APPENDIX

A Data appendix

Price data

Information on prices comes from primary and secondary sources. In particular, prices in Toledo come from Hamilton (1934, 1947) and from the reports of the Faithful Executors of Toledo (*Juzgado de Fieles Ejecutores de Toledo*).[1] For Barcelona, prices largely come from Feliu (1991). Information is missing for some years. When information is missing for five or fewer consecutive years, I filled the blanks by interpolation. In other cases, I used information on prices of related items or in nearby cities.[2]

Original prices are in maravedis and *cuartos* in Toledo and *sueldos* in Barcelona. Prior to interpolation, all prices were converted to grams of silver per kilogram. I relied on Hamilton (1934, 1947) and Feliu (1991) to obtain the quantity of grams of silver per maravedi and per *sueldo*. One *cuarto* was equivalent to four maravedis.

Original prices are in different physical units. Prices in Toledo are expressed in pounds, arrobas, fanegas, azumbres, and prices in Barcelona are expressed in *cuarteras*,

[1] García (2016) describes the characteristics of the reports of the Faithful Executors of Toledo. This primary source contains a list of prices collected by the Municipality of Toledo for several days per year.

[2] In general, denote goods A and B as the prices of related items. I calculated Q as the relative price of A with respect to B. Whenever it was possible, I interpolated Q to fill the blanks. When there are missing ratios for more than 10 years, I assumed that the initial value in the missing period was equal to the average ratio in the previous 10 years and the last value was equal to the average ratio in the following 10 years. I then interpolated for the missing values. Denote t_0 as the earliest year for which there is information on Q and t_1 as the latest year. Information was then missing in every year between 1785 and $t_0 - 1$ and in every year between $t_1 + 1$ and 1900. For the period [1785, $t_0 - 1$], I assumed that Q was equal to the average ratio between t_0 and $t_0 + 9$; for the period [$t_1 + 1$, 1900], I assumed that Q was equal to the average ratio between t_1-9 and t_1. I then estimated the price of A as the multiplication of Q and the price of B. If $t_1 < t_0 + 10$, I calculated the average ratios using the available information, i.e., with fewer than ten years of data.

pounds, butcher's pounds, quintals and arrobas. Following Hamilton (1934, 1947), *Instituto Geográfico y Estadístico* (1886) and Feliu (1991), I assumed the following conversion rates: one quintal = 4 arrobas, one fanega = 55.501 litres, one azumbre = 0.125 *cantaras*, one *cantara* = 16.22 litres, one *cuartera* = 69.518 litres. In addition, I assumed one pound = 0.46 kg in Toledo and 0.4 kg in Barcelona. One arroba of solid items was equivalent to 25 lb in Toledo and 26 lb in Barcelona, whereas one arroba of oil was equivalent to 12.5 litres in Toledo and 11.93 litres in Valencia. I also assumed that one butcher's pound was equivalent to 1.2 kg in Barcelona, one hen weighed 1.5 kg and one egg weighed 60 grams.[3] To convert litres to kilograms for some items, I used density information from FAO (2012).[4]

Some prices are retail prices, whereas others are wholesale. For some products, the prices refer to pounds or kilograms. For others, the prices refer to arrobas, *cuarteras* or fanegas. Low-income families probably did not purchase goods in large quantities. I then converted wholesale prices to retail prices. For some products, information on wholesale and retail prices was available. On average, retail prices were 21% higher than wholesale prices and this figure is used to convert wholesale prices into retail prices.

Prices in Toledo come from Hamilton (1934, 1947) and the reports of the Faithful Executors of Toledo (FET).[5] Hamilton collected prices from institutions in Toledo. The reports of FET include prices collected by the Municipality of Toledo.[6] I relied on Hamilton to obtain the prices of wheat, barley, rice, beans, mutton, hens, eggs, codfish,

[3] The weight of one hen refers to a common hen and comes from Balaguer y Primo (1977): 769. The weight of one egg comes from the U.S. Department of Agriculture (1939).
[4] Most of these equivalences come from the U.S. Department of Agriculture (1939).
[5] Most prices of Hamilton (1934, 1947) refer to Toledo. Hamilton's data has been largely used in historical studies of Spain.
[6] These reports are manuscripts.

sugar, honey and wine. I obtained additional prices of rice, chickpeas, eggs, mutton, cheese, garlic and olive oil from the reports of the FET. In cases where there are two series of prices, I calculated the average price for each year. The series are usually not complete; in such cases I estimated the missing prices. When information is missing for five or fewer consecutive years, I used interpolation. In addition, I estimated the missing prices using the ratio of prices between the series. For missing observations, I estimated the ratio using interpolation and extrapolation.[7] In addition, I used López and Piquero (2021), Herrero (2012) and López (2013) to fill the blanks.[8] In some cases, I used the relative price of Toledo with respect to Barcelona to fill the blanks. Wages are originally expressed in maravedis and *sueldos*. Prior to interpolation, I converted those figures to grams of silver.

I estimated the price of wheat bread in Toledo using the price of wheat in Toledo from Hamilton and the relative price of wheat bread with respect to wheat in Madrid from López and Piquero (2021). I estimated the price of barley bread using the price of barley and the wage of artisans.[9] Prices of beans are missing for 1600-66 and prices of rice are missing for 1600-50; for these cases, I used prices in Barcelona from Feliu (1991) to

[7] Denote goods A and B as two price series of the same item. I calculated Q as the ratio A/B. Whenever it was possible, I interpolated Q to fill the blanks. When there are missing ratios for more than 10 years, I assumed that the initial value in the missing period was equal to the average ratio in the previous 10 years and the last value was equal to the average ratio in the following 10 years. I then interpolated for the missing values. Denote t_0 as the earliest year for which there is information on Q and t_1 as the latest year. Information was then missing in every year between 1600 and $t_0 - 1$ and in every year between $t_1 + 1$ and 1800. For the period [1600, $t_0 - 1$], I assumed that Q was equal to the average ratio between t_0 and $t_0 + 9$; for the period [$t_1 + 1$, 1800], I assumed that Q was equal to the average ratio between t_1-9 and t_1. I then estimated A as the multiplication of Q and B. If $t_1 < t_0 + 10$, I calculated the average ratios using the available information, i.e., with fewer than ten years of data.

[8] López and Piquero (2021) and Andrés and Lanza (2014) collected new data for several items in Madrid. Relying on new price data and on the data from Andrés and Lanza (2014) and Hamilton (1934, 1947), López and Piquero estimated the silver prices of a number of items in Madrid. López and Piquero´s estimates are available from https://addi.ehu.es/handle/10810/40426?show=full. López (2013) reports prices in Casarrubios del Monte in Toledo. Herrero (2012) reports prices in Palazuelos in Old Castile,

[9] I used the equation of the price of bread as a function of the price of the related grain from Allen (2001).

estimate the prices in Toledo. For linen, I assumed prices in Toledo in 1600-50 were the same as in Leon. I assumed the price of lamp oil was the same as the price of olive oil. I estimated the prices of soap in 1600-50 using tallow prices and the relative price of soap with respect to tallow. The price of oats in 1799 comes from Madoz (1849). I estimated the price of oats in Toledo in 1700-1800 using information from Herrero (2012) for oat prices in Old Castile and the ratio of wheat prices between Toledo and Old Castile. Oat prices are not available for 1600-1700. I used the price of milk to estimate the price of cheese in 1600-50.

Prices in Barcelona largely come from Feliu (1991). Feliu collected prices from the purchases of foodstuffs by institutions, such as the Cathedral of Barcelona and convents in Barcelona, as well as official lists of prices (*mercuriales*) in Barcelona. Feliu also reports prices for other cities in Cataluña. I relied on Feliu to obtain prices of wheat, barley, oats, rice, beans, mutton, codfish, eggs, sugar and honey. For some items, Feliu reports a single price series. For other products, two or more price series are reported. In these cases, I used the average price of the series. Since the series are not complete, I first filled the blanks.

For Barcelona, wheat prices are the average of prices from the Cathedral of Barcelona, the Convent of San Agustin and the official list of prices (*mercurial*) of Barcelona. I estimated the price of barley bread using the price of barley and the wage of artisans. Rice prices are the average of the price of rice for purchases in pounds and the price of rice for purchased in arrobas. Mutton prices are the municipal prices in Barcelona. Prices of codfish, hens, eggs, coal and tallow candles correspond to the prices from

convents´ purchases. Sugar and honey prices are the average of prices for purchases in pounds and in arrobas. For olive oil, I relied on the series of prices per *cuartanes*.[10]

Wage data

Wage data comes from secondary sources. For 1596-1600 and 1737-1800, I obtained daily wages of laborers in Toledo from Hamilton (1934, 1947). I filled the blanks using information on wages from López and Piquero (2021) and the ratio between Hamilton´s wages and López and Piquero´s wages.

Wages of laborers in Barcelona come from Feliu (1991). When information is missing for up to five consecutive years, I filled the blanks by interpolation. When information is missing for six or more consecutive years, I estimated wages in Barcelona, using the information on wages in Gerona and the ratio between the wages in Barcelona and those in Gerona.

Wages are originally expressed in maravedis and *sueldos*. I converted those figures to grams of silver.

Chemical composition of foods

In the linear programming model, $\alpha_{k,j}$ is the quantity of nutrient *k* in a purchased kilogram of food *j*. To calculate the value of $\alpha_{k,j}$, I collected information on the chemical composition of foods. Table A.1 reports the content of nutrients per purchased kilogram of foods.

[10] I also relied on Madoz (1846) for the price of oats in Barcelona in 1799.

To estimate the composition of wheat and barley bread, I relied on the composition of wheat flour and barley flour, respectively. Baking, however, led to the loss of some nutrients. In addition, a kilogram of flour yielded 1.28 kilograms of bread.[11] Denote θ_k as the relative loss of nutrient *k* due to the baking of flour and β_k as the quantity of nutrient *k* in a kilogram of raw flour. The quantity of nutrient k in a purchased kilogram of bread is calculated as $\alpha_k = (1 - \theta_k)\beta_k/1.28$. Recent composition tables do not reflect the composition of some items prior to 1900, especially for flour (Gazeley & Horrell, 2013). I then relied on McCance and Widdowson (1946) and Paul and Southgate (1978) to obtain the food composition of wheat flour at 100% and barley flour. Calories, proteins, fat and iron come from McCance and Widdowson (1946). Information on other nutrients and the loss of vitamins due to baking comes from Paul and Southgate (1978).

In addition, I collected information on nutrients for other foods. Food composition corresponds to raw foods. I considered that a portion of the purchased food was discarded. For instance, the bones of mutton were discarded. Denote $\alpha_{k,j}$ as the consumption of nutrient *k* in a kilogram of the purchased food *j*. Then $\alpha_{k,j} = e_j\beta_{jk}$, where e_j is the edible portion of the food j, and β_{jk} is the quantity of nutrient *k* in a kilogram of food *j*. For most of those items, food composition and edible portion on most of those items come from McCance and Widdowson (1946), Paul and Southgate (1978) and U.S. Department of Agriculture (1979). For dried beans, information comes from FAO (2021).[12]

[11] Allen (2001) indicates that 3 lb 2 oz of flour gave around 4 lb of bread.

[12] Cooking reduces the amount of some nutrients, especially vitamins. Indian dietary requirements, however, already consider possible losses of nutrients during cooking (Allen, 2017; Rao, 2009).

TABLE A.1

Content of nutrients per kilogram

	Calories (kcal)	Proteins (g)	Fat (g)	Iron (mg)	Thiam. (mg)	Niacin (mg NE)	Vit. B12 (µg)	Folate (µg)	Vit. C (mg)
Basic model									
Wheat bread	2,601.6	69.5	17.2	23.8	3.1	41.6	0.0	222.7	0.0
Barley bread	2,812.5	60.2	13.3	5.2	0.8	18.6	0.0	78.1	0.0
Rice	3,610.0	62.0	10.0	4.5	0.8	15.0	0.0	290.0	0.0
Beans	2,580.0	214.0	16.0	66.5	4.5	25.0	0.0	4,000.0	0.0
Mutton	2,797.2	122.6	256.2	11.8	0.8	33.6	16.8	33.6	0.0
Hens	1,395.2	120.3	101.8	3.8	0.4	48.0	6.4	44.8	0.0
Eggs	1,450.7	105.9	109.5	22.5	0.8	0.6	25.8	222.5	0.0
Codfish	782.1	181.2	5.9	4.0	0.8	13.9	19.8	49.5	0.0
Sugar	3,940.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Honey	2,880.0	4.0	0.0	2.0	0.0	2.0	0.0	20.0	0.0
Olive oil	9,290.0	0.0	999.0	0.8	0.0	0.0	0.0	0.0	0.0
Wine	680.0	2.0	0.0	9.0	0.0	0.9	0.0	2.0	0.0
Onions	223.1	8.7	0.0	2.9	0.3	1.9	0.0	155.2	97.0
Garlic	774.2	62.4	4.7	15.0	1.0	2.4	0.0	39.5	134.3
Lettuce	77.0	7.7	2.8	5.1	0.5	2.1	0.0	238.0	105.0
Cabbage	141.5	15.4	0.0	4.5	0.4	1.8	0.0	553.5	353.6
Additional foods									
Wheat	2,175.6	58.1	14.4	19.9	2.6	34.8	0.0	186.2	0.0
Barley	2,174.4	46.5	10.3	4.0	0.7	15.1	0.0	120.8	0.0
Oats	2,561.4	76.7	55.2	26.1	3.2	6.3	0.0	380.4	0.0
Noodles	3,780.0	136.0	10.0	12.0	1.4	20.0	0.0	130.0	0.0
Chickpeas	3,200.0	213.0	54.0	55.0	3.9	19.0	0.0	4,000.0	0.0
Broad beans	2,450.0	261.0	21.0	55.0	5.0	26.0	0.0	2,500.0	0.0
Beef	1,852.5	130.5	147.8	12.5	0.3	31.5	10.0	57.5	0.0
Milk	660.0	33.0	37.0	0.8	0.4	0.8	3.0	50.0	15.0
Cheese	3,810.0	237.0	318.0	3.0	0.2	1.0	16.0	390.0	0.0
Butter	7,400.0	4.0	820.0	1.6	0.0	0.0	0.0	0.0	0.0
Chicory	71.1	6.3	0.0	5.5	0.4	4.0	0.0	410.8	31.6
Lemons	148.5	7.9	0.0	3.5	0.5	2.0	0.0	24.9	792.0
Plums	230.0	5.0	0.0	2.7	0.5	5.0	0.0	30.0	30.0
Grapes	570.0	5.5	0.0	3.1	0.4	2.5	0.0	55.0	35.0
Cherries	370.0	3.0	0.0	2.9	0.4	3.0	0.0	70.0	40.0

Notes : The table reports the composition of nutrients in each food item per kilogram purchased in the market or per kilogram obtained from the garden. See the text for a description of the procedure used to obtain the nutrients.

Calculation of requirements of nutrients of an average person and of a family

In order to estimate the requirements of nutrients of an average person and of each member of a family, I use the distribution of population by age and sex in the late 18th century, according to the census of 1787 (Eiras, 1987: 88). The census provides population figures for age ranges. I assumed a uniform distribution of the population within every age range.

From Llopis (2004), I assumed the birth rate was 4.2%. I also assumed an infant death rate of 268 deaths per thousand births, which was the average death rate of Catalonia and interior Spain in the second half of the 18th century (Gutiérrez, 2014). These figures were useful to estimate the number of pregnant women and the number of lactating women. I assumed that pregnant and lactating women were between 15 and 40 years of age, that pregnant and non-pregnant women had the same age distribution, and that lactating and non-lactating women also had the same age distribution. Under these assumptions, pregnant and lactating women accounted for 7.3% of the total population of Spain.

I also assumed that children of up to six months only obtained their nutrients from their mothers, through lactation.

To find the nutritional requirements of a family in section 4, I calculated the weighted average of nutrients of three family types that included two adults and two children: i) a family with an adult man, a non-pregnant wife and two children of 1 to 15 years, ii) a family with an adult man, a pregnant wife and two children of 1 to 15 years, and iii) a family with an adult man, a lactating wife, a child of less than six months and a child of 1 to 15 years. The weights were the relative proportions of non-pregnant women, pregnant women, and lactating women in Spain in 1787.

A.2 Extensions of the model

I have made a number of assumptions to estimate the welfare ratios of Toledo and Barcelona. In particular, I have assumed that a family could only purchase twelve foodstuffs. I also assumed that a family obtained vegetables for free. In this section, I estimate welfare ratios changing those assumptions.

Cereals

The basic model assumes that a person could purchase the following products: wheat bread, barley bread, rice, dried beans, mutton, hens, dried codfish, eggs, sugar, honey, olive oil and wine. I did not collect information on prices of barley bread. Those prices were estimated using barley prices and wages. In addition, I did not include barley and oats in the model. Other studies have included those two items in the basket.

I excluded barley bread from the basic model. The only cereals in the model are now wheat bread and rice. Model A in Table A.2 reports the results. The results are practically the same as those in the basic model: compared with the ratios in the basic model, the ratio in Model A is 0.1% lower for Toledo and 3% lower for Barcelona. In addition, Spain had lower ratios than Northern Europe in most of this period.

Model B replaces barley bread with barley. The results are very similar to those of the basic model. Compared with the welfare ratios in the basic model, the new ratios are higher by 0.3% for Toledo and lower by 0.1% for Barcelona.

Model C includes oats and barley. I do not have complete information of oat prices in Toledo in the 17th century, so I only estimate the model for 1700-1800. Compared with the basic model, the welfare ratios in Toledo and Barcelona are higher by 0.1% to 14%, depending on the city and the period. Importantly, in the 18th century, the welfare ratios of

Toledo and Barcelona were still lower than those of Northern Europe. In addition, the trends remain the same; the welfare ratios in Toledo and Barcelona were lower in 1751-1800 than in 1700-50.

Additional foodstuffs

In the basic model, I only included the foodstuffs for which I had prices in both Toledo and Barcelona. For some products, prices are available for one of the two cities. Prices of chickpeas, beef, milk, cheese and butter are only available for Toledo, whereas prices of noodles and broad beans are only available for Barcelona. Will the welfare ratios change much if those items are included in the model? Having more options to choose could yield a lower food cost and thus higher welfare ratios.

I then include chickpeas, beef, milk, cheese and butter in the model for Toledo, and noodles and broad beans in the model for Barcelona. I maintain the assumption of the basic model that people could purchase barley bread, but not barley or oats. Model D reports the results. The new model yields higher welfare ratios in Spain. The variation in welfare ratios, however, is not very large and does not change the main results. The welfare ratio only increased by 2% in Toledo and Barcelona. Importantly, the welfare ratios in Spain were still below those in Northern Europe for the entire period. The divergence in living standards started prior to the Industrial Revolution.

Vegetables and fruits

I only had prices of vegetables and fruits for Toledo, not for Barcelona. For this reason, I assumed that people obtained those foods for free in the basic model.

Model E assumes that people could purchase vegetables and fruits in the market, but that they still received free vegetables (the same as in the basic model). In particular, I assumed that families in Toledo could purchase not only the foods of the basic model, but also onions, garlic, chicory, lemon, plums, grapes and cherries. I estimated the model for 1650-1800. Prior to 1650, prices of onions and garlic are not available.

By including additional products in the linear programming model, the cost of food could decline, thus increasing the welfare ratios. The results, however, show that the lowest-cost basket does not change and so the welfare ratios do not change. Given that the free provision of vegetables already satisfied the requirement of vitamin C, purchasing fruits or vegetables would not be efficient. Vegetables and fruits were also sources of calories, folate and other nutrients; but other foods provided these nutrients at a lower cost.

Model F assumes that families did not obtain free vegetables. In this case, families needed to purchase vegetables or fruits in the market to obtain vitamin C. Families could purchase the same products as in model E. The new optimal basket includes onions in every decade. Other sources of vitamin C were more expensive. Importantly, the results show that the welfare ratios in Toledo are lower than in the basic model. On average, the welfare ratios were 15% lower. The trend of the welfare ratio, however, does not change. As in the basic model, the welfare ratio in Toledo in Model F also declined over time.

TABLE A.2

BN welfare ratios: extensions to the model

	1600-1650	1651-1700	1701-1750	1751-1800
Basic model				
Toledo	1.18	1.22	1.32	0.79
Barcelona	0.76	1.04	0.90	0.86
Model A: Excluding barley bread from the basic model				
Toledo	1.18	1.22	1.32	0.79
Barcelona	0.69	1.03	0.89	0.85
Model B: Adding barley to the basic model and excluding barley bread				
Toledo	1.18	1.22	1.33	0.80
Barcelona	0.72	1.04	0.90	0.86
Model C: Adding oats and barley to the basic model and excluding barley bread				
Toledo	1/	1/	1.51	0.84
Barcelona	1/	1/	0.90	0.87
Model D: Adding cereals, legumes and animal-derived foods to the basic model				
Toledo	1.18	1.29	1.35	0.80
Barcelona	0.80	1.06	0.91	0.86
Model E: Adding vegetables and fruits to the basic model				
Toledo	2/	1.22	1.32	0.79
Model F: Adding vegetables and fruits to the basic model and eliminating free provision of vegetables				
Toledo	2/	1.01	1.09	0.68

Notes: The table reports BN welfare ratios. For Toledo and Barcelona, the table reports the estimations of the present study for the basic model for six alternative models. 1/ Prices of oats are not available for 1600-1700. 2/ Prices of onions and garlic are not available for 1600-50.

A.3 Additional tables

TABLE A.3

Cost of nutrients (grams of silver)

	1,000 kcal calories	One g of proteins	One g of fat	One mg of iron	One mg of thiamine	One mg NE of niacin	One µg of vit. B12	One µg of folate
Toledo								
Wheat bread	0.381	0.014	0.058	0.042	0.324	0.024	a/	0.004
Barley bread	0.399	0.019	0.085	0.215	1.410	0.061	a/	0.014
Rice	1.081	0.063	0.390	0.867	4.880	0.260	a/	0.013
Beans	1.185	0.014	0.191	0.046	0.679	0.122	a/	a/
Mutton	1.375	0.031	0.015	0.327	5.088	0.114	0.229	0.114
Hens	4.661	0.054	0.064	1.693	14.515	0.135	1.016	0.145
Codfish	8.701	0.038	1.146	1.718	8.592	0.491	0.344	0.137
Eggs	3.956	0.054	0.052	0.255	7.166	9.213	0.222	0.026
Sugar	3.951	a/	a/	38.919	a/	a/	a/	a/
Honey	1.535	1.105	a/	2.211	a/	2.211	a/	a/
Olive oil	0.540	a/	0.005	6.271	a/	a/	a/	a/
Wine	1.464	0.498	a/	0.111	a/	1.106	a/	0.498
Barcelona								
Wheat bread	0.430	0.016	0.065	0.047	0.366	0.027	a/	0.005
Barley bread	0.384	0.018	0.081	0.206	1.355	0.058	a/	0.014
Rice	0.796	0.046	0.287	0.639	3.592	0.192	a/	0.010
Beans	0.612	0.007	0.099	0.024	0.351	0.063	a/	a/
Mutton	1.310	0.030	0.014	0.312	4.848	0.109	0.218	0.109
Hens	3.963	0.046	0.054	1.440	12.341	0.115	0.864	0.123
Codfish	5.059	0.022	0.666	0.999	4.996	0.285	0.200	0.080
Eggs	3.466	0.047	0.046	0.223	6.278	8.072	0.195	0.023
Sugar	3.416	a/	a/	33.649	a/	a/	a/	a/
Honey	1.450	1.044	a/	2.088	a/	2.088	a/	a/
Olive oil	0.502	a/	0.005	5.825	a/	a/	a/	a/
Wine	1.044	0.355	a/	0.079	a/	0.789	a/	0.355

Notes: The table reports the cost of nutrients for a set of foodstuffs. The cost was obtained as the ratio of the price of a kg of the item divided by the amount of nutrients per kg of foodstuff. a/ The item does not contain any amount of the nutrient.

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