prussia alone cover grain prices in roughly 200 towns in the late 1860s. We do not include all this information in our database. Rather, the criterion of inclusion is the availability of grain prices from before 1800 with a minimum number of observations of 50 years for at least one type of grain. Altogether this leads to a sample of 70 towns, which are shown in Figure 2. Information on available years is documented for each city and grain type in the Supplementary Appendix (SA2, overview Table S11 on p. S6).

The database focuses on annual prices of four grain types, namely, barley, oats, rye and wheat. Sources often provide information on prices of other food items as well, such as peas and – in the 19<sup>th</sup> century – potatoes, but we do not include them in our data in a systematic way.<sup>17</sup> Spelt prices are available for seven cities located in southwestern Germany (Augsburg, Heilbronn, Mainz, Mannheim, Speyer, Trier, and Überlingen). We developed series in grams of silver per litre, but do not include these data in the aggregation procedure described in Section 5.2. Given the focus on annual prices we recorded prices at lower time intervals only where necessary.

### 3. Overview of sources

Nominal grain prices in historical currencies and volumes stem from several types of sources. The bulk of the data are from published compilations that report grain prices in historical volume units and currencies. The most important body of information is from work by the group around Karl Heinrich Kaufhold and Hans-Jürgen Gerhard, which focuses on north-western Germany. This material is now available in digital form from the HISTAT project.<sup>18</sup> An important early compilation includes a voluminous study on grain trade in 19<sup>th</sup>-century Bavaria published in 1857, followed by studies of grain trade in 18<sup>th</sup>-century Prussia conducted within the framework of the *Acta Borussica* project undertaken by members of the historical school around the turn of the 20<sup>th</sup> century.<sup>19</sup> Notable work undertaken during the interwar years includes the contributions to the International Scientific Committee on Price History (ISCPH) of the interwar years,

16 Groß (2015); Kramper (2019), pp. 375–386. Where necessary, we applied the conversion factors suggested by Kopsidis (1996), p. 543.

17 Prices for a basket of eleven products in twelve cities can be found in Pfister (2017), Supporting information S4.

18 Gerhard/Kaufhold (1990; HISTAT ZA8512); Gerhard/Engel (2006; HISTAT ZA8632); a useful addition is Oberschelp (1986).

19 Seuffert (1857); Naudé/Schmoller (1901); Naudé et al. (1910); Skalweit (1931).



above all by Elsas, and the publications by Jacobs and Richter at the *Statistisches Reichsamt*.<sup>20</sup> More recent compilations are the online databases authored by Robert Allen and David Jacks.<sup>21</sup> An important part of Jacks' database consists of hitherto unpublished material of the above-mentioned ISCPH. We checked the series taken from the two online databases with the original publication wherever possible.

A second, much smaller body of data comes from local or regional studies on grain markets that have not been covered by earlier compilations. Notably information on Cologne, Nuremberg, Würzburg and several smaller towns in Saxony is from this type of source.<sup>22</sup> Moreover, Walter Bauernfeind kindly shared an extended version of his nominal price series covering Nuremberg.<sup>23</sup>

A third group of sources consists of short tracts that present price data and include little text otherwise. They mostly consist of submissions to scholarly periodicals that sprang up during the Age of Enlightenment of the late 18<sup>th</sup> century and to early statistical journals emerging in the course of the 19<sup>th</sup> century. Projects of public libraries to digitise historical publications are continuously expanding the body of this type of source.

Fourth, we collected a limited amount of data from primary sources. Alfred Reckendrees has kindly shared the scan of a manuscript compilation of food prices in Prussian cities in 1811/16–1859 drawn up around 1860, from which we have gleaned grain prices for 20 markets. We also used digitally available newspapers to assemble data on grain prices at weekly markets. Semi-official *Intelligenzblätter* and official *Amtsblätter* containing the relevant information are available from the middle of the 18<sup>th</sup> century and become more frequent during the first half of the 19<sup>th</sup> century. Particularly the digipress (*Bayerische Staatsbibliothek*) and the *zeit.punktNRW* projects continuously expand the availability of this type of sources. Finally, the statistical offices of some German states began to collect and publish data on grain prices in the 1860s. We preferred this kind of information, covering the final years of the period of observation, to material collected from newspapers.

In short, a great variety of information, that is, published compilations, online databases, regional studies, and primary sources such as early statistical journals are merged in this dataset. All details on sources used are documented in full detail in the Supplementary Appendix (SA2).

20 Elsas (1936–1949); Statistisches Reichsamt (1935). The data of the latter study are available from HISTAT ZA8296.

21 These databases are based on Allen (2001) and Jacks (2004), respectively. See Allen (2010) and Jacks (2016).

22 Ebeling/Irsigler (1976); Bauernfeind (1993); Christoforatu (2010); Uebele et al. (2013). The data for Cologne are also available from HISTAT ZA 8014. For a discussion of these data, see Rahlf (1996); among others, Persson (1996) has analysed these data.

23 The most recent and longest version is used in Bauernfeind et al. (2001).

## 4. Methodology

As mentioned in the introduction, price information from historical sources and contained in existing data compilations is heterogeneous in several respects. To make it amenable for comparative analysis, it has to be homogenized with respect to currency and volume units, time reference, and stage of marketing.<sup>24</sup> In what follows, we explain the procedures we apply to transform the heterogeneous source material into a database containing calendar-year-based price series in grams of silver per litre.

### 4.1 Conversion to grams of silver per litre

The currency regimes that prevailed in the German lands are highly complex compared to other European countries. A recent analysis of monetary developments during the pre-industrial era includes many countries of Europe but does not cover the German lands, because no unified territory with a common coinage existed.<sup>25</sup> The capacity to mint coins for larger territories was highly fragmented and several regimes coexisted.<sup>26</sup>

Nevertheless, in the majority of German speaking cities, grain trade was based on silver-based currencies (Bremen was the exception). Thus, we converted all prices to grams of silver per litre (g Ag per l) via the fine metal content. For this purpose, we apply the following basic relationships: 1 *Mark* of Cologne = 233.8555 g Ag.<sup>27</sup> Following the Vienna treaty of 1857 most German states shifted to a new system in 1858 where 1 *Mark* equalled 500 grams of fine silver.<sup>28</sup> The resulting difference in the silver content of regional currencies was small, however.<sup>29</sup> We combined these basic relationships with knowledge on the local currency regimes based on specialised literature. In the Supplementary Appendix, we document the state of knowledge on the currency system for each city (SA2). Based on this description, we document how we converted local prices.

In a few cases, prices are reported in money of account (which has no metal content).<sup>30</sup> We converted money of account to silver using exchange rates with gold currencies (*Rheinischer Gulden*) and gold-silver ratios.

An earlier study on prices in pre-industrial Germany has argued against the use of silver as a common denominator on the grounds of the low degree of integration of bullion markets.<sup>31</sup> However, gold-silver price ratios in Cologne and Vienna were cointegrated from 1480 to 1790, suggesting some degree of bullion market integration. The existence

24 For an overview, see also Gerhard/Engel (2006), pp. 39, 55–59. An early compilation of rye prices in grams of silver per litre covering 12 cities for the period 1500–1800 is Rahlf (1996; HISTAT ZA 8140).

25 Karaman et al. (2020).

26 See, e.g., Gerhard (2002) for an overview.

27 Rittmann (1975), p. 535–537.

28 Zich (2009), p. 126.

29 Statistisches Reichsamt (1935), p. 310.

30 See Gerhard/Engel (2006), pp. 40–46, 59; Metz (1990).

31 Gerhard/Engel (2006), pp. 43 f.

of currency unions and, from 1566, of a common currency regime support this conclusion.<sup>32</sup> Both findings justify the use of silver as a common denominator for grain prices in German towns. Nevertheless, one limitation of using the silver content of currency to standardise prices remains. We are often unable to establish the intrinsic content of coins during periods of massive currency debasement with sufficient detail. In these cases, our series overestimate silver price inflation. Three periods of intensive currency debasement, during which the quality of our silver price information is highly doubtful, stand out: the *Kipper and Wipper* era at the beginning of the Thirty Years' War (1620–1623), the Seven Years' War (1756–1763) and the Revolutionary and Napoleonic Wars (1792–1815).<sup>33</sup>

Apart from regionally different currencies, local volume measures existed. We used information on the factors for converting local volumes to litre either directly as given by the author of a regional study or relevant handbooks.<sup>34</sup>

#### 4.2 The calendar year as time reference

Original data also differs with respect to time reference and frequency. Many sources and compilations report calendar year average prices. However, some sources list prices prevailing in November or December, particularly around *Martini* (Martinmas, November 11), and some aggregate weekly or monthly prices to crop year prices. Transforming data to a common time reference is essential for studying co-movement and level differences between prices in different cities.<sup>35</sup>

*Martini* prices were recorded because they frequently served as the basis for the monetisation of peasant dues.<sup>36</sup> Crop year prices refer to the period from one harvest to the next, such as August 1501 to July 1502. Finally, monthly data are reported for some cities (e.g., Cologne, Nuremberg). For some cities and select periods, we also work with weekly data, which we aggregate to monthly data. We first discuss how we deal with *Martini* and crop year prices. Second, we introduce the definition used to calculate calendar year averages based on weekly and monthly data.

##### 4.2.1 Conversion of *Martini* and crop year prices

We convert *Martini* and crop year prices to calendar year prices in two steps: First, we transform original data to prices in grams of silver per litre. Second, we convert the latter to calendar year prices following the principles established in the econometric analysis by Albers and Pfister (2021, SA2).

32 Boerner/Volkart (2011); Gerhard (2002); Pfister (2017), pp. 706 f.

33 Kindleberger (1991); Denzel/Gerhard (2005), pp. 169–176.

34 Witthöft (1993); Verdenhalven (1993).

35 What follows is based on Albers/Pfister (2021), pp. S3 f., S30–S43.

36 Gerhard/Kaufhold (1990) p. 396; see also Elsas (1933), p. 228.

There are two cases: (i) cities for which local information on both calendar year and *Martini* prices during a particular (first) period can be used to convert *Martini* prices for another (second) period to calendar year prices. In this case, the two series in the first period can be used to estimate a local relationship between calendar year and *Martini* prices. This relationship then serves to convert *Martini* prices available in the second period to calendar year prices. (ii) There are cities for which such local information is not available. In this case the extrapolation rules developed for other cities can be applied to convert *Martini* or crop year prices to calendar year averages. For convenience, we reproduce the main elements of the procedures for each type of data in the Supplementary Appendix to this article (SA1.1).

Extrapolations of *Martini* and crop year prices is the only reason why we interpolate a limited number of values for some cities. In this case interpolation serves the purpose of avoiding a loss of data that results from the fact that multiple sequential years are needed to predict a calendar year price from *Martini* or crop year prices (two years of *Martini* prices, three years of crop year prices). Single missing data points in series relating to *Martini* and crop year prices were interpolated with the mean of the two adjacent years before the conversion to calendar years. We never interpolated more than 5 percent missing observations within each of the following sub-periods: (a) 1371–1510, (b) 1511–1650, (c) 1651–1790, and (d) 1791–1850. The sub-periods are chosen based on two major historical events, namely the Thirty Years' War (1618–1648), and the Revolutionary and Napoleonic Wars (1792–1815). These events frame sub-period (c). The other sub-periods follow as backward extensions by 140 years, and forward extension into the 19<sup>th</sup> century.<sup>37</sup> For full transparency, the interpolated years are documented in Table S10 in SA1.2.

#### 4.2.2 Aggregation of monthly and weekly prices

With regard to data sources that provide monthly data, we aggregate calendar year averages based on the following definition: Calculation of a calendar year average price requires at least two prices from different parts of the year: one price covering the sub-period from January to May, and one price covering the sub-period from September to December. The reason for this procedure is the following: assuming locally constant demand within a calendar year, supply determines prices. The supply side in turn is driven by trade and the outcome of the local harvest. Since it is likely that trade has not yet fully offset local harvest surpluses or shortfalls during the period under study, local harvests played a pivotal role in price formation. For a calendar year, there are two harvests that potentially impact on prices, namely, the one of the same calendar year and the one of the previous calendar year.

The above criterion ensures that both harvests, which locally co-determine the supply within a calendar year, are represented in the calendar year average price. This crite-

37 There is no interpolation after 1850, and most interpolations are for years prior to 1800.

tion also provides the rationale for processing sources that do not systematically report monthly data but provide information on two or several market days distributed over the year (e. g., Herdecke). In addition, the criterion circumvents the uncertainty about the historical harvest times in summer, which varies across Germany, and by crop. From a crop production point of view, only the harvest of the previous year can be locally decisive for supply up to and including May of the calendar year, as grain is harvested in Germany from mid-June at the earliest. From September, in turn, the crop of the same calendar year was harvested, and the threshing process followed. Unlike today, threshing was technologically separated from harvesting and extended until the end of winter.<sup>38</sup>

Finally, in a few cases we used weekly data (e. g., extension of series for Mainz into the 19<sup>th</sup> century, several Bavarian cities in 1856–1868). These data were first aggregated to monthly averages. For the latter the above description of aggregation to calendar year averages applies.

#### 4.3 Same stage of marketing

Wherever possible we employ retail prices because we expect them to reflect local market conditions from a consumer's perspective. Where we draw on a mixture between retail and wholesale prices we adjust the latter to the level of retail prices (e. g., Hamburg).

### 5. Organisation of dataset

We start by introducing the structure of the city files; in the second subsection, we explain how to aggregate the information from the individual city files.

#### 5.1 Structure of excel files

During the process of data collection and preparation it turned out that a decentralised organisation by city has several advantages compared to having one excel file with all data. The main advantage is that the size of each excel file remains manageable compared to one centralised file containing all data. Even a single city file can become very complex given the combination of multiple data sources, types of prices, conversion of currencies and volumes, aggregation or conversion to calendar years and interpolation if necessary. Furthermore, the decentralised structure allows future users to add data for new cities without having to understand and handle the details of a large centralised dataset.

38 Troßbach/Kopsidis (2005).

The data come in excel files to ensure full replicability of the data handling process. There is a separate file for each city, and each file consists of three groups of sheets:

- Nominal prices (sheets 11, 12, etc.): Nominal prices transcribed from sources in historical currency and unit. We also use German designations of grain types in these sheets.
- Prices in grams of silver per litre (sheets 21, 22, ..., 29): Where applicable, this group includes sheets with *Martini* prices, crop year prices ('Martini metric', 'crop year metric') and/or monthly prices ('monthly metric'). If we add interpolations, we do this in a separate auxiliary sheet (e.g., '211 crop year metric interpol'). If data from several sources overlap, we aggregate them in a sheet containing all calendar year prices in grams of silver per litre ('all data calendar year metric'). The last sheet in this group contains the final series of calendar year prices in grams of silver per litre and is always designated as '29 calendar year metric'.
- Auxiliary information: This group of sheets starts with '31 Measures', that is, the fixed factors employed to convert historical volumes to litre. '32 Currency' contains and documents the information on the silver content of local currency required to convert prices to grams of silver. For some cities with monthly price data we also include a sheet '33 Currency monthly'. Sheet '34 Notes' documents the sources of the price data, provides brief descriptions of them and explains the procedures followed in constructing the final series in grams of silver per litre. Sheet 35 contains the bibliography. In addition to these excel sheets, the auxiliary information necessary to convert prices to grams of silver per litre is documented for each city in written form in the Supplementary Appendix (SA2).

## 5.2 Information aggregation and data density

To analyse the grain prices of more than one town, a user needs to aggregate the data across several or all city files. There are two ways to achieve this. First, a future user can create her own Excel (or similar spreadsheet software) file in which she imports the final series for each city from sheet '29 calendar year metric'. As a second alternative, we provide a software code for the open-source software R, which uses the R-package 'openxlsx'.<sup>39</sup> After small adjustments, this code allows the user to automatically construct an excel file for each grain type.

Overall, the database contains 259 time series. Rye prices are available for all 70 cities (Table 2, 'Rye', row 1); for wheat information from only four cities is missing. Barley and oats prices are available for fewer cities than for rye and wheat. The number of observations per series varies; in all cases there are short series below 50 observations (row 'Min. obs. per series') and long series with more than 400 observations ('Max. obs. per series'); half of the series for each type of grain have more than 120 observations ('Me-

39 R Core Team (2022); Schaubberger et al. (2023). The software code and an accompanying readme file are available for download with the dataset.

Table 2: Overview on scope of dataset

	Barley	Oats	Rye	Wheat	Total
Number of series	65	58	70	66	259
Min. number of years per series	28	38	49	28	
Median number years per series	129	120.5	156.5	124.5	
Max. number of years per series	417	413	411	406	
Total number of observations	9,725	8,710	12,643	9,938	41,016

Source: Dataset of this study.

dian obs. per series'). Data availability is highest for rye, with a total number of price observations of 12,643 (last row). A closer look at rye reveals that the series with the smallest data coverage is Mannheim (1791–1853) with 49 observations.<sup>40</sup> By contrast, the rye series for Munich covers the years 1452 until 1871 and has 411 observations.<sup>41</sup> On the one hand, these examples demonstrate the scope of the database. On the other hand, they show that simply counting the number of cities in a dataset for such a long period is not very informative: what matters for long-term analysis is data coverage over time.

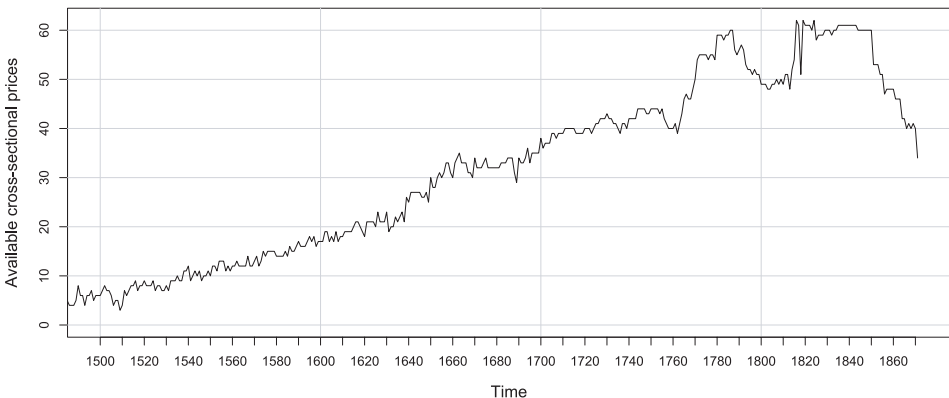


Fig. 3: Data coverage over time, rye prices in individual cities, 1500–1871.

Source: Own representation based on the dataset of this study.

Figure 3 provides an overview of the dataset of rye prices with regard to data coverage across time. For some cities such as Frankfurt a. M., Nuremberg, Munich, Rostock, Strasbourg<sup>42</sup> and Xanten, data reach back to the 15<sup>th</sup>, and partly to the 14<sup>th</sup> century. From about 1550 onward the dataset is based on at least ten cities but sample composition

<sup>40</sup> Note that there are 52 oats prices reported for Mannheim, which qualifies this city for inclusion into the database.

<sup>41</sup> Strasbourg has the maximum number of observations if considered until 1871 but as argued above it is part of 'Germany' only until 1681.

<sup>42</sup> This city is excluded from Figure 3 after 1681.

varies frequently. A clear increase of data quantity is visible after the Thirty Years' War in about 1650 (about 30 cities per year) and from the 1760s onwards (from 40 to 60 cities per year), while the Revolutionary and Napoleonic Wars (1792–1815) are associated with a temporary decrease in data coverage. Between the late 1810s and 1850 data coverage is relatively stable between 50 and 60 cities but then drops below 40 until 1871.

## 6. Current research based on grain prices

Section 6.1 briefly introduces several lines of research that study historical grain prices. Section 6.2 illustrates an analysis of the dataset with a focus on market integration.

### 6.1 Four lines of enquiry employing historical grain prices

The literature dealing with grain prices is large and given space constraints we only provide an overview of the four main lines of inquiry we identify: historical demography, climate change impacts, storage, and market integration. The focus is on studies that analyse developments in the German lands.

The literature on historical demography and famines employs grain price variations over time as an indicator of economic stress and restricted access to food.<sup>43</sup> This strand of research is interested in the response of vital rates such as fertility and mortality to food price variations. In fertility decisions, the real household budget constrains the quantity of children that the household can afford. Surging grain prices at constant nominal incomes depressed household budgets; restricting fertility could be one strategy to prevent further shortfalls in the household's consumption.<sup>44</sup> With regard to famines and mortality, mostly access to food is of concern, which is limited by higher grain prices that are typically used to approximate harvest shortfalls.<sup>45</sup>

Because the production of grain is weather- and climate-sensitive, an emerging literature on climate change in past societies employs grain price data to study how variations of weather and climate impacted on pre-industrial economies, in particular when agricultural output data are not readily available or to cross-check these data. This includes work on the debate surrounding the existence of the Little Ice Age and the role of variation of solar activity and its impact on pre-industrial economies.<sup>46</sup>

Grain is harvested once a year, but humans have to consume food every day to stay in good health. While this database mostly focuses on calendar year average prices, it also contains monthly data, which allows to tackle research questions related to storage. A profit-seeking investor will hold stocks from month to month between harvests if the

43 For example, Alfani/Ó Gráda (2018); Dribe/Scalone (2010); Fertig et al. (2018).

44 Dribe/Scalone (2010), pp. 414–416.

45 Alfani/Ó Gráda (2018), p. 285.

46 Kelly/Ó Gráda (2014), pp. 1377 f.; Albers/Pfister (2021); Ljungqvist et al. (2022).



monthly price increase compensates her for the costs associated with holding stocks. These costs include opportunity costs, depreciation due to losses and storage costs such as renting facilities and maintaining stocks in good order. Consequently, with rational investors and competitive markets, grain prices should rise monotonously between harvests.<sup>47</sup> Earlier research on grain prices in Cologne and Nuremberg has failed to establish such a pattern and has concluded that there was no intertemporal arbitrage on the grain markets of pre-industrial Germany.<sup>48</sup> Recent work, however, presents a more nuanced view based on monthly series from this dataset and the rational competitive storage model.<sup>49</sup> Between harvest and the end of winter, grain prices were driven by arbitrary short-time shocks in supply and demand. This was the period when grain was in the process of being threshed, so only small fractions of the grain harvest were available for marketing. From the end of winter to early summer, wheat prices – but not rye prices – rose monotonously already in the pre-industrial period. Thus, markets for wheat, which was a cash crop, behaved in a way that is consistent with the presence of profit-seeking actors at least during a part of the crop year. This was not the case for rye, which was a subsistence crop.

Whereas studies on grain storage are concerned with arbitrage across time, the market integration literature analyses arbitrage across space. Market integration improves the allocative efficiency of production factors via market access, which is relevant for economic development. Prior to the acceleration of technological progress in the wake of the Industrial Revolution, market integration was a prime mover of economic growth. Given the absence of trade statistics, grain prices are a preferred object of study, because grain is a relatively homogenous good, and sufficient amount of data are available that allow quantitative analyses. Next to these reasons, grain was an important consumption good in pre-industrial times as shown above. Thus, grain price gaps between cities, which serve as a measure of trade costs, are the most important indicator of market integration. Existing research at the European level documents considerable reductions in price gaps during the pre-industrial era that are of similar or greater magnitude than those that took place in the wake of the transport revolution of the 19<sup>th</sup> century.<sup>50</sup> The following subsection provides an overview of this process for the German lands.

## 6.2 Application: market integration in Germany, 1551–1871

This section illustrates the last step in Figure 1 (see Section 1), that is, ‘statistical analyses’. Specifically, we employ the new database to quantify the process of price convergence. One simple way to estimate the degree to which prices equalise in an economy (the ‘law of one price’), is to compute price dispersion by means of the coefficient of variation:

47 Important historical studies on storage and intertemporal arbitrage include McCloskey/Nash (1984); Nielsen (1997); Persson (1996, 1999).

48 Persson (1996), (1999), pp. 65–72; Bauernfeind et al. (2001).

49 Hartermann (2019), ch. 2; Williams/Wright (2005).

50 Chilosi et al. (2013); Federico (2018); Federico et al. (2021).

$$CV_t = \frac{\text{standard deviation}}{\text{mean}} = \frac{\sqrt{\frac{1}{N-1} \sum_{i=1}^N (p_{it} - \bar{p}_t)^2}}{\bar{p}_t}, \quad (1)$$

with city  $i = 1, \dots, N$  and year  $t$ . Figure 4 shows the coefficient of variation for two samples. The first sample is an unbalanced sample that includes the entire dataset of rye from 1550–1871; it serves to show how representative the results of the second sample are. This is the stable sample that includes 10 cities with no more than 10 % missing observations per series to ensure comparability across time (see note to Figure 4 for a list of these cities).

While there are ups and downs, it becomes evident in Figure 4 that price dispersion decreased in the long-run. To illustrate, the CV for the stable sample is on average 0.31 in 1566–1590 but only 0.13 in 1847–1871. That is, price dispersion in the German economy decreased by more than 50 % across these 300 years.

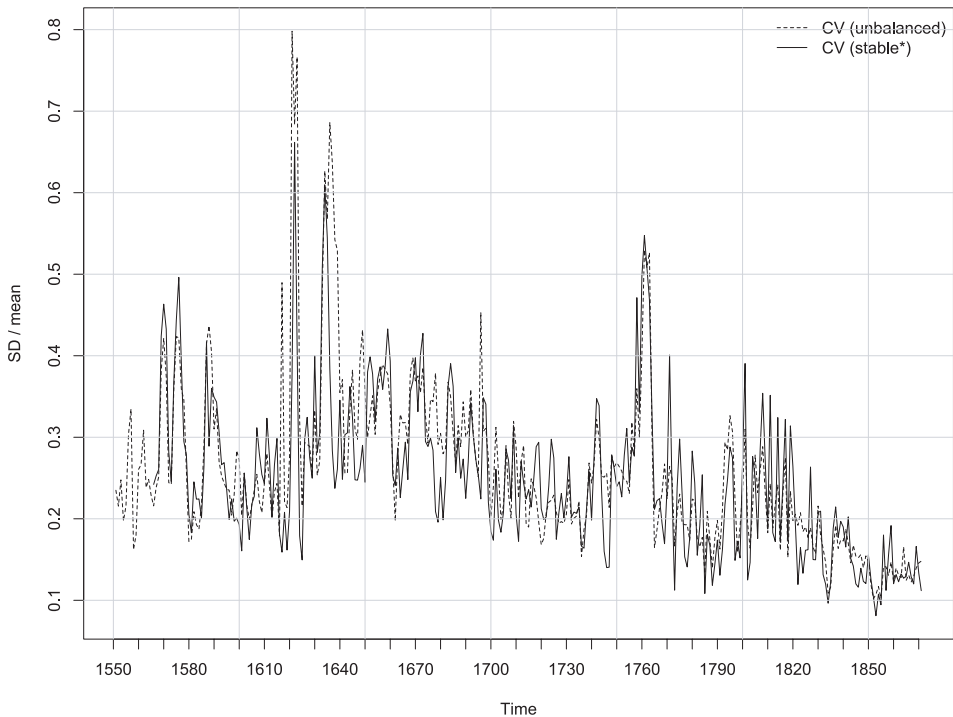


Fig. 4: Inter-urban price dispersion, rye, 1551–1871.

Note: The coefficient of variation for two samples: unbalanced sample of 70 cities (dashed line), and stable sample of 10 cities (solid line). The stable sample includes Augsburg, Braunschweig, Cologne, Gdansk, Hamburg, Hildesheim, Münster, Munich, Nuremberg, Würzburg.

Source: Own representation based on the dataset of this study.

From the 16<sup>th</sup> to the 18<sup>th</sup> century, grain market integration in Germany slowly caught up on the core regions in the southern North Sea that had already reached a high level of

market integration by the 16<sup>th</sup> century, such as England and the Netherlands.<sup>51</sup> This process was temporarily reversed during the Thirty Years' War. For example, the CV for the stable sample in Figure 4 is about 0.25 before the War (1591–1615) but roughly 0.33 after the War (1651–1673).

The downward trend of the CV that started before the War regained momentum thereafter and proceeded at a particularly rapid pace at the end of the seventeenth and the beginning of the 18<sup>th</sup> century. Until the period immediately preceding the outbreak of the Revolutionary Wars, it had reached an average level of 0.2 (1767–1791). The downward trend of the CV during this period was interrupted by an episode of massive price dispersion around 1760. It is not clear to what extent this phase reflects a temporary disintegration of grain markets during the Seven Years' War (1756–1763) and to what extent it results from the impossibility to adequately adjust all series for coin debasement, which was widely used as an expedient for war finance during these years.<sup>52</sup> After the disintegration during the Revolutionary and Napoleonic Wars (1792–1815) the CV remained practically unchanged with a value of 0.19 (1816–1833) but then declined to the aforementioned 0.13. Overall, Figure 4 documents a substantial decline in price dispersion, which indicates that prices equalised much better at the end of the observational period than at the beginning. Nevertheless, this figure raises several questions that it cannot answer: Where do prices converge? What are the factors driving this development? Is the convergence trend robust to alternative measurement methods? We now draw on the answers provided by the recent literature with regard to these three questions.<sup>53</sup>

Based on a variance decomposition, Albers and Pfister reveal that the decline of price dispersion until 1790 was concentrated on north-western Germany – that is, the fringe of the North Sea core – but extended into a wider hinterland along major rivers. These results hold net of weather shocks and the potential effect of climate change on regional differences with respect to grain price levels.<sup>54</sup> Regression models show that next to rivers, population growth was also conducive to the decline of price gap, which is consistent with a pattern of Smithian growth.

The relevance of the profound deepening of grain market integration during the late seventeenth and the early 18<sup>th</sup> century is illustrated by two theoretically related developments: the proliferation of regional export industries (regional specialisation) and the beginnings of sustained growth of real GDP per capita (gains from trade), albeit on a very modest level.<sup>55</sup> The integration of Germany into the orbit of the dynamic economies of the North Sea was pivotal for deepening specialisation between regions producing grain surpluses and proto-industrial regions, which contributed to initiating a first phase of economic development.

51 Chilosi et al. (2013), pp. 58–60; Federico et al. (2021), pp. 292 f.

52 Pfister (2017), p. 707. For analogous reasons, Figure 4 may overstate market disintegration around 1620 and at the beginning of the nineteenth century.

53 Albers/Pfister (2021a; 2023); Keller/Shiue (2014; 2020); Uebele/Gallardo (2015).

54 Albers/Pfister (2021); Federico (2011).

55 Pfister (2022).

The Revolutionary and Napoleonic Wars were another important phase in the history of grain market integration. Keller and Shiue have argued that French-inspired institutional reforms in the German lands as a result of the Wars led to more inclusive markets and hence, market integration in the 19<sup>th</sup> century.<sup>56</sup> A more recent study emphasises two other complementary aspects: Apart from the institutional reforms that Keller and Shiue focus on, the Wars led to sweeping territorial consolidation. Furthermore, polities which had been semi-autonomous estates within the Holy Roman Empire now became sovereign states. This opened the room for trade reforms that replaced poorly structured internal tariffs by unified systems of external tariffs. The removal of domestic tariffs promoted market integration: In Bavaria and Prussia, which accounted for about 60 % of the German population in 1816, the combination of territorial consolidation and trade reform reduced bilateral rye price gaps among city pairs by 31 % relative to the pre-war period and pairs of cities that remained separated by borders.<sup>57</sup>

However, as documented above by means of the CV, grain price gaps changed little between the 1780s and 1820s at the level of Germany as a whole. This suggests that while territorial consolidation and the shift from heterogeneous internal tariffs to unified systems of border tariffs created internal markets at the state level, there were also trade-diverting effects. Consistent with this view, Hanover, for instance, which implemented trade policy reforms comparably late, experienced disintegration.<sup>58</sup> Gaining access to the large Prussian market and avoiding transit tariffs most likely constituted an important motive for southern German states to engage in the formation of a customs union, the *Zollverein*, which became effective in 1834. According to an earlier study of Keller and Shiue, this second round of trade reform brought down grain price gaps by another 28 %.<sup>59</sup> Infrastructure development also contributed to market integration during the second and the third quarter of the 19<sup>th</sup> century, first in the form of the construction of paved roads, second through the development of railway networks.<sup>60</sup>

A potential concern with this history of market integration developed for the German lands might be that the results presented for rye potentially underestimate the degree of price convergence, because rye is a subsistence crop, and not a cash crop like wheat. The latter is also focused by analyses of market integration involving multiple countries.<sup>61</sup> To examine the extent to which the results might differ for wheat, we calculated the CV for a stable sample of the same 11 cities with both rye and wheat prices with less than or equal 10 % missing observations for each series for the period 1631–1871. Until the year 1630, the stable samples are again contextualized with the unbalanced samples with all available data.

Figure 5 shows that the trends in the dispersion of rye and wheat prices are remarkably similar. Note that the stable samples are less representative for Germany as a whole

56 Keller/Shiue (2020).

57 Albers/Pfister (2023).

58 Albers/Pfister (2023), pp. 417, 419.

59 Keller/Shiue (2014); see also Huning/Wolf (2019).

60 Kopsidis (2002); Uebele/Gallardo (2015); Keller/Shiue (2020), pp. 265 f.

61 E.g., Chilosi et al. (2013); Federico et al. (2021); Uebele (2011).

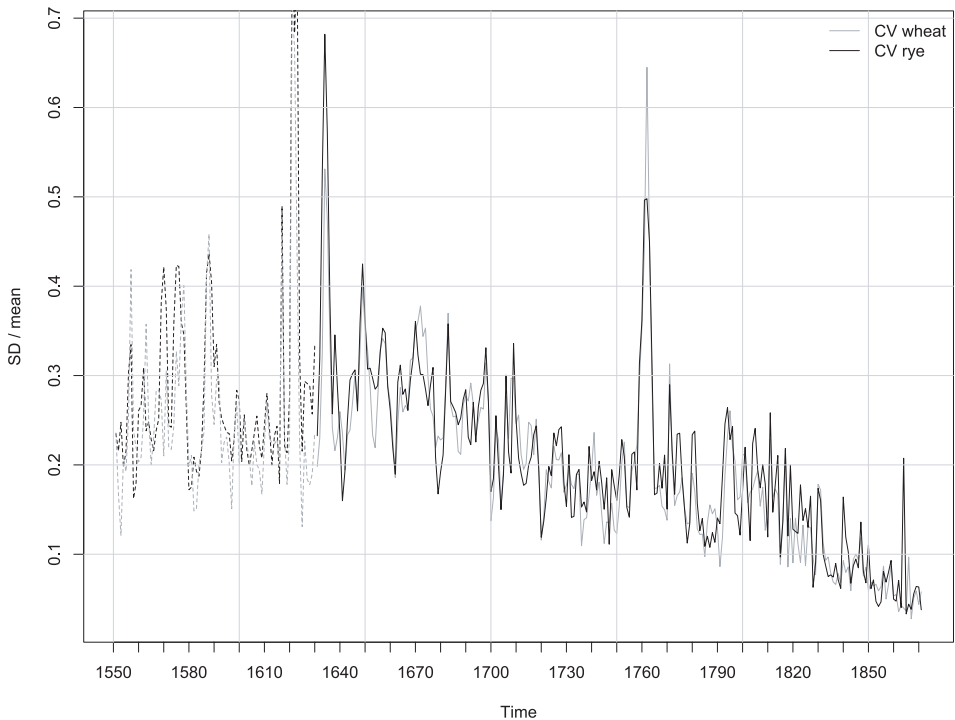


Fig. 5: Inter-urban price dispersion, rye and wheat, 1551–1871.

Note: The coefficient of variation for two grain types, rye and wheat. Dashed lines refer to unbalanced samples, which includes all available data. Solid lines (from 1631 onwards) refer to stable samples, which include the same 11 cities for both grain types: Braunschweig, Cologne, Dresden, Göttingen, Halle, Hanover, Hildesheim, Münster, Nuremberg, Osnabrück, Paderborn.

Source: Own representation based on dataset.

compared to Figure 4, because data coverage of wheat prices is weaker in Southern Germany due to the regional reliance on spelt as discussed above (Section 2.1; for the list of included cities, see note to Figure 5). This explains the lower level of the CV at the end of the sample period in Figure 5 compared to Figure 4.

In short, this large dataset of grain prices allows to track the history of market integration of the German lands from the end of the 16<sup>th</sup> century until the foundation of the nation state. Apart from war periods as such, this account is a history of convergence resulting from a combination of gradual market expansion, political shocks, and the emergence of modern trade policy. The dispersion of prices more than halved between the late 16<sup>th</sup> century and 1871. Before 1800, driving factors were integration along major rivers, and growing market size was also associated with improved arbitrage. After 1800, two factors stand out. The first one relates to territorial unification in combination with trade liberalization within those states that gained size and sovereignty with the dissolution of the Holy Roman Empire in 1806. This was followed by interstate cooperation through the *Zollverein* until national unification in 1871.

## 7. Conclusion

Based on previous research undertaken by various economic historians during the last decades, and our own work, this study publishes the largest homogenous dataset on grain prices for four major types of grain for pre-industrial Germany. Homogenisation of the data is labour-intensive, and requires profound information on the historical background. We develop and document a methodological strategy to transform heterogeneous source information into time series that can be used by economic and social historians. The relevance of this undertaking stems from the fact that given the absence of data on output and trade volumes, grain prices constitute the single most important type of information on the agrarian economy during the pre-industrial era. Hence, they hold the potential to yield relevant insights from various research perspectives. We deepened one such perspective and demonstrated how an analysis of this database helps to integrate several aspects studied in the quantitative market integration literature into one coherent historical narrative.

The dataset is accessible online and designed in a way that allows improvements of data for available cities, and the sequential addition of new cities based on archival research, e. g., as a part of future research projects focused on one specific region or city. Apart from grain prices, this may also include data on the monetary history of Germany for which the provided files are a useful source of local information. In a wider research context, enquiries into topics such as market integration, storage, historical demography or climate change impacts can benefit from this dataset.

### Online appendices/dataset

DOI: 10.15456/vswg.2023264.1254496983

- Data Appendix: 70 Excel files with data of grain prices in individual cities, readme file and R code serving to aggregate the data.
- Supplementary Appendix: Details regarding conversion of data to calendar year averages; documentation of price data.

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