Economic Growth in Germany, 1500–1850

Ulrich Pfister

New data are used to construct a time series of real GDP in Germany for the period 1500–1850 using an indirect output estimation technique that relies on wages, prices, and sectoral employment. Until the mid-seventeenth century, real GDP per capita moved inversely with population. The eighteenth century saw a modest rise in output per head. From the late 1810s, economic growth gradually accelerated. The results shed new light on the reversal of fortunes in early modern Europe and the transition from a Malthusian regime to modern economic growth.

This study constructs a time series of real GDP in Germany for the period 1500–1850 using an indirect output estimation technique that relies on wages, prices, and sectoral employment. It thereby contributes to a growing body of partial national account reconstructions for western European economies during the pre-statistical era.[1] Given its territorial extension and population, Germany was already one of the largest economies in the western part of the European mainland during the early modern period. Hence, a GDP projection back to 1500, however tentative it may be, has the potential to shed light on two major research issues in economic history.

The first issue relates to the nature and the forces underlying the reversal of fortunes in early modern Europe. Whereas central and northern Italy entered into a long phase of economic decline after about 1400, the Northern Netherlands and, after the middle of the seventeenth century, Britain experienced a rise in real GDP per capita, producing an intra-European (little) divergence in real income. Human capital accumulation, patterns of family organization, Atlantic trade, and institutions placing constraints on rulers and securing inclusive markets have been proposed as factors contributing to this reversal of fortunes (Acemoglu, Johnson, and Robinson 2005; de Moor and van Zanden 2010; Broadberry et al. 2015, pp. 374–83; de Pleijt and van Zanden 2016). Recent work on

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[1] Malanima (2011); Schön and Krantz (2012); van Zanden and van Leeuwen (2012); Álvarez-Nogal and Prados de la Escosura (2013); Broadberry et al. (2015); Malinowski and van Zanden (2017); Palma and Reis (2019); Prados de la Escosura, Álvarez-Nogal, and Santiago-Caballero (2020).

the growth experiences of Spain and Portugal has refined our knowledge concerning the timing and the forces underlying early modern divergence (Álvarez-Nogal and Prados de la Escosura 2013; Palma and Reis 2019; Prados de la Escosura, Álvarez-Nogal, and Santiago-Caballero 2020). The present study contributes to this literature by showing that Germany experienced a massive decline in real GDP p. c. during the sixteenth century, which is consistent with a reversal of fortunes from inland regions to economies involved in transcontinental trade at the beginning of the modern era.

The second research field that this investigation addresses relates to the transition from a Malthusian regime to modern economic growth. Earlier studies, among them Abel (1980) and Rostow (1956), have depicted Germany as being characterized by Malthusian stagnation right until the middle of the nineteenth century, when a rapid take-off into sustained economic growth took place. The present investigation contributes to more recent literature, which argues that the development of modern economies had early modern roots (van Zanden 2002; Broadberry et al. 2015, ch. 10). Specifically, I relate the long-term trajectory of the German economy to the stylized sequence of growth regimes advocated by Galor (2005, 2011, chs. 2 and 5; Galor and Weil 2000) based on unified growth theory. From this perspective, the new evidence suggests that Germany's transition from a Malthusian regime to modern growth was a long-drawn-out process starting in the second half of the seventeenth century and coming to an end only in the last two decades of the nineteenth century.

The study starts with a description of the indirect method to construct central aggregates of the output side of the national accounts and continues with a presentation of the data required to apply this method. Brief presentations of the resulting series follow, together with an overview of sensitivity tests. The final section before the conclusion places the results in a wider research context to produce a stylized account of economic growth in Germany during the first three-and-a-half centuries of the modern era.

THE INDIRECT OUTPUT ESTIMATION APPROACH

Reconstructions of the national accounts of England and Holland for the pre-statistical era have focused on a reconstruction of output-side GDP (van Zanden and van Leeuwen 2012; Broadberry et al. 2015). Data sources for preindustrial Germany are insufficient to follow this approach. Instead, I rely on an indirect technique to estimate output-side GDP or aggregate value added based on wages, prices, and sectoral employment. It was originally developed to estimate agricultural output by Crafts (1985, pp. 39–41) and applied to an analysis of growth and labor productivity in preindustrial European agriculture by Allen (2000, pp. 13–14). Subsequent works have extended it to estimate aggregate GDP. The procedure is as follows.

Net agricultural output is given by

$$Q_{At} = r_t \, c_t \, N_t, \tag{1}$$

where Q_{At} is agricultural output, N_t total population, c_t real food consumption per capita, and r_t the ratio of food consumption to food production, all at time t. r_t is thus an indicator of the balance of external trade in agricultural products.

Real food consumption per capita is estimated using a demand equation:

$$c_t = a \, P_{Ft}^{\ e} \, I_t^g \, P_{NFt}^{\ b}, \qquad \text{s. t.} \quad e + g + b = 0, \tag{2}$$

where a is a scaling factor, P_{Ft} the real price of foodstuffs, I_t real income per head, and P_{NFt} the real price of consumer goods apart from food, all in year t. e, g, and b are the own price, income, and cross-price elasticities of food demand. Substituting Equation (2) into Equation (1) yields

$$Q_{At} = ar_t \, N_t \, P_{Ft}^{\ e} \, I_t^g \, P_{NFt}^{\ b}. \tag{3}$$

To estimate agricultural output (Q_{At}), I use data on population (N), income (I), prices of food (P_F), and non-agricultural products (P_{NF}) and will make assumptions about the elasticities (e, g, b) and the ratio of food consumption to food production r. The scaling factor a is chosen so as to fix the level of Q_{At} to value added in agriculture in the year when direct estimates for agriculture production begin.

With agricultural output and population known, a simple measure for average labor productivity in agriculture, *ALPA* is

$$ALPA = Q_{At}/L_{At}, \tag{4}$$

with L_A denoting employment in agriculture.

To calculate an index of real GDP, the majority of the literature divides food consumption per capita by the share of agriculture in total employment ($Q_{At}/[L_{At}/L_t]$); examples include Malanima (2011, p. 185) and Palma and Reis (2019, p. 496). This procedure assumes that labor productivity in the agricultural and non-agricultural sectors is identical. The strong shifts in relative prices that will be documented in the next section suggest that this assumption is too restrictive. Therefore, I follow Álvarez-Nogal and Prados de la Escosura (2013, pp. 13, 16; see also Prados de la Escosura, Álvarez-Nogal, and Santiago-Caballero 2020, p. 14) and proxy value added of industry and services with non-agricultural employment L_{NAt}.

Agricultural output Q_{At}, non-agricultural employment L_{NAt}, and sectoral prices—agricultural prices P_{At} and a price index for industry and services P_{It}[2]—serve to compute a Fisher ideal index of real output-side GDP at factor cost. This methodological choice follows Diewert (1992) and the System of National Accounts (European Commission et al. 2009, ch. 15). In a preliminary step, not only agricultural output, but also the volume index of non-agricultural output proxied by non-agricultural employment is calibrated so that current price values added ($P_{At}Q_{At}$ and $P_{It}L_{NAt}$, respectively) in the year when direct estimates become available equal observed values. I use the averages from 1856–1860 for calibration.

The Fisher quantity index (QI_F) is the geometric average of the Laspeyres (QI_L) and the Paasche indices (QI_P):

$$QI_{Lt,t+1} = \frac{P_{At}Q_{At+1} + P_{It}L_{NAt+1}}{P_{At}Q_{At} + P_{It}L_{NAt}} \tag{5}$$

$$QI_{Pt,t+1} = \frac{P_{At+1}Q_{At+1} + P_{It+1}L_{NAt+1}}{P_{At+1}Q_{At} + P_{It+1}L_{NAt}} \tag{6}$$

$$QI_{Ft,t+1} = (QI_{Lt,t+1}QI_{Pt,t+1})^{1/2} \tag{7}$$

$QI_{Ft,t+1}$ is the rate of change of aggregate output from year t to $t + 1$. Multiplying values for consecutive years yields a chain index that can be normalized to any year.

The prior literature suggests that the indirect approach to estimating output-side GDP yields valid results under some conditions. The application to England by Nuvolari and Ricci (2013) suggests lower rates of real GDP growth in the long run than found by Broadberry et al. (2015). The use of day wages to proxy income appears to be the main reason why the indirect method underestimates economic growth relative to a direct output estimate, as the number of days worked increased over the early modern period (Broadberry et al. 2015, pp. 257–65).

[2] Whereas P_F and P_{NFt} in Equation (2) refer to real prices, P_{At} and P_{It} are price indices; $P_{Ft} = P_{At}/CPI_t$. P_{It} differs from P_{NFt} with respect to coverage in that it does not include prices for energy. See the section on prices and Online Appendices A1.2 and A1.6.

For Spain, Prados de la Escosura, Álvarez-Nogal, and Santiago-Caballero (2020, pp. 10–13) compare the estimate of agricultural output using the demand approach with an aggregate index of tithe returns for major agricultural products. The two series move broadly in parallel, which suggests that they present the long-term trajectory of agricultural output in the correct way. For Germany, Pfister and Kopsidis (2015, p. 284 and Online Appendix) combine the indirect approach with contemporary harvest statistics for 1792–1812 and 1815–1830 to study agricultural output in Saxony, the most important early industrial region of Germany. The fit between estimated and observed food production is poor during the first sub-period, when war-related events disrupted markets, so that prices (and possibly wages) did not reflect conditions of supply and demand. By contrast, the fit is satisfactory for the post-war period, but by no means perfect. Results also show that the indirect approach is best capable to track output in basic food crops, that is, rye, wheat, and potatoes, excluding barley and oats.

The bottom line of these cross-checks is that the indirect approach produces valid results on economic growth in the mid-term, albeit with a considerable margin of error. In the short run, estimates strongly depend on fluctuations in prices of basic food grains, which introduces spurious volatility already in the estimate of agricultural output. Thus, preference should be given to smoothed values or trend growth rates.

SOURCES, ASSUMPTIONS, AND DATA DEFINITIONS

This section describes the sources, key assumptions and the data definitions underlying the variables and parameters required to implement the indirect output estimation approach. All relevant data series can be found in Online Appendix 3.

The primary geographical unity of study is the overlap between the Holy Roman Empire in the borders of 1792 and the territory of the nation state formed in 1871 (see Figure 1; Fertig et al. 2018, pp. 8–9; Pfister and Fertig 2020, p. 1151). Relative to the borders of the present-day Federal Republic of Germany, this aggregate of "historical Germany" additionally includes Eastern Pomerania, Silesia, and the small territory of the German-speaking Community of Belgium. By contrast, South Schleswig is excluded. Choice of this geographical frame of reference is mainly guided by data availability: The territory thus defined is covered by early statistical compilations reaching back into the eighteenth century and by a German-language historiography on preindustrial population and urban development.

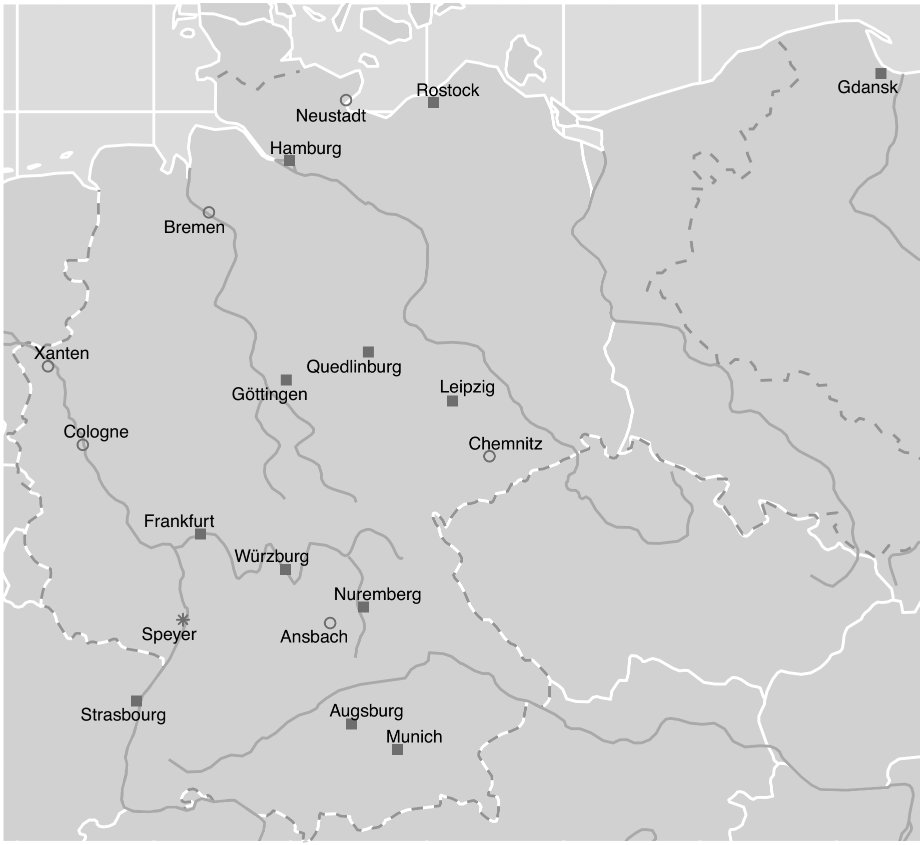

FIGURE 1
MAP OF AREA STUDIED

Note: White lines: present-day territorial borders; broken grey line: overlap of Holy Roman Empire in 1792 and the nation state of 1871; squares: consumer price index and wage data; circles: wage data only; asterisk: additional price data.
Source: This study.

For prices and wages, which mostly relate to individual towns, I also draw on information for Strasbourg (until 1681 only) and Gdansk, which are both located outside the area defined as historical Germany but for which sources are particularly rich. Gdansk was a member of the Hanseatic League until the seventeenth century, but became an autonomous community within the kingdom of Poland from the middle of the fifteenth century. In 1793, it was integrated into the Prussian state that had acquired the town's hinterland in successive steps from the early sixteenth century. Strasbourg was an independent city within the Holy Roman Empire until it was taken over by the French king in 1681.

One may duly ask whether historical Germany, as defined previously, constitutes a meaningful unit of analysis given poor market integration in

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most inland areas before the railway age. In particular, it has been argued that bullion and money markets in the Holy Roman Empire were highly fragmented (Gerhard and Engel 2006, pp. 43–44). This point is relevant because the wage and price series relate to values in grams of silver as the common denominator to aggregate local information into national series. With non-integrated bullion and money markets, this procedure would be invalid. Reassuringly, however, gold-silver price ratios in Cologne and Vienna were cointegrated from 1480 to 1790, suggesting some degree of bullion market integration (Pfister 2017, pp. 706–7). The existence of currency unions and, from 1566, of a common currency regime support this conclusion (Boerner and Volckart 2011; Cunz 2002, pp. 197–290).

Moreover, cities in the spatial aggregate under study shared both a common trajectory of product prices over time and highly symmetric shocks (Pfister 2017, p. 710). Finally, capital markets in what is termed here as historical Germany plus the Southern and Northern Netherlands were better integrated than those in more developed central and northern Italy (Chilosi, Schulze, and Volckart 2018). In sum, the territory studied here shared a common experience in a sufficient number of economically relevant aspects to make it a meaningful object of analysis.

Foreign Trade in Foodstuffs

I set r, the ratio of agricultural production to food consumption in Equation (1), to 1. At their probable historical maximum in the 1850s and early 1860s, German grain exports amounted to about 3 percent of domestic consumption (Grant 2005, p. 220; Pfister 2015, pp. 208–13). Thus, fluctuations in r have a negligible impact on the estimate of agricultural output.

Total Population

Figure 2 shows the evolution of population size. For the nineteenth century, information rests on a reconstruction based on official statistics (Fertig et al. 2018). The series for 1730–1815 combines censuses from individual German territories with published parish registers relating to some 140 parishes (Pfister and Fertig 2010, pp. 9–10, 13–30). In 1690–1730, evidence is largely confined to parish registers, and the consistency of the estimates of population and vital events is less clear. This is why the values for this period are shown as a broken line. The point estimates for 1500–1650 are from Christian Pfister (1996, pp. 38–43), adjusted for the

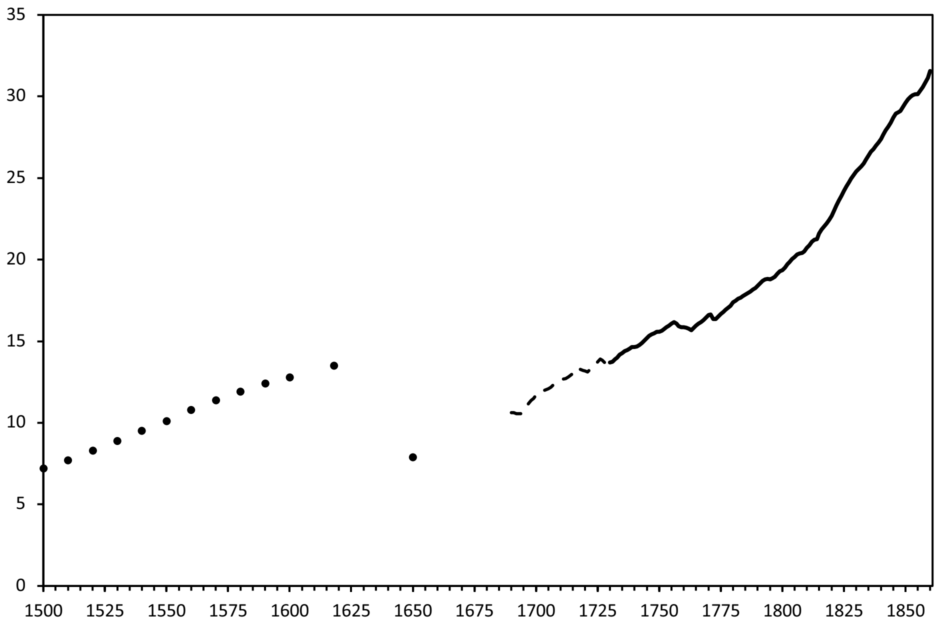

FIGURE 2
POPULATION (MILLION)

Sources: 1500–1650 Pfister and Fertig (2010, p. 5); 1690–1870 Pfister and Fertig (2020, Online Appendix B).

territory as shown in Figure 1 (Pfister and Fertig 2010, p. 5). To arrive at an annual series, I fill in gaps before 1690 with exponential interpolation.

The resulting series indicates the following demographic development: Population grew by about 0.4–0.5 percent annually both in the sixteenth and the eighteenth centuries. By contrast, the period of the Thirty Years' War (1618–1648) saw a massive demographic downturn by some 40 percent. War-related mobility facilitated the spread of epidemic diseases, particularly plague, and disrupted agricultural production. Food crises were further aggravated by requisitions and looting of troops. Finally, after the turn of the nineteenth century, population growth accelerated to an annual rate of 0.8 percent.

Sectoral Employment

L_{NAt}, the index of employment outside agriculture, is approximated by the urbanization rate (U_t/N_t) and the share of the non-agricultural population in the rural population ($sNAR_t$):

$$L_{NAt} = [U_t/N_t + sNAR_t\,(1 - U_t/N_t)]\,N_t \tag{8}$$

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TABLE 1
NON-AGRICULTURAL RURAL POPULATION IN SAXONY AND GERMANY
(PERCENT OF WORK-FORCE)

	(1) Saxony Rural Craftsmen	(2) Saxony Proto-Industry	(3) Germany Rural Craftsmen (1) times 0.9	(4) Germany Proto-Industry (2) times 0.33	(5) Germany Total Non-Agric. (3) + (4)
1780	19	18	17.1	5.9	23.0
1810	24	20	21.6	6.6	28.2

Sources: Columns (1) and (2): Weiss (1993, pp. 104, 108); Columns (3) to (5): this study.

The procedure assumes a constant labor force participation rate. Figure 3 shows the urbanization rate and the estimated share of the non-agricultural labor force in total employment, that is, L_{NAt}/L_t.

Data for urban population come from a compilation covering communities with more than 5,000 inhabitants located in the territory as defined in Figure 1. Values between census years were calculated with exponential interpolation, and the trajectory of the population of the towns with information for both the early and the middle of the seventeenth century served to extrapolate figures for towns for which information is sparse before 1700 (Pfister 2020b).

The modest fall in the urbanization rate from 1500 to 1560 indicates that Figure 2 may overstate population growth during this period. However, the urbanization rate is usually considered to vary with income per capita, and the real wage also declined during this period (see Figure 6), which renders a concomitant decrease in the urbanization rate plausible. In sum, Figure 3 suggests that after an initial decline, the urbanization rate stagnated at a level slightly below 10 percent during the early modern period. Sustained urbanization set in only after the turn of the nineteenth century.

The series for the share of the non-agricultural population in the rural population (*sNAR*) relies on point estimates for 1780 and 1810 and assumes a constant value for 1500–1650. The estimates for 1780 and 1810 rest on Weiss's (1993) figures for Saxony, which are calibrated to the national level (Table 1). To clarify the following discussion, "Rural craftsmen" designate handicraft activities serving a local clientele, such as construction workers, shoemakers, bakers, and so on; "proto-industry" refers to regional export industries, which consisted mainly of linen, worsted, and cotton manufacture.

Weiss also gives the number of rural craftsmen per thousand inhabitants; for 1780, the figure was 38. This value can be compared with information for other German territories. Schultz (1981, pp. 36–37) provides figures for 18 regions that are part of Germany as defined in Figure 1;

the mean year is 1790. The average craftsmen-population ratio was 32.4 per thousand, that is, 15 percent inferior to the value for Saxony in 1780. For Germany as a whole, Kaufhold (1978, pp. 37–39) places the ratio of master artisans to the total population at 36.4 per thousand around 1800. Because Saxony's countryside was arguably the most commercially developed region in Germany in the late eighteenth and early nineteenth centuries, it is plausible that rural craftsmen were more numerous there than elsewhere. Thus, I deflate the share of craftsmen in the labor force in Saxony by 10 percent to estimate the corresponding figure for Germany as a whole.

The development of export-oriented regional proto-industries added a significant segment to the occupational structure of many rural areas in the course of the early modern era (Kaufhold 1986; Ogilvie 1996). By the early nineteenth century, rural export industries existed, notably in Saxony, Silesia, parts of the Rhineland and Westphalia, the Upper Palatinate, Eastern Swabia, and Württemberg (Kaufhold 1986). In c. 1815/16, all these regions made up between one-third to two-fifths of the German population (Pfister 1994, pp. 19–23). Consequently, I estimate the national mean for the non-agricultural population apart from crafts to be 33 percent of the share recorded for Saxony (Column (4) in Table 1). The sum of the share of rural craftsmen and of proto-industrial workers yields a tentative estimate of the share of non-agricultural employment in the countryside for 1790 and 1810 (Column (5) in Table 1).

Weiss (1993) also provides estimates of non-agricultural employment in rural Saxony at 30 to 40 year intervals back until 1565. However, before 1660 they are in the range of 5 to 13 percent, which is implausibly low. Allen (2000, pp. 6–8) assumption that about 20 percent of the rural labor force in England and France was employed outside agriculture around 1500 is probably too high for Germany. Schultz (1981, pp. 36–37) reports ratios of rural craftsmen to population below 30 per thousand for several regions as late as the end of the eighteenth century. If multiplied by a household size of 5, such values are consistent with a share of rural crafts in the labor force of some 15 percent at best. Therefore, I set the value for *sNAR* at 1500 to 15 percent and left it constant at that level until 1650.

To obtain an annual index of L_{NAt} from 1500 to 1810 using Equation (8), I interpolate values between key years in the population series, the urbanization rate, and Column (5) of Table 1 using exponential interpolation. The same method serves to interpolate values between 1810 and 1849, when census information becomes available (Hoffmann 1965, pp. 204–6). The result is shown in Figure 3 (grey graph: L_{NAt}/L_t).

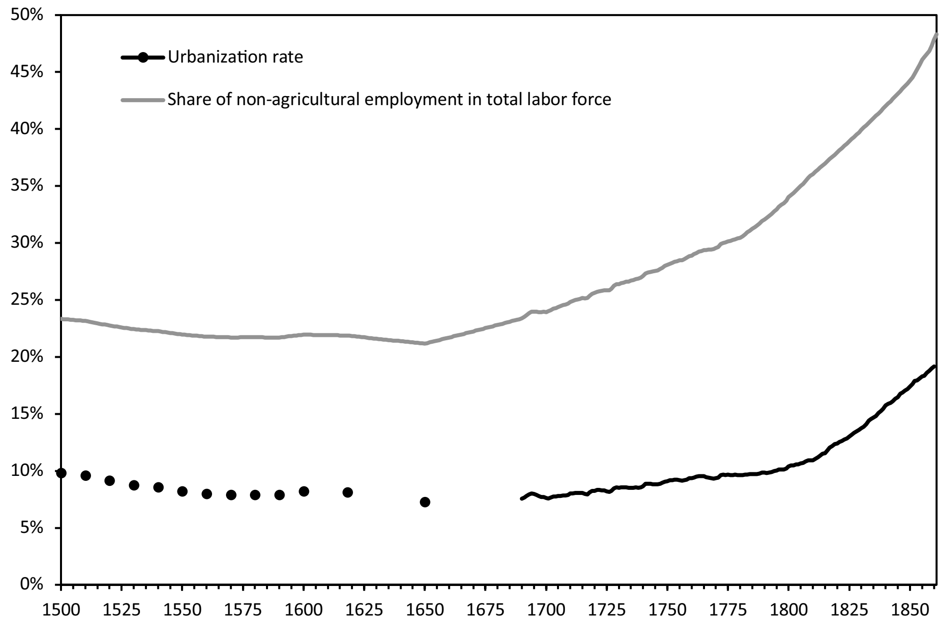

FIGURE 3
URBANIZATION RATE AND SHARE OF NON-AGRICULTURAL EMPLOYMENT (PERCENT)

Sources: Urbanization rate: Pfister (2020b, pp. 15, 27–29); share of non-agricultural employment: this study.

For the sixteenth century, the series quantifies the idea that the development of new textile districts did not compensate for the relative stagnation of the large linen and fustian complex of Swabia and the massive decline of copper and silver refining in central Europe (Kiessling 1998, pp. 49–54; Westermann 1986, pp. 196–201). The disruption of markets during the Thirty Years' War most likely caused a continuation of this trend. The steady increase of the share of employment outside agriculture after the mid-seventeenth century mirrors two stylized facts stressed by the existing literature. On the one hand, regional export industries, or proto-industries, experienced a sustained expansion. The annual rate of increase of non-agricultural employment in 1700–1791—0.8 percent—is at the same order of magnitude as the one of fragmentary series of regional textile production during varying subperiods of the eighteenth century: linen, mostly from Silesia (0.8 percent), worsted from Württemberg (0.7–0.8 percent), and cotton manufacture (1.0 percent; Kaufhold 1986, pp. 173, 186; Pfister 2015, pp. 202–8). On the other hand, regardless of whether a region engaged in the production of manufactures for export or not, crafts serving a local clientele comprised a growing fraction of

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the rural work force (Schremmer 1972). In 1800, the estimated employment share of the non-agricultural sectors is 34 percent. This value tends towards the lower end of earlier estimates given by Henning (1971, p. 115; 38 percent), Kaufhold (1983, pp. 24, 31; 33 percent), and Dipper (1991, p. 98; 37.5 percent).

Elasticities of Food Demand

The elasticities in demand Equation (2) are taken from the literature. Allen (2000) uses the values of $e = -0.6$, $g = 0.5$, and $b = 0.1$. Álvarez-Nogal and Prados de la Escosura (2013, p. 6) use the values $e = -0.4$, $g = 0.3$, and $b = 0.1$. Tentative estimates of the income elasticity of food demand in Germany during the decades prior to WWI, both at the aggregate and household levels, suggest values of $g = 0.6$ and higher (Hoffmann 1965, p. 118; Fischer 2011, p. 180). On the background of this evidence, I opt for Allen's values.

Prices and the Consumer Price Index (CPI)

The analysis of prices follows the methodology defined by Allen (2001). Thus, the CPI is the annual cost of a basket with fixed quantities of 11 goods—six foodstuffs and five non-food items—in grams of silver. Data refer to the 12 towns shown in Figure 1 and are aggregated to a national CPI (Pfister 2017, pp. 703–09, Supporting Information S2, pp. 1–11).

In the framework of the Allen methodology, the real price of food P_F (Equation (2)) is simply the share of foodstuffs in the total cost of the consumer basket, which forms the CPI, and the real price of non-foods P_{NF} equals $1 - P_F$. Figure 4 shows the trajectory of the share of food in the CPI. Values fluctuate within a narrow band of 0.75 to 0.85. The cost of food rose relative to the cost of the whole consumer basket from 1500 to about 1625 and increased again in the last quarter of the seventeenth century. From the beginning of the eighteenth century, the share of food in the CPI fell, interrupted by spikes connected with well-known subsistence crises, notably those in 1771/72, 1817, and 1846/47.

Since foodstuffs are land-intensive products and non-foods include manufactures, whose production is labor-intensive, the long-term comovement of the share of food in the CPI with population (Figure 2) during the sixteenth and seventeenth centuries reflects the relationship between factor proportions and the relative price of products with a differing composition of factor inputs. However, after about 1700,

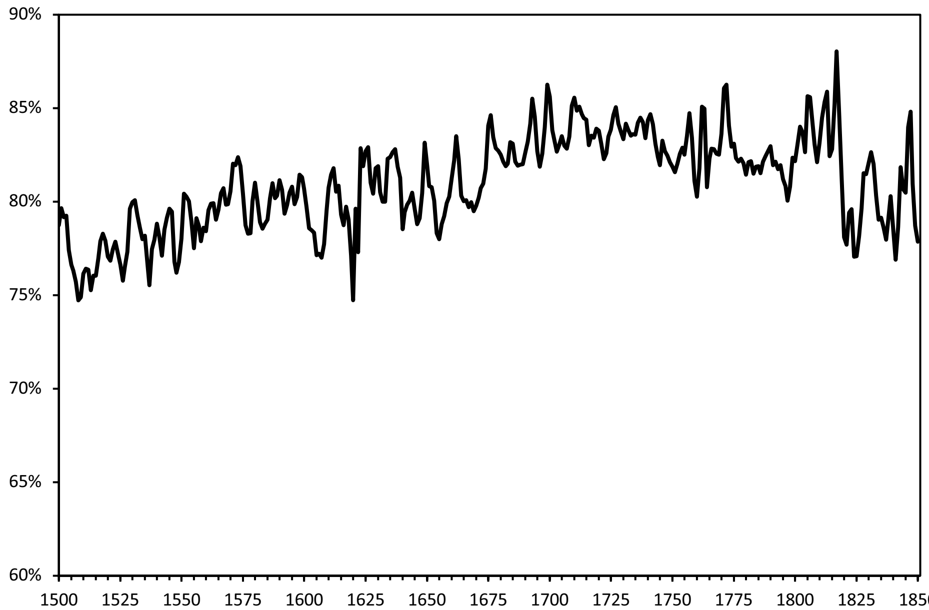

FIGURE 4
SHARE OF FOOD IN TOTAL COST OF CONSUMER BASKET (PERCENT)

Sources: Own computation based on price data underlying consumer price indices of 12 towns as shown in Figure 1; on the method of aggregation, see Online Appendices A1.1 and A1.2.

this relationship broke down; the share of food in the CPI fell despite continued demographic expansion. Closer inspection of the non-food category reveals contrasting trajectories of the prices of textiles and energy (firewood and charcoal), which can be attributed to their differing input structures. Figure 5 shows the price of these two goods relative to the price of rye. The relative price of textiles fell from the fifteenth to the eighteenth century, that is, for several centuries before the industrial revolution mechanized textile manufacture. Textiles are a labor-intensive product, whereas rye is a land-intensive good. Thus, the decline in the price of textiles relative to rye reflects the change of factor proportions, that is, the decline of the land-labor ratio, as a consequence of secular population growth. The demographic depression in the wake of the Thirty Years' War brought only a temporary reversal of this trend. The small magnitude of the effect of the demographic depression of the seventeenth century can be attributed to the fact that the price of textiles relative to rye was not only driven by factor proportions but also by differential productivity growth, perhaps mainly as a result of an improvement in business techniques in the non-agricultural sectors. Whereas one meter of linen twill cost the equivalent of 1.9 working days of an unskilled urban

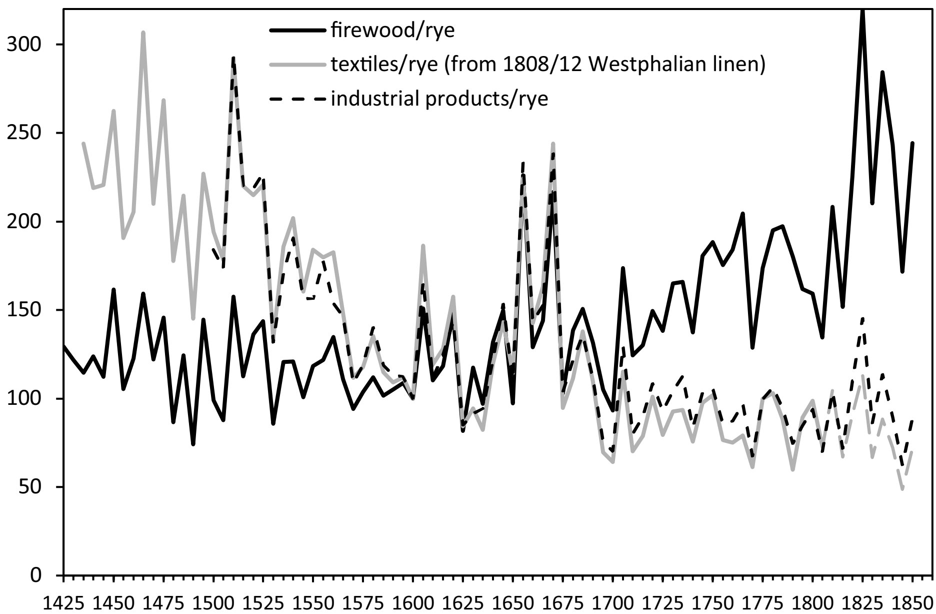

FIGURE 5
PRICES OF ENERGY, TEXTILES, AND INDUSTRIAL PRODUCTS RELATIVE TO RYE
(INDICES, 1600=100; FIVE-YEAR CENTERED AVARAGES)

Sources: This study, see Online Appendices A1.3–6.

laborer in 1603/07, the price had shrunk to the equivalent of 0.6 days in 1708/12 (wage as in Figure 6). Note that the relative price of industrial products (Online Appendix A1.6) follows almost the same trajectory as that of textiles. Similar trends have been found for other European countries (Álvarez-Nogal and Prados de la Escosura 2013, p. 15; Broadberry et al. 2015, p. 193).

Forestry is similar in land intensity to agriculture, so we should not expect the relative price of energy to rye to fluctuate in parallel with population. In conformity with this expectation, the energy to rye price ratio was trendless from the fifteenth to the seventeenth centuries. After 1700, however, the relative price of energy embarked on a rising trend, which is consistent with the expansion of non-agricultural employment from around this time (Figure 3); because metal manufacture and processing constituted an important segment of Germany's industry already around this time, (proto-)industrial growth increased the energy intensity of the economy. The energy to rye price ratio experienced a peak during the agrarian price depression of the 1820s and fell thereafter, possibly as a response to the beginning substitution of biomass with coal.

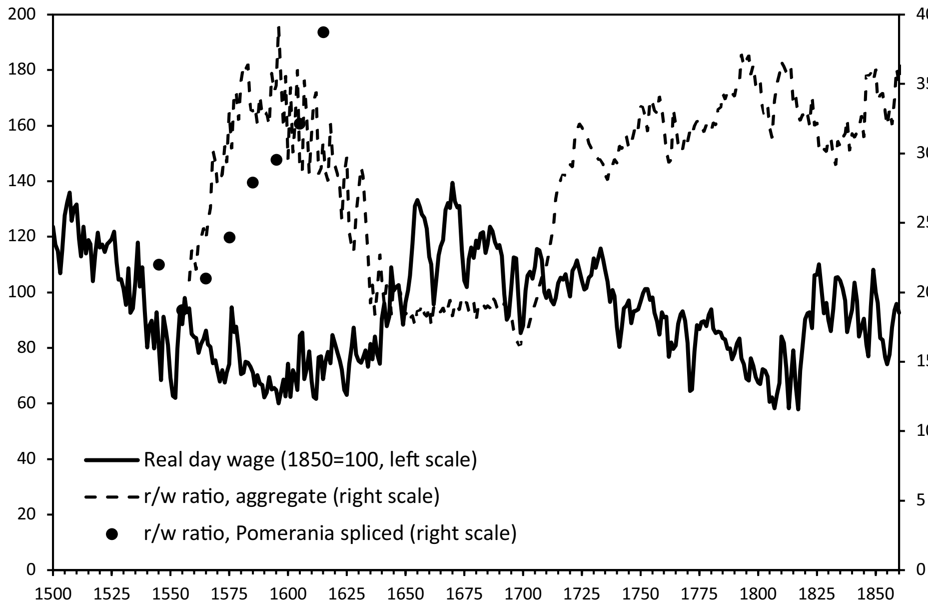

FIGURE 6
REAL WAGE INDEX (1850=100) AND RENT-WAGE RATIO (DAYS PER HECTARE)

Sources: Real day wage of unskilled urban building laborers in 17 towns 1500–1850 from Pfister (2017) spliced with real wage in industry and urban crafts in 1850 (Pfister 2018). Aggregate rent-wage ratio from Bracht and Pfister (2020, p. 277) divides leasehold rent per hectare in Westphalia by nominal day wage of unskilled urban building laborers, and wages in industry and urban crafts (from 1850). Information on the rent-wage ratio in Pomerania, which refers to ten-year averages, is spliced to the aggregate series in the 1590s (Bracht and Pfister 2020, p. 249).

Income: Day Wages and Land Rent

The real day wage of unskilled male urban building laborers shown in Figure 6 is a first potential proxy for income (*I* in Equation (2)). Comparison with Figure 2 suggests that until about 1800, real wages fell when the population expanded and rose when the population contracted. This reflects the negative association between population and material welfare in pre-industrial economies (Clark 2007, p. 20). After 1800, this relationship ended since the acceleration of population growth went together with real wage stability at a level that was significantly higher than in the late eighteenth century.

For three main reasons, the real day wage of male construction workers in towns may not accurately reflect household income. First, they may not be representative of the wage income of the whole population. This possibility can be explored using evidence relating to three wage gaps: the rural-urban gap, the gender gap, and the skill premium (Pfister 2019).

Wages of agricultural workers and unskilled urban building laborers were apparently close to par in many regions and their ratio remained broadly stable or declined very slowly (at an annual rate of –0.1 percent at most) between 1500 and the onset of rapid industrialization in the 1840s (for Strasbourg until 1700 see also Geloso (2018, p. 519): *journalier* annual/ *ouvrier* summer). Within agriculture, the gender gap widened between the second quarter of the sixteenth to the early seventeenth centuries, but this phenomenon may have been limited to the vicinity of towns, where guilds progressively excluded women from skilled occupations. From the middle of the seventeenth to the early nineteenth centuries, the gender gap seems to have remained stable. The widening of the gender gap in the century preceding the Thirty Years' War was paralleled by an increase in the skill premium, that is, the ratio of the wage of master artisans and journeymen to the wage of unskilled laborers in urban construction. However, this trend came to a halt around 1600, and by the 1630s, the skill premium had fallen back to the level prevailing in the second quarter of the sixteenth century, at which it stayed until the second half of the nineteenth century. At the bottom line, since likely trends move in opposite directions, there is no reason to conclude that the wage of unskilled urban building laborers grossly misrepresents the evolution of labor incomes of German households.

Second, the real day wage may not adequately capture annual income because the number of days worked per year may have changed. Given the current state of research, we do not know the duration of the working year before the late nineteenth century. Therefore, a sensitivity test will explore the effect of a potential increase in the work effort per employee on the results (Table 4).

Third, income from factors of production other than labor may have followed a different path than real wages. This holds in particular for the land rent. Figure 6 includes the rent-wage ratio, where land rent refers to the lease price per hectare in grams of silver on five estates in Westphalia back to 1558. In 1540–1558, data refer to Pomerania, spliced with the Westphalia series using the average in 1560–1569. With a given area of arable land, population growth leads to factor substitution: Land is cultivated more intensively, so that the real land rent increases, whereas the decline in the land-labor ratio leads to a reduction in the real wage. Consequently, the rate of technical substitution (the number of days one needs to work in order to substitute one hectare of land and maintain output constant; right scale in Figure 6) rises, implying that the real wage and the rent-wage ratio moved in the opposite direction, and the real land rent compensated partly for fluctuations in the real wage. Figure 6 is fully consistent with this line of reasoning as far as the pre-1800 period is concerned. At the same time, however, with largely constant land resources population growth diminishes the average share of the individual household in the aggregate land rent. With diminishing returns, the effect of population growth to dilute the endowment of labor with fixed resources surpassed the intensification effect (see the discussion of Table 2).

Against this background, I construct an index of aggregate real income as follows. Land rent is the series underlying the rent-wage ratio in Figure 6. Because land endowment per unit of labor changed over time, I adjust nominal rent with the ratio of the proportion of arable in total surface to population. Bork et al. (1998, p. 161) provide point estimates of the proportion of arable in total surface for the 1520s (0.38), c. 1610 (0.41), the 1650s (0.32), 1780s (0.39), and 1870s (0.40). These figures probably underestimate the expansion of the arable during the modern era (Bracht and Pfister 2020, pp. 264–65); later in the study, I shall explore the sensitivity of the results with respect to this likely error. I compute values for the intervening years using exponential interpolation. Adjusted nominal land rent and day wage indices, each normalized to 1850, are weighted according to the factor shares prevailing in 1851–1859, which imply weights of 0.2 and 0.8, respectively (Pfister 2020a, Online Appendix 2). Aggregate nominal income is deflated with the CPI (Pfister 2017, Supporting Information S3). Before 1540, estimated income rests solely on the real day wage of unskilled urban laborers.

OUTPUT AND LABOR PRODUCTIVITY IN AGRICULTURE

Figure 7 plugs the data described earlier into Equations (2) to (4) to derive estimates of food consumption per capita and average labor productivity in agriculture. Because relative prices between foodstuffs and non-food products changed little (Figure 4), estimated food consumption is mostly driven by income, particularly the real wage (Figure 6).

According to the baseline specification, food consumption per head tended to decrease over the early modern era, albeit not evenly. This finding is consistent with the literature on physical stature, which suggests that the biological standard of living tended to decline in mainland Europe between the early Middle Ages and the nineteenth century (Koepke and Baten 2005, pp. 75–76; Meinzer, Steckel, and Baten 2019, pp. 235–36).

More specifically, Figure 7 suggests four phases.

The first phase relates to the period c. 1500–1650 and is characterized by a long swing. From the 1510s to the early 1570s estimated food

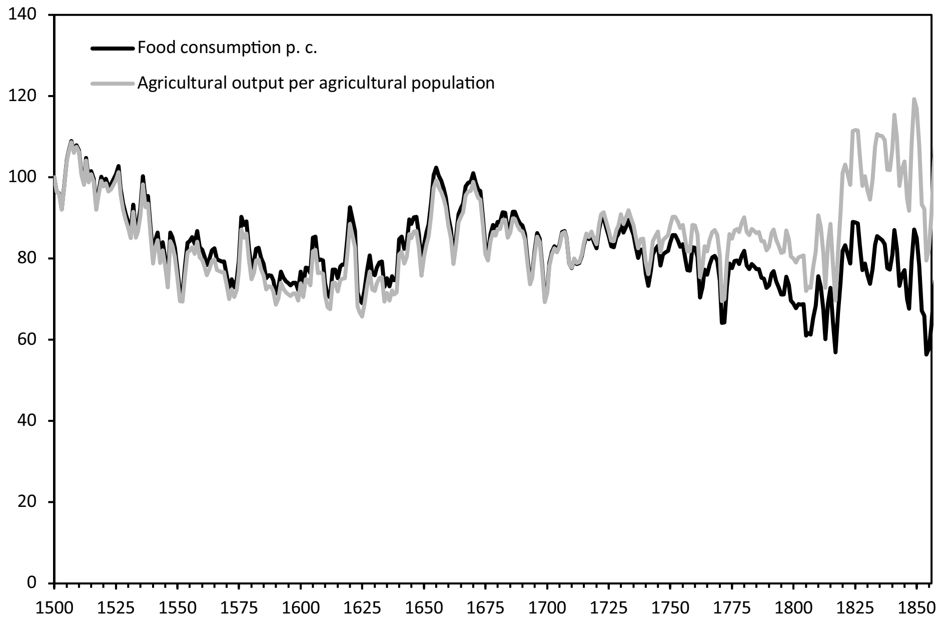

FIGURE 7
FOOD CONSUMPTION PER CAPITA AND AVERAGE LABOR PRODUCTIVITY IN AGRICULTURE, 1500–1855 (1500=100)

Sources: Own computation based on data described in the text; series in Online Appendix 3.

consumption per head fell dramatically by about 30 percent, followed by a slower decline until the 1620s and a marked recovery in the 1640s and 1650s. This long swing in food availability inversely parallels the long cycle of demographic expansion during the sixteenth century and contraction during the Thirty Years' War, which replicates the negative relationship between material welfare and population found for the real wage noted previously.

During a second period, which extends from the late 1640s to the mid-1730s, food consumption per capita remained at a roughly constant level. Until the end of the seventeenth century, however, there was considerable volatility. The high frequency of strong negative shocks can be related to the Maunder Minimum (c. 1645–1715), a period characterized by reduced solar irradiance that led to a series of severe winters and cold springs (Albers and Pfister 2021, p. 472 and Appendix SA5.2). Stability during the initial phase of renewed population growth, particularly after the turn of the eighteenth century, may have been due to the fading of the Maunder Minimum, which went together with a significant rise in average annual temperature and a likely increase in soil productivity.

The third phase, from the mid-1730s to the early nineteenth century, was again characterized by a decrease in estimated food consumption per capita. Like the sixteenth century, this was a period of population growth (Figure 2) and unfavorable climatic conditions: The years 1730–1800 stand out for abnormally high levels of precipitation (Büntgen et al. 2010, pp. 1010, 1015). A likely decline in food availability per head was mitigated by the development of food output per agricultural laborer, that is, average labor productivity in agriculture. Despite adverse conditions, it remained roughly constant during the five decades after the 1730s. This took place on the background of a progressive integration of grain markets during the late seventeenth and early eighteenth centuries (Albers and Pfister 2021). Regional studies for Saxony and the lower Rhineland show that regions engaged in export-oriented textile manufacture succeeded in maintaining per-capita supply of food constant, despite an expansion of the regional population (Pfister and Kopsidis 2015; Kopsidis et al. 2017). Demand that stemmed from rising incomes from non-agricultural activities and market integration stimulated at least some degree of agricultural specialization and intensification already in the eighteenth century.

The final phase began after 1817 (the food crisis following the eruption of Mount Tambora in 1815) and was characterized by a sustained increase in average labor productivity in agriculture. As a result, food consumption per head was slightly higher in 1820–1849 than during the 1780s (by about 4 percent), despite a doubling of the rate of population growth relative to the eighteenth century and the rapid expansion of non-agricultural employment. Also note that the average annual temperature in the 1840s and 1850s was on average –0.4 degrees Celsius cooler than during the exceptionally warm 1820s, which must have adversely affected agricultural productivity (Rapp 2000, pp. 138–40). On this background, even a modest increase in food availability per head is remarkable and suggests the beginning of modern agricultural development in the late 1810s.

REAL GDP PER CAPITA

Real output in agriculture (i.e., food consumption per capita multiplied by population), the size of the non-agricultural population (the share displayed in Figure 3 multiplied by population), food prices (Online Appendix A1.2), and prices for industrial products and services (Online Appendix A1.6) serve to construct a chain index of real GDP at factor cost back to 1500 (cf. Equations (5) to (7)). Output in agriculture is spliced to the average of current price value added in this sector in 1856–1860 from Hoffmann (1965, table II/59, pp. 316–19). There is no

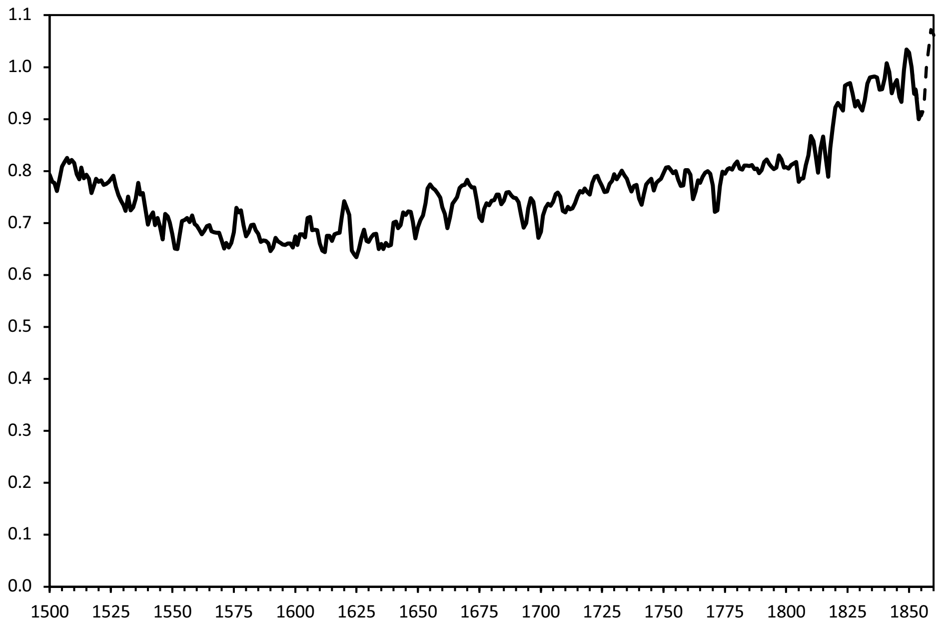

FIGURE 8
REAL GDP PER CAPITA, 1500–1855 (INDEX, 1851=1)

Sources: Solid line: this study, see text and Online Appendix 3; broken line (from 1851): compromise estimate from Pfister (2020a, Online Appendix A2).

full reconstruction of the current price output side of German GDP (or net national product (NNP)) prior to 1913. Hence, subtracting current price value added in agriculture from the reflated compromise estimate of NNP at factor cost (Pfister 2020a, Online Appendix 2) in 1856–1860 provides a rough benchmark for current price value added in industry and services. Non-agricultural population, which serves as a proxy for output in industry and services, is calibrated to this value.

The result of these calculations is a quantity index of real GDP based on chaining Fisher quantity indices for adjacent years, which I normalize to 1851 = 1. Figure 8 as well as Online Appendix 3 present annual estimates, but it should be borne in mind that, by construction, short-term fluctuations reflect mainly variations in the harvested quantities of basic vegetable foodstuffs. Therefore, trends over several decades are the most informative; Table 3 presents annual growth rates for select periods.

Comparison of Figures 6 and 8 suggests that at least in some periods, the real wage and real GDP per capita behave differently, and the trajectory of real GDP per capita suggests a more optimistic view of the evolution of material welfare in the long run than the real wage. A similar pattern

TABLE 2
PROXIMATE SOURCES OF GROWTH OF REAL GDP PER CAPITA
(RATES OF CHANGE IN PERCENT)

	1500–1600	1600–1650	1650–1700	1700–1800	1800–1820	1820–1850
Increase of real GDP p. c.	–15	5	1	16	11	11
Increase of real wage	–41	44	–2	–27	22	13
Increase of real income incl. land rent	–38	31	–12	–21	16	9
Increase of output per head in agriculture	–22	13	–10	–9	11	2
Increase of output per head outside agriculture	–6	–3	13	42	12	17
Change of P_I/P_A	–29	14	–16	–5	9	–4
Weight of agriculture (geometric average)	0.505	0.526	0.523	0.467	0.411	0.389

Notes: Values are based on centered five-year averages (1500 refers to 1500–04). Weight of agriculture is geometric mean of share in current price output in t_0 and t_1.
Source: This study.

holds for Britain, and the discrepancy calls for an explanation (Angeles 2008; Broadberry et al. 2015, ch. 6). Since in the indirect approach, the real wage enters the procedure to estimate GDP as data, the question is mainly about how the indirect method operates with the underlying data series. Table 2 shows rates of change in percent between key years for the main variables entering the estimate of agricultural output (Equation (3)) and the index of real GDP (Equations (5) and (6)): Total real income per head (wage and land rent combined), real output per head in agriculture and in the non-agricultural sectors (Q_A/N and L_{NA}/N), and the relative price of non-agricultural goods vs. foodstuffs (P_I/P_A). An increase in the relative price of industry and services raises the weight of the rate of change of output in the non-agricultural sectors. A decline has the opposite effect. The last line gives the geometric average of the share of agriculture in current price value added in the two respective key years. It gives a rough impression of the weight of the sectoral growth rates in the growth rate of aggregate GDP (for 1820–1850: 0.389 × 2 + [1 – 0.389] × 17). Given the construction principle of the Fisher ideal index, this procedure does not produce the result with exactitude (mainly in 1700–1800).

Three observations stand out from the data in Table 2. First, the inclusion of land rent—which moved in the opposite direction to the real wage (Figure 6)—dampens fluctuations in income per head, and the fact that income enters the calculation of agricultural output with a weight of 0.5

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(Equation (3)) further reduces the variation of the latter relative to the real wage. Specifically, the massive fall of the real land rent in the wake of the Thirty Years' War, reflecting a reduction of the endowment of land with labor and capital, meant that combined income rose by only 31 percent in the first half of the seventeenth century, compared to a 44 percent increase in the real wage. Consequently, agricultural output per head grew by less than one-third (13 percent) of the rate of increase of the real wage. A reverse effect is visible in the eighteenth century, when the stability of the land rent and the limited responsiveness of food consumption to changes in income mitigated the effect of the fall of the real wage on estimated agricultural output. Changes in the functional distribution of income clearly explain part of the discrepancy between the real wage and real GDP per capita (Angeles 2008, p. 152).

Second, positive rates of change in real GDP per capita after 1650 result primarily from an increase in the output of the non-agricultural sectors, which is proxied by employment outside agriculture. This is because average labor productivity in industry and services was about one-third higher than in agriculture: In 1856–1860 the labor share of the non-agricultural sectors was 47 percent, whereas their share in value added was 64 percent (similar values are obtained from current price estimates for earlier years). This differential in labor productivity contrasts with the small magnitude of the rural-urban gap with respect to day wages (cf. the earlier discussion of wages and income). With homogenous labor and competitive labor markets, the productivity differential must result from differences with respect to the labor effort, that is, the number of days worked (Angeles 2008, pp. 151–52). A likely cause is the lower level of seasonal unemployment in the non-agricultural sector.

Third, the effects of changes in relative prices were apparently minor. The most important case concerns the sixteenth century, when the massive fall in prices in industry and services relative to food prices reduced the power of the relative stability of non-agricultural output to mitigate the impact of the massive fall in agricultural output per head on the estimate of total value added.

Figure 8 and the growth rates in the lower panel of Table 3 suggest three distinct phases of economic growth between the sixteenth and the nineteenth centuries. The first phase extended from the beginning of the period under study until the middle of the seventeenth century. After the 1510s, real GDP per capita fell almost continuously over several decades and reached a nadir sometime between the 1590s to the 1620s at 15 to 20 percent below the initial value. The 1640s and early 1650s saw a substantial recovery; the sensitivity and consistency tests carried out in the next

TABLE 3
ANNUAL GROWTH RATES OF REAL GDP PER CAPITA IN EIGHT EUROPEAN COUNTRIES (PERCENT)

	Germany								
	Exponential Trend	Between Key Years	Central and Northern Italy	England/ Great Britain	France	Holland/ Netherlands	Spain	Portugal	Sweden
1500–1570	–0.30	–0.22	–0.07	0.04	–0.24	0.26	0.17		
1570–1600	–0.10	–0.02	–0.24	–0.06	0.55	0.96	–0.72		–0.75
1600–1650	0.04	0.09	0.04	–0.02	0.12	–0.18	–0.35	0.16	
1650–1700	–0.06	0.01	0.12	0.69	0.14	0.20	0.24	0.58	
1700–1750	0.15	0.25	0.08	0.18	0.08	0.03	0.18	1.10	–0.88
1750–1800	0.08	0.04	–0.24	0.39	–0.11	0.17	0.09	–1.34	–0.11
1800–1820	0.53	0.70	0.51	0.13	0.19	0.54	0.69		
1820–1850	0.35	0.24	–0.06	1.14	1.19	0.69	0.23		

Sources: Germany (figures for key years rest on five-year centered averages; the figure for 1500 refers to 1500–04): this study, Online Appendix 3; Central and northern Italy, England/Great Britain, Holland/Netherlands: Broadberry et al. (2015, pp. 375–76); Holland 1800: van Zanden and van Leeuwen (2012, data files); France: Ridolfi and Nuvolari (2020; data series kindly provided by the authors); Spain (five-year centered averages): Prados de la Escosura, Álvarez-Nogal, and Santiago-Caballero (2020, pp. 45–58); Portugal: Palma and Reis (2019, p. 500); Sweden: Schön and Krantz (2012, p. 546). Apart from the first column, growth rates are based on values for key years.

section suggest that the rate of increase of real GDP per capita between the 1620s and the 1650s and 1660s was probably even stronger than suggested by Figure 8 and Table 3. It may well be that during the third quarter of the seventeenth century, real GDP per capita was at a similar level as during the first two decades of the sixteenth century. Thus, material welfare evolved in inverse parallel to the long swing of the population (Figure 2).

The second phase lasted from the third quarter of the seventeenth century to the Revolutionary and Napoleonic Wars (1792–1815) and was characterized by the onset of slow economic growth. During the second half of the seventeenth century, real GDP per capita was trendless, and in 1700–1791, the trend growth rate amounted to 0.1 percent per annum. Expansion of the non-agricultural sectors, where employment was more continuous over the year and natural resource constraints were less binding than in agriculture, was capable of compensating for the decline of the marginal product of labor apparent in the trajectory of the real wage (Figure 6), particularly after the mid-1730s (cf. discussion of Table 2).

The third phase began after the Napoleonic Wars and lasted at least until the 1850s. The jump in real GDP per head between 1800 and 1820 by more than 10 percent can be partly ascribed to post-war recovery and short-term changes in climate. Poor availability and quality of data for the war years may also have a negative effect on the accuracy of the growth estimate for this period. The sensitivity and consistency checks carried out in the next section suggest that the likely true level of real GDP around 1820 may have been roughly the same as around 1790. In 1820–1850, economic growth accelerated to 0.3 percent vs. 0.1 percent in 1700–1791. This is all the more noteworthy as the population grew much faster than in the eighteenth century and the favorable weather conditions of the 1820s exerted a negative base effect on the agricultural sector.

In an international comparison, German economic decline during the sixteenth century parallels the experience of central and northern Italy and corroborates the idea of a reversal of fortunes connected with the rise of Atlantic trade, which benefitted the Northern Netherlands and, until the 1560s, Spain (Table 3). The findings of this study also confirm the second half of the seventeenth century as a pivotal period with respect to the divergence between England and mainland Europe. Around 1650, real GDP per head may have been at a similar level in England and Germany. In the subsequent half-century, stagnation in Germany contrasts with a 40 percent increase in England. Further divergence between the two economies set in with the industrial revolution in Britain during the second half of the eighteenth century. At the same time, the stagnation of the German economy during the second half of the seventeenth century also contrasts with small positive growth in other large continental economies, namely, France, central and northern Italy, and Spain. The eighteenth century saw a reversal of this picture: Whereas the German economy expanded slowly, France, central and northern Italy, Portugal, and Sweden experienced stagnation or decline.

SENSITIVITY AND CONSISTENCY TESTS

To explore the sensitivity of the estimate of real GDP per capita with respect to variations in underlying assumptions and particular data series, I developed several alternative indices of real GDP per capita. Online Appendix 2 presents them in detail; this section provides an overview and discusses the implications of the results.

Two tests explore the sensitivity of the GDP series with respect to the assumptions underlying the elasticity of food demand. Assuming constant food consumption per head or weaker income and price elasticity than in the baseline specification has little effect on results from 1570 (lines 1 and 2 in Table A2.1 and Section A2.1). For the first part of the sixteenth century, these two alternative specifications suggest a weaker decline in real GDP per head than the baseline estimate. However, this is not very plausible because the reduction of meat consumption per capita by about 50 percent during the sixteenth century suggests elastic food demand (Pfister 2017, Supporting Information S2, pp. 2–3).

Two further tests combine a plausible assumption concerning the evolution of the number of days worked per year between the early eighteenth and early nineteenth centuries with a tentative construction of factor shares in national income (lines 3 and 4 in Table A2.1 and Sections A2.2–3). Three results stand out: First, assuming an increase in days worked is essential in order to get plausible values for the labor share of national income. Second, income from land must have risen faster than in the baseline specification; otherwise, land shares during the sixteenth century would be implausibly high. Third, to be consistent with a non-negative capital share, GDP levels between 1650 and 1790 must have been 10 to 13 percent higher than suggested by the baseline estimate. I consider the outcome of this consistency test as the most likely alternative course of real GDP per capita between 1500 and 1850. Table 4 presents exponential growth rates between key years.

TABLE 4
PREFERRED VARIANT: INDEX LEVELS (1851=1) AND GROWTH RATES OF REAL GDP PER CAPITA GROWTH BETWEEN KEY YEARS (PERCENT, BASED ON CENTERED FIVE-YEAR AVERAGES)

	1500	1570	1600	1650	1700	1750	1790	1820
Index	0.691	0.599	0.600	0.706	0.722	0.845	0.887	0.898
	1500–1570	1570–1600	1600–1650	1650–1700	1700–1750	1750–1790	1790–1820	1820–1850
Growth rate	–0.20	0.00	0.33	0.05	0.32	0.12	0.04	0.36

Sources: Own computation based on assumption of increasing labor input per head, 1710–1810, and faster growth of land rent than observed; values in 1650, 1700, 1750, and 1790 are augmented by 12 percent. See Online Appendix 2, line 4 in Table A2.1 and Section A2.3.

The remaining sensitivity tests modify the assumptions underlying the estimate of output in the non-agricultural sectors. The first raises the share of non-agricultural employment in the rural labor force in 1500 from 15 to 20 percent. While this value is not very plausible (see the earlier discussion), the test shows that results are sensitive to the assumption of the initial value concerning the non-agricultural rural population (line 5 in Table A2.1 and Section A2.4).

The baseline estimate assumes that labor productivity in industry and services remained constant. However, the massive decline in the price of textiles relative to the price of rye (Figure 5) suggests that labor productivity rose in some non-agricultural activities prior to the onset of industrialization. A further sensitivity test, therefore, uses the coefficient of the unskilled urban day wage and the price of textiles (meter per day) as a simple indicator of labor productivity outside agriculture (line 6 in Table A2.1 and Section A2.5). The modification increases estimated economic growth between 1570 and 1700 and between 1820 and 1850.

The last test follows the majority of the applications of the indirect output estimation approach and constructs an index of real GDP per capita by dividing food consumption per capita by the share of agriculture in total employment (line 7 in Table A2.1 and Section A2.5). As noted in the exposition of the indirect approach, this entails the assumption that labor productivity in the non-agricultural sectors was the same as in agriculture. This variant suggests much smaller rates of economic growth than either the baseline estimate or the test that takes account of the likely increase in labor productivity outside agriculture. This sensitivity test underscores the relevance of making explicit assumptions about labor productivity in industry and services when implementing the indirect approach to output-side GDP reconstructions.

Two conclusions emerge from these sensitivity tests. The plausible variants all imply somewhat higher rates of economic growth than the baseline estimate; the latter clearly errs on the conservative side. Specifically, the tests allowing for a likely increase in labor productivity outside agriculture (number 6 in Table A2.1) and an increase of the labor input per head combined with faster growth of the land rent (number 4 in Table A2.1) both suggest that the likely true level of real GDP per head in 1500–1600 may have been 10–15 percent lower than the baseline estimate. The alternative results displayed in Table 4 imply that growth in 1700–1790 and 1820–1850 was more vigorous than according to the baseline estimate.

Second, growth estimates for major war periods—the Thirty Years' War and the Revolutionary and Napoleonic Wars—suffer from serious issues probably related to data availability and data quality. Assuming plausible factor shares renders it likely that the recovery of real GDP per capita between the 1620s and 1650s or 1660s was much more vigorous than suggested by the output-side reconstruction, and that real GDP per head in 1820 was virtually the same as around 1790 (Table 4). Consequently, the level of economic activity between the third quarter of the seventeenth century and 1790 may have been 10 to 15 percent higher than suggested by the baseline estimate.

DISCUSSION

This section characterizes individual phases of the trajectory of the German economy between the sixteenth and the nineteenth centuries and identifies likely factors that caused transitions between phases. The focus is on the long swing in material welfare between 1500 and 1650, the onset of a slow increase in real GDP per capita around 1700, and the acceleration of economic growth from the 1810s.

The Long Swing in a Malthusian Regime, 1500–1650

Between 1500 and 1570, real GDP per head fell by about 15 percent and reached a nadir sometime between the 1590s to the 1620s, followed by a recovery until the 1650s and 1660s, whose exact magnitude is difficult to determine. Population evolved an inversely parallel development: Demographic expansion in the sixteenth century was followed by a massive contraction during the Thirty Years' War (Figure 2). The inverse comovement of population and material welfare is consistent with Malthusian theory, which posits that with given technology and fixed natural resources, there is a negative relationship between population and material welfare (Clark 2007, ch. 2). From a European perspective, German economic decline during the sixteenth century parallels the development of central and northern Italy and France (until 1570). At the same time, it contrasts with the increase of real GDP per capita in the Netherlands and (until about 1570) Spain (Table 3). Germany's experience is thus consistent with the idea of a reversal of fortunes from inland regions to maritime powers connected with the rise of Atlantic trade.

A Late Malthusian Economy, 1650–1790

A salient feature of Germany's economic development between the second half of the seventeenth century and the outbreak of the Revolutionary Wars in 1792 is the onset of modest economic growth at a rate of 0.1 percent or slightly more in 1700–1790, despite parallel demographic expansion at a rate of 0.45 percent. The negative relationship between population and material welfare that forms a characteristic of Malthusian economies had thus vanished. Moreover, as a result of the absence of the Malthusian positive check, in the long run, population size exceeded the level reached in the early seventeenth century by a constantly widening margin from the second quarter of the eighteenth century onwards (cf. Figure 2; Pfister and Fertig 2020). Most formulations of the unified growth theory posit a positive relationship between the population and the rate of technological change. This implies that the negative effect of population on income per capita weakens as the population becomes larger over time (Kremer 1993; Galor and Weil 2000; Galor 2005, 2011, chs. 2 and 5). The combination of an unprecedently large population with slow positive economic growth thus characterizes eighteenth-century Germany as a late Malthusian economy.

Structural change and regional specialization, fostered by domestic and international market integration, were the prime engines behind the increase in the level of technology and the onset of modest economic growth. The period from 1650 to 1790 saw a massive shift of employment from agriculture to non-agricultural activities, mainly to regional export industries or proto-industries (Figure 3). It compensated for the fall in the real wage because output per head was higher in the non-agricultural sectors, mainly because seasonal employment was less frequent than in agriculture (see discussion of Table 2). In addition, the fall of the price of textiles relative to the price of rye and to the nominal wage indicates that labor productivity in the non-agricultural sectors, probably mainly in the service sector, was much higher in 1700 than a century earlier (Figure 5 and discussion of line 6 in Table 4). Demand for foodstuffs in expanding industrial districts created an incentive to expand commercial agriculture in regions possessing a comparative advantage with respect to arable farming, which increased labor productivity in these areas as well (see discussion of Figure 7).

Structural change and regional specialization rested on domestic and international market integration; economic development during the late Malthusian era was thus characterized by Smithian growth. The pull of the Atlantic economy, which was centered on the south rim of the North Sea, was pivotal to this process. Shortly after the middle of the seventeenth century, Germany's seaports, situated on the estuaries of major rivers, the most important being Hamburg, developed into important hubs connecting inland regions with overseas markets. Parallel to rapid demographic expansion, real wages in this town increased massively during the third quarter of the seventeenth century to a level comparable with London and Amsterdam (Pfister 2017, pp. 721–22). Centered in northwestern Germany and the rivers extending into a wider hinterland, grain markets became progressively integrated, which promoted regional specialization between agrarian and manufacturing regions. Population growth, which raised market thickness, contributed to this process (Chilosi et al. 2013, pp. 58–60; Albers and Pfister 2021, pp. 482–85). During the eighteenth century (1740s to 1790s), foreign trade grew by about 1 percent per annum in real terms (Pfister 2015, pp. 181–85). With annual growth rates of 0.4–0.5 percent for population and 0.1 percent of real GDP per capita, this signals an increase in openness and thus international market integration.

In addition to the pull of the emerging Atlantic economy, state development at the regional level may also have been conducive to market integration. From the 1670s to the 1710s, the regulative output of public authorities in 20 German polities expanded more than threefold (Albers and Pfister 2021, pp. 482–83), which suggests a massive increase in legal capacity. The chronological parallel of increasing regulative activity and rising grain market integration in Germany offers a striking contrast with Poland, where a decline in the regulative capacity of public authorities went together with market disintegration (Malinowski 2019). This is consistent with the hypothesis that the system of decentralized and competitive state building within the larger framework of the Holy Roman Empire, which emerged in the wake of the Thirty Years' War, was conducive to economic development (Volckart 1999).

From a European perspective, Germany's trajectory from the late seventeenth century to 1790 marks a middle path between Britain and the less dynamic parts of the European mainland (Table 3). On the one hand, slow growth in Germany contrasts with stagnation and decline in several other

European economies, most notably northern and central Italy and France. On the other hand, this phase was also marked by a strong divergence between Britain and Germany: Economic growth in the century preceding the Industrial Revolution was much faster in the former than in the latter economy. To put it in other words: While the pull of the Atlantic economy and possibly state growth were pivotal in mitigating the Malthusian nexus between population and welfare, their effect on economic growth remained modest. This reflected the fact that Germany was mostly a landlocked country and had no direct access to trade with other continents. Consequently, the rate of growth of foreign trade during the eighteenth century mentioned previously—about 1.0 percent per year—was small in comparison with other economies that were part of the emerging Atlantic economy (Freire Costa, Palma, and Reis 2015, p. 9). The modest degree of internal market integration is testified by the low level and slow growth of the urbanization rate (Figure 3). A low urbanization rate also implied that thick market effects connected with a spatial concentration of food demand in cities, which stimulated an agrarian revolution in northwestern Europe, were absent in Germany (Pfister and Kopsidis 2015). The tyranny of distance prevailing over inland regions constituted an important obstacle to economic growth in pre-industrial Germany.

The Post-Malthusian Regime, 1810s–1870s

From the 1810s to the 1870s, Germany can be characterized as a post-Malthusian economy (cf. with Galor 2005, pp. 185–95, 2011, pp. 17–30). Growth of real GDP per capita was faster than in the eighteenth century and accelerated from 0.2–0.4 percent p. a. in 1820–1850 to 0.6–1.1 percent in 1851–1880 (for the latter period, see Pfister (2020a, p. 517)). Recall that low temperatures in the 1840s and 1850s depressed the growth rate during the first subperiod and introduced a base effect in the second. The acceleration of economic growth was accompanied by a doubling of the rate of population growth in 1816–1870 compared to 1730–1799. Thus, the effect that population growth had on diluting resources per capita was compensated for by an increase in the rate of technological change. Since the positive relationship between income and fertility persisted at a constant magnitude (Pfister and Fertig 2020, pp. 1159–61), these findings also imply that increases in income were primarily channeled into population growth. Incentives to limit the number of offspring, such as a high rent on human capital or an old-age pension scheme, were absent at this time.

Likely drivers of economic growth from the 1810s to the 1870s were directly or indirectly linked to the population, which is consistent with the relationship between population size and the rate of technological change stressed by proponents of the unified growth theory. Infrastructure development, first in the form of the construction of paved roads, and from the 1840s in the form of the development of a railway network, absorbed the bulk of fixed capital formation outside agriculture during the first stage of industrialization (Tilly and Kopsidis 2020, chs. 2–7). Together with institutional integration, particularly the creation of a customs union (*Zollverein*) in 1834, infrastructure development broke the tyranny of distance that had curtailed economic development in the seventeenth and eighteenth centuries and created a new potential for Smithian growth, whose limits were continuously extended through population growth. Specifically, infrastructure development stimulated urban growth (Hornung 2015); hence, the onset of a sustained rise in the urbanization rate from the 1810s is also a characteristic feature of the transition to the post-Malthusian era (Figure 3). Urban growth, in turn, raised spatially concentrated demand for foodstuffs and thus amplified incentives for farmers to expand market-oriented production (Kopsidis and Hockmann 2010; Kopsidis and Wolf 2012; Tilly and Kopsidis 2020, ch. 9). This stimulated Boserupian growth in the form of an adoption of the labor-intensive innovations of the first phase of the German agricultural revolution, such as all-year-round stall-feeding, and the cultivation of fodder crops and potatoes. Rapid population growth supplied the labor required for such a growth path.

The trajectory of the German economy after the 1810s is not only consistent with stylized facts modeled by unified growth theory, it also replicates the Crafts-Harley view of the British industrial revolution (Crafts 1985; Crafts and Harley 1992; Pfister 2020a). Rapid output growth in mining and a few leading sectors in manufacturing during the first phase of modern industrialization from the 1840s to the early 1870s (Tilly and Kopsidis 2020, ch. 7) had merely a modest impact on aggregate economic activity, mostly because the modern sector was initially quite small. Only from the 1880s did GDP per capita expand at a pace that is typical for modern growth regimes (1.5 percent per annum in 1880–1913). Thus, the transition to modern economic growth was characterized by a gradual acceleration of growth in GDP per capita over a long period beginning in the late seventeenth century. This picture of German economic development differs radically from an older scholarship, which posited a rapid take-off into sustained growth connected with industrialization around the middle of the nineteenth century (Abel 1980; Rostow 1956; Henning 1973, p. 25).

The post-Malthusian pattern of economic growth emerged at the end of the Revolutionary and the Napoleonic Wars (1792–1815), which led to a massive reduction of the number of polities and stimulated sweeping administrative, economic, and social reforms. The most likely immediate economic effect of the wars resulted from the creation of relatively large territories with sovereign public authorities. Heightened state capacity rendered possible trade reforms and programs of public road construction (Pfister 2022a). Thus, as in the case of the emergence of a late Malthusian pattern of economic growth, state development may also have contributed to the transition to the post-Malthusian growth regime.

CONCLUSION

This projection of German GDP back to the beginning of the modern era rests on assumptions and incomplete data. Nevertheless, it points to two conclusions. First, from c. 1500 to 1600, real GDP per capita experienced a long downswing, followed by a rapid recovery during the second quarter of the seventeenth century. This trajectory is consistent with the inverse relationship between population and material welfare characterizing Malthusian economies. Second, economic growth accelerated gradually c. 1700–1880. The characteristics of this process are broadly consistent with the late Malthusian and post-Malthusian growth regimes posited by the unified growth theory. Transitions between growth regimes coincide with episodes of rapid state growth, suggesting that economic forces and institutional shocks interacted in shaping patterns of long-term economic development.

Online Appendices

A1: Construction of price indices
A2: Sensitivity and consistency checks
A3: Data series (Excel file, deposited at Pfister (2022b)).

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