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Articles

Economic growth, nutrition and living standards in 19th century Lima: new estimates of welfare ratios using a linear programming model

Crecimiento económico, nutrición y niveles de vida en Lima en el siglo XIX: nuevas estimaciones de ratios de bienestar usando un modelo de programación lineal

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Abstract. This study relies on a linear programming model to estimate welfare ratios in 19th century Lima. By using a linear programming model, the food basket guarantees the intake of basic nutrients at the minimum cost. The subsistence cost includes the cost of food and other basic needs. The estimates show that low-skilled workers in Lima were able to cover their basic needs in 1800-1875. The results also show that living standards of low-skilled workers declined during the Guano Era. Living standards in Lima, however, compared favorably to several cities in Europe.

Key words: living costs; prices; wages; Lima.

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Resumen. Este estudio se basa en un modelo de programación lineal para estimar ratios de bienestar en Lima en el siglo XIX. Usando un modelo de programación lineal, la canasta de alimentos garantiza el consumo de nutrientes básicos al mínimo costo. El costo de subsistencia incluye el costo de los alimentos y otras necesidades básicas. Las estimaciones muestran que trabajadores poco calificados en Lima pudieron cubrir sus necesidades básicas en 1800-1875. Los resultados también muestran que los niveles de vida de los trabajadores poco calificados disminuyeron durante la Era del Guano. Los niveles de vida en Lima, sin embargo, no eran bajos en comparación con varias ciudades de Europa.

Palabras clave: costos de vida; precios; salarios; Lima.

JEL: N36; I32; J31; C61.

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INTRODUCTION

In the last years, several studies have focused on the standards of living in Latin America. Information on real wages and height suggests that living standards in many parts of Spanish America compared favorably to Europe in late colonial times (Dobado-González and García-Montero, 2014). In the 19th century, real wages improved in some Latin American economies and remained or declined in others.¹ There were important differences in living standards within Latin America; Argentina, for instance, had higher living standards than other cities in the region.²

Peru in the 19th century constitutes an interesting study case of living standards. Peru was one of the main commercial and economic centers in the Americas in colonial times. After Independence, Peru remained an important economy in the region. In the first decades of the 19th century, political instability affected the economy. The economic situation of Peru changed in the mid-19th century. In the 1850s and 1860s, Peru experienced a commercial boom due to the exportation of guano. The Guano Era was in fact one of the periods of fastest export growth in Latin America. The expansion of foreign trade led to the expansion of the economy in several regions of Peru, especially on the coast.

Could Limenians cover their basic needs in the 19th century? How did living standards evolve during this period? Did low-income families experience an improvement in living standards during the Guano Era?

Some studies suggest that low-income families in Lima did not increase their living standards during the Guano Era. For instance, Twrdek and Manzel (2010) indicate that height (proxy for nutrition) did not change during this period in spite of the economic bonanza. Other studies suggest that low-skilled workers could cover their basic needs, but experienced a decline in living standards during the Guano Era (Arroyo-Abad, 2014; Zegarra, 2020a).

¹ Some of the studies on living standards in Latin America are Challú & Gómez-Galvarriato (2015), Gelman and Santilli (2018), Arroyo-Abad (2014, 2013), Zegarra (2020).

² For estimates of welfare ratios for Argentina, see Gelman and Santilli (2018).

Welfare ratios constitute a useful indicator to determine the capacity of families to cover their basic needs. The welfare ratio is calculated as the ratio between total family income and the cost of subsistence.³ The cost of subsistence (also known as poverty line) is the cost of basic needs, such as food, clothing, fuel, housing, among others. If the welfare ratio is higher than 1.0, families are able to cover their basic needs.

Two methods can be employed to estimate the subsistence food basket and welfare ratios. One of those methods consists of using historical diets to determine the composition of the subsistence basket. In this case, welfare ratios are consistent with consumption habits. A potential weakness of relying on historical diets is that habits could vary across people and over time; so choosing a particular diet may be arbitrary and may introduce biases in the estimation of welfare ratios. An alternative methodology to estimate welfare ratios consists of using a linear programming model. Linear programming can be used to estimate the least-cost food basket that guarantees a minimum intake of important nutrients. Linear programming has been recently used for the estimation of welfare ratios in several economies (Allen, 2017, 2020; Zegarra, 2021). This method is useful to determine theoretically the food basket that a family must consume in order to ingest basic nutrients at the lowest possible cost. A potential weakness of the method is that families do not necessarily count with complete information on prices and nutrients and do not rely on a mathematical tool for the selection of their diets.⁴

Two studies have estimated welfare ratios for 19th century Lima. Like most historical estimations of welfare ratios, Arroyo-Abad (2014) relied on historical diets to estimate welfare ratios. In another study, I relied on a linear programming model to estimate the cost of food, but assumed that the composition of the food basket was not very different from 1860s diets (Zegarra, 2020a). Importantly, both studies assume that people should ingest at least minimum quantities of calories and proteins. A balanced-nutrition diet, however, should also include other nutrients, such as fat, iron and vitamins.

In this study, I estimate welfare ratios for low-skilled workers in 19th century Lima using an alternative methodology. I use a linear programming model and assume that the food basket should guarantee the intake of calories, proteins, fat, iron and some basic vitamins at the lowest possible cost. I do not assume that the food basket should be close to historical diets. I add expenses on fuel, clothing, housing and other basic goods in order to calculate the cost of subsistence. I then estimate the welfare ratios of low-skilled workers as the ratio between the family income and the cost of subsistence. The results of the linear programming model show that the least-cost food basket was composed of a large quantity of chickpeas, in addition to potatoes and mutton.

The estimates show that the welfare ratio in Lima was usually above 1.0. Low-skilled workers earned enough to cover the basic needs of their families. However, living standards declined during the Guano Era. Living standards were then negatively correlated with economic growth, at a time of increasing terms of trade and immigration of chinese workers. This result is consistent with the

³ When analyzing short-term differences in welfare ratios, one must take the results with caution. Welfare ratios may be more helpful when analyzing long-term or large differences in living standards across cities or countries. Other two methods can be used to analyze living standards. One could determine whether the actual intake of nutrients allow people to cover their basic nutrition needs, using information on actual diets. Alternatively, one could study biological measures of living standards. Height, for example, could be used to determine living standards. As López-Alonso (2016) indicates, there are several reasons to study biology measures of living standards. One of them is the lack of national statistics of other indicators of living standards. In addition, biological measures are useful to determine the inequalities of living standards and their evolution in the long run.

⁴ Families are not cost minimizers in the linear programming sense.

findings for other countries in Latin America: the evidence for the region suggests that if economic growth is associated with an increase in terms of trade and massive immigration, real wages may decline. Nevertheless, in spite of the decline in real wages during the Guano Era, low-skilled workers in Lima in the mid-19th century were not poorer than some of their Western European counterparts. Although living standards in Lima were below those in London, the welfare ratio in Lima was similar to the ratios in Amsterdam, Paris and Strasbourg in the 19th century.

HISTORICAL BACKGROUND

Peru has always been an economy in rich natural resources. The country has abundant mining resources in the highlands and rich valleys on the coast. Historically, Peru has exported natural resources. In colonial times, most of Peruvian exports were minerals and agricultural products. Among minerals, Peru's main export was silver. The country also exported agricultural products, such as sugar and bark. After Independence, Peruvian exports were also natural resources. From the late 1840s, Peru exported guano, entering into the Guano Era. In the 1870s, nitrates increased in importance. Sugar and cotton were also important exports in the 19th century.

The importance of the Peruvian export sector varied across regions. In the northern highlands, most of the southern highlands and in the jungle, mining had a limited scope and most agriculture was not destined to exportation. Exports came primarily from the coast and the central highlands.

By the mid-19th century, Lima had around 100 000 inhabitants. Lima was the largest city of Peru, a country of 2 000 000 inhabitants. Limenians conducted a variety of activities. In 1858, low skilled workers represented around 40% of the labor force (Zegarra, 2020a); among them, servants, launderers, cooks, laborers and mailmen were relatively important. In addition, artisans accounted for 25% of the labor force of Lima and merchants for 15%. The State employed around 12% of the labor force of Lima, including military personal and bureaucracy. Some people worked in nearby chakras, but they represented a minor proportion of the labor force of Lima (only 1%).

The Peruvian economy experienced important changes during the 19th century. In the 1820s, Independence wars affected the export sector. Exports of minerals fell between 1795 and 1830. Civil wars hit the country following Independence. Civil wars were frequent in 1825-1845 (Tantaleán, 2011). The Presidency changed 18 times between 1830 and 1845. Evasion, low levels of economic activity and civil unrest contributed to the limited capacity of the State to collect taxes.

The political and economic situation of the country dramatically changed from the mid-1840s. Civil wars were less frequent and governments were more stable. In addition, Peru started the exportation of guano from the late 1840s (Hunt, 2012). The export sector increased rapidly in the following years. In particular, the value of exports increased from 9 000 000 dollars in 1850 to 31 000 000 in 1860 and 50 000 000 in 1870 (Zegarra, 2018). Economic activity in Lima expanded. The credit market of Lima increased during the Guano Era (Camprubí, 1957): credit remained below 500 000 dollars in 1835-1845, but then increased to nearly 2 000 000 dollars in 1855 (Zegarra, 2016).

NUTRITION IN 19TH CENTURY PERU

Peruvians consumed a variety of foods in the 19th century. Some people consumed much meat and bread, whereas others consumed large quantities of maize, legumes and tubers.

In Lima, bread, meat, maize and tubers were widely consumed. In 1839, the annual consumption of an average Limenian included around 115 kg of bread, 67 kg of meat, 55 kg of maize, 43 kg of tubers (potatoes, sweet potatoes and yucas), among other items (see table 1). In the late 1860s, the annual diet of artisans in Lima was composed of almost 170 kg of meat, more than 100 kg of bread, 63 kg of rice, 42 kg of beans, in addition to lard, sugar and other items. Soldiers consumed similar quantities of meat, bread and beans as artisans, but far more tubers, more noodles and less rice. Convicts also consumed large quantities of meat and bread; in addition, they consumed far more potatoes than artisans and soldiers.⁵

The consumption of meat in Lima was relatively large for international standards. For instance, in modern Europe, a respectable diet of laborers included around 26 kg of meat per year (Allen, 2001). The high consumption of meat in Lima could be explained by a relatively low price of meat. Meat was indeed relatively cheap in Lima compared to London. In 1800-1850, one kilogram of beef in Lima cost around 2.5 times a kilogram of maize, the cheapest source of calories. In London, in the same period, one kilogram of beef cost around five times a kilogram of oats or barley, the cheapest sources of calories. Certainly, relative prices are not the only possible factor behind the large consumption of meat: one could also argue that living standards in Lima were relatively high.

In the highlands, the diet was different. It seems Indigenous people in Peru rarely consumed meat. Hill (1860), for example, indicated that people in Cuzco (in the Southern highlands of Peru) rarely ate meat more than once a week; and, on the rest of the week, their diets were primarily composed of maize and barley.⁶ In the late 1860s, laborers in the highlands consumed meat, but their diets were largely composed of maize. Potatoes, legumes and bread were also important items in their diets.

Diets varied according to economic level and social status. As expected, low-income families consumed smaller quantities of meat and other expensive sources of calories than medium-or high-income families. All over the coast, coolies did not consume as much meat as artisans;⁷ instead, they consumed more rice and legumes. Slaves consumed large quantities of potatoes. Laborers in the highlands also consumed large quantities of potatoes and maize.

⁵ Travelers' accounts also provide information on consumption habits. According to traveler Johann von Tschudi (1842), in Lima *sancochado* was the typical dish for breakfast and *puchero* was common for dinner. *Sancochado* was prepared with mutton, yucas and potatoes, whereas *puchero* was prepared with beef, pork, ham, sausage, poultry, cabbage, yucas, sweet potatoes, potatoes, rice, peas, maize and bananas. Outside the city, in Chorrillos, "they [Indians] subsist on fish and maize, and the sugar cane, of which there are some plantations in the neighborhood" (Mathison, 1825, p. 279).

⁶ Hill (1860, vol. I, p. 259).

⁷ Artisans were usually not rich, but probably had higher living standards than coolies.

Thiam.	128	87	146	138	81	122	107
Niacin	149	182	211	195	99	201	138
Vit. B12	211	383	425	398	188	0	132
Folate	206	314	357	413	466	1001	447
Vit. C	92	8	67	130	138	31	110

Notes: The table reports diets of Peruvians in 1839 y 1869, and the intake of nutrients as a percentage of the minimum requirement for an adult male. The nutrition requirements are 3 300 kcal calories, 60 g of proteins, 38 g of fat, 17 mg of iron, 1.7 mg of thiamine, 21 mg NE of niacin, 1 μ g of vitamin B12, 200 μ g of folate and 40 mg of vitamin C per day.

Sources: Córdova y Urrutia (1992) and Pardo et al (1870) reports the production of the main foodstuffs in the valleys of Lima to be sold in the city of Lima, as well as the importation of foodstuffs from other provinces into Lima. From those figures, one can obtain total consumption in Lima. To calculate per-capita consumption, I rely on the population of Lima in 1836. To calculate the equivalent of a male adult, I rely on the ratio of calorie requirements of a male adult with respect to the calorie requirements for an average person. The table also reports the food baskets of male adults in Peru in 1869 from Pardo et al (1870). For soldiers, the table reports the average quantities in the diets of a soldier from the Army and a sailor from the Navy (Pardo et al, 1870). For convicts, the table reports the average quantities in the diets of convicts in two jails in Lima (Pardo et al, 1870). For coolies, the table reports the average quantities using several diets of coolies (Pardo et al, 1870). For laborers in the highlands, the table reports the average quantities from the diets of a mining laborer in Cerro de Pasco, a railroad laborer in Arequipa and a Indigenous laborer (Pardo et al, 1870).

Did Peruvians and, in particular, Limenians consumed enough nutrients for a healthy life? To answer this question, I rely on the nutrients' requirements for a healthy life and the chemical composition of foodstuffs. People require calories and proteins for survival. In addition, people require fat, iron and vitamins for a balanced nutrition. Requirements of nutrients depend on age, height, weight and type of occupation. Calorie requirements partly depend on weight. I assume a weight of 55 kg for adult men and 50 kg for adult women.⁸ I also assume a daily energy requirement of 2.2 BMR for men and 1.8 BMR for women, which implies heavy work for men and moderate work for women. A man of 18-30 years of age would then need 3 300 kcal calories per day, and a woman in the same age range would need 2 200 kcal calories per day.⁹ Following Allen (2017), I rely on Indian dietary requirements of proteins, fat, iron and vitamins (Rao, 2009). Since Indian dietary requirements are calculated assuming a weight of 60 kg for men (only slightly more than the weight of Limenians), those requirements may be close to the nutrition needs of 19th century Limenians. Therefore, in addition to 3 300 kcal calories, a male adult would require 60 g of proteins, 38 g of fat, 17 mg of iron, 1.7 mg of thiamine, 21 mg NE of niacin, 1 μ g of vitamin B12, 200 μ g of folate and 40 mg of vitamin C per day.

Information on the chemical composition of foodstuffs comes from several sources.¹⁰ I adjust the information from the composition tables to obtain the actual consumption of nutrients per purchased kilogram of food. In particular, I take into account that some portions of the foods were discarded. Indian dietary requirements take into account the loss of nutrients during cooking (Allen, 2017; Rao, 2009).

Let us analyze whether Limenians obtained enough nutrients for a healthy life. In the late 1830s, Limenians did not consume enough calories. On average, a male adult consumed 2 700 kcal calories per day. This amount was below the daily requirement of 3 300 kcal calories for hard work. In the late 1860s, some consumed enough calories. Artisans, for instance, obtained 15% more calories than needed. Soldiers and convicts also covered their requirements of calories. Coolies, slaves and laborers in the highlands, however, consumed fewer calories than required. For some people, other nutrients were not ingested in sufficient quantities. For instance, slaves did not consume vitamin B12, because of the lack of meat in slaves' diets (as reported by contemporary accounts). Some diets were also deficient on vitamin C.

Therefore, our calculations suggest that diets varied across locations and occupations and that not all Peruvians satisfied their nutrition needs. Nevertheless, one must be cautious about these calculations. The information on diets is scattered. I do not count with detailed information about the diets of Limenians. For 1839, I estimated the average consumption of foods in Lima. For that year, however, it is not possible to determine how diets varied across Limenians. There is information on the diversity of diets in Peru for some occupations for 1869, but not for other years.

In the following sections, I opt for a different method to determine whether Limenians were able to cover their basic needs. In particular, I estimate welfare ratios.

⁸ I do not have information on weight of Limenians. I rely on information about height. The height of an average male adult in Peru was around 1.60-1.65 m (Twrdek and Manzel, 2010). For a height of 1.63 m, a weight of 55 kg would imply a BMI of 20.7, reflecting a normal weight.

⁹ For pre-1900 Europe, Allen (2009) assumed that an adult man would need less than 2 000 kcal/day of calories. Humphries (2013), however, challenged such assumption.

¹⁰ See the appendix for a further discussion of the sources and methodology to obtain the chemical composition of foodstuffs.

ESTIMATING THE COST OF A BALANCED-NUTRITION DIET

In the last two decades, a large number of studies have estimated welfare ratios in order to determine the capacity of workers to cover the basic needs of their families. The welfare ratio is calculated as the ratio of total family income divided by the cost of subsistence, where the cost of subsistence includes the cost of food and other basic expenses. If the welfare ratio is greater than 1.0, then the family income is higher than the cost of subsistence. If the welfare ratio is less than 1.0, then the family income is lower than the cost of subsistence.

Methodology to estimate the food basket

To estimate the cost of food, one needs to assume the composition of the food basket at subsistence levels. Most studies usually rely on historical diets in order to estimate the cost of food of low-income families. Historical diets constitute valuable information on consumption patterns. Relying on historical diets to estimate the cost of subsistence, however, may be problematic. One potential problem is that historical accounts usually do not provide information on all types of diets, but only on an average diet. Using an average diet for a long period may overshadow the differences in diets over time and so bias the results. On the other hand, when comparing living standards across countries, it is not clear which food baskets should be used. Using the same basket for all countries may not account for the differences in relative prices and habits. Assuming different diets, however, also involves challenges: it would be hard to determine whether the different baskets are comparable.¹¹

In addition, one must be careful about the content of nutrients in historical diets. If the consumption habits in the past did not grant the intake of all necessary nutrients for a healthy life, then one must necessarily adjust those diets. Diets with excessive nutrients may be also problematic: diets with excessive calories may be relatively expensive. By using an over-expensive food basket, one may reach the incorrect conclusion that wages were not high enough to cover the basic nutrition needs of low-income families.

Foodstuffs vary on the composition of nutrients. Some items provide many calories. Others provide many proteins and vitamins. Foodstuffs also vary on price. For instance, meat was far more expensive than maize and tubers in 19th century Lima. Considering the differences in prices and in the chemical composition of foodstuffs, it is not clear which basket would be the cheapest form of ingesting all necessary nutrients. Should the subsistence basket include maize and meats? Should it also include legumes and potatoes?

Linear programming can be very useful to estimate the composition of the subsistence food basket. By using a linear programming model, one can determine the quantities of foodstuffs that minimize the cost of food subject to restrictions on nutrients' intakes.

I use a linear programming model to determine the least-cost food basket of Lima in the 19th century. I assume that Limenians could consume the following items: wheat bread, maize, rice, noodles, quinoa, common beans, chickpeas, butter beans, potatoes, beef, mutton, chicken, lard and sugar.¹² I only rely on these goods because of the availability of price information. Limenians could have also consumed other goods, but information on prices of other goods is scattered.

¹¹ In fact, López-Losa and Piquero-Zarauz (2021) argue that much of the cross-country differences in welfare ratios could be explained by the selection of the food basket.

¹² I do not include fish due to lack of price information. Including fish could potentially increase welfare ratios.

The linear programming model can be expressed as follows:

$$\text{Min}_{\{q_j\}_{j=1}^N} \sum_{j=1}^N p_j q_j$$

subject to

$$\sum_{j=1}^N \alpha_j q_j \geq F_L^K$$

$$q_j \geq 0$$

where $\sum_{j=1}^N p_j q_j$ is the total cost of the food basket, N is the number of items in the food basket, p_j is the price of good j per kilogram, and q_j is the consumed quantity of good j in kilograms. I impose K restrictions on nutrients. In those restrictions, α_{jk} is the quantity of nutrient k in a kilogram of product j ($k = 1, 2, \dots, K$), F_L^K is the minimum quantity of nutrient k for a healthy nutrition.

Following Allen (2017, 2020), I calculated the requirements of nutrients for an average person. To do so, I relied on the distribution of the population for Lima from the Census of 1876. Requirements of calories come from FAO (1985); requirements of other nutrients come from Rao (2009). Then an average person in 19th century Lima would need at least 2,538 kcal calories, 52 g of proteins, 33 g of fat, 19 mg of iron, 1.3 mg of thiamine, 16 mg NE of niacin, 0.7 μg of vitamin B12, 183 μg of folate and 41 mg of vitamin C per day.

Linear programming is not exempted from criticism. The optimal basket may not reflect consumption habits, and habits may be hard to change. In addition, families do not necessarily count with complete information on prices and nutrients. Families also do not rely on a mathematical tool such as a linear programming model when selecting their diets. For low-income families, however, relative prices may play a key role (Allen, 2017).

Rather than stating that a linear programming model is superior to using historical diets, I argue that both methodologies are complementary. Each method has advantages and disadvantages. When using historical diets, welfare ratios are useful to determine the capacity of families to cover their actual consumption habits. When using linear programming, welfare ratios are useful to determine whether the incomes of families could have granted their basic needs, including having a balanced-nutrition diet.

The balanced-nutrition basket

I rely on the linear programming model to estimate the composition of the food basket. I assume p_j is equal to the median prices in 1800-1873 for each product in Lima. I take into account the requirements of calories, proteins, fat, iron, thiamine, niacin, vitamin B12, folate and vitamin C. I call the optimal basket the “balanced-nutrition basket” or simply BN basket.

Table 2 reports the balanced-nutrition basket for an average person. The basket is composed of 239 kilograms of chickpeas, 15 kg of potatoes and 17 kg of mutton per year. The basket satisfies all restrictions. The binding constraints are those for calories, vitamin B12 and vitamin C. Chickpeas have a large participation in the food basket. This result is not surprising: at median prices of 1800-1873, one gram of silver on chickpeas yielded 2 248 kcal calories, much more than one gram of

silver on other foodstuffs. Chickpeas also provided more proteins, iron, thiamine and folate per gram of silver than other foodstuffs. Meanwhile, the selection of mutton can be explained by the provision of vitamin B12: one gram of silver on mutton provided 3.8 μg of vitamin B12, whereas one gram of silver on beef provided 2.6 μg of vitamin B12.

Figure 1 depicts the evolution of the cost of the balanced-nutrition food basket per day. The daily food cost for the average person was around one gram of silver in the 1800s. It then increased during Independence wars, surpassing 1.9 grams of silver in the late 1810s. After Independence, the daily cost of food declined to 1.2 grams of silver in the early 1830s. It remained around one gram of silver in the late 1840s and early 1850s. During the Guano Era, however, the food cost increased. In the early 1870s, the daily cost of food was around two grams of silver per day.

I calculated a single food basket for the entire period of 1800-1873 using median prices for this period. Food baskets, however, could have changed in response to changes in prices over time. Are there differences in the food cost when allowing food baskets to change over time? To answer this question, I estimate the food basket for each decade, using the median prices of each decade.¹³ Our estimates show that changes in the food basket do not affect the food cost significantly (see figure 1). The main differences in the cost of food between the fixed basket and the changing baskets refer to the late 1810s, late 1830s and early 1840s. Even then, however, the differences in the food cost were not large.

Let us compare the balanced-nutrition food basket (BN basket) and the baskets from Gootenberg (1990), Arroyo-Abad (2014) and Zegarra (2020), which partly rely on historical diets (see table 3). Those studies report food baskets for a male adult; for comparison purposes, I converted those baskets to baskets for an average person. Gootenberg (1990) relies on historical diets to estimate a price index for Lima. Gootenberg's food basket was not a subsistence basket but was supposed to reflect the consumption habits of artisans. The basket for an average person is composed of more than 80 kg of bread and around 130 kg of meat per year. This basket is also composed of dozens of kilograms of rice and beans per year. The basket was very expensive: at median prices of 1800-1873, it would cost around 3.2 grams of silver per day, equivalent to 2.5 times the cost of the BN basket. Other studies assume that the food basket was similar to 19th century consumption habits (Arroyo-Abad, 2014; Zegarra, 2020a). Those baskets were more expensive than the BN basket, but cheaper than Gootenberg's basket.¹⁴

¹³ Alternatively, one could calculate the geometric mean of relative prices to take into account the effect of relative prices on consumption (Allen, 2001). When using the geometric mean, the series of the cost of food is practically the same as the original cost of the fixed basket.

¹⁴ On the other hand, the three historical baskets only satisfy some of the nutrients' requirements imposed in our balanced-nutrition linear programming model. The estimates of Arroyo-Abad (2014) and Zegarra (2020) rely on the traditional assumption that an adult should consume at least 1 900 kcal/day. The BN linear programming model in this study imposes higher restrictions on calories. In addition, this study imposes restrictions on fat, iron and vitamins.

TABLE 2. BALANCED-NUTRITION FOOD BASKET

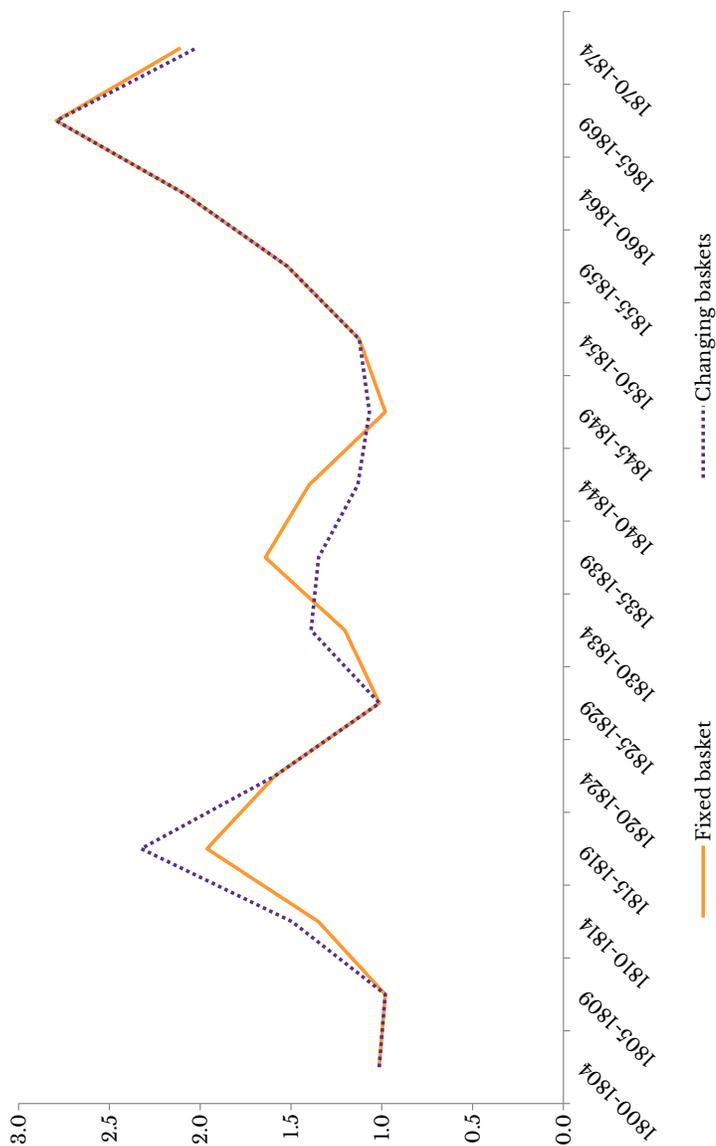
	<i>Fixed basket</i>		<i>Decade baskets</i>					
	1800-1809	1810-1819	1820-1829	1830-1839	1840-1849	1850-1859	1860-1869	1870-1878
<i>Consumption per year</i>								
Bread	0	0	0	0	0	0	0	0
Maize	0	0	0	0	0	0	0	0
Rice	0	0	0	0	0	0	0	0
Noodles	0	0	0	0	0	0	0	0
Quinoa	0	217	0	0	0	0	0	0
Beans	0	0	0	180.6	180.6	0	0	0
Chickpeas	239.4	0	239.4	79.8	79.8	239.4	239.4	183.4
Butter beans	0	0	0	0	0	0	0	65.1
Potatoes	15.1	158.4	15.1	46.1	46.1	15.1	15.1	0
Beef	0	0	0	0	0	0	0	0
Mutton	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
Chicken	0	0	0	0	0	0	0	0
Lard	0	0	0	0	0	0	0	0
White sugar	0	0	0	0	0	0	0	0
<i>Cost of food (grams of silver per day)</i>	1.29	0.97	1.24	1.32	1.08	1.20	2.28	1.96
<i>Nutrients per day</i>								
Calories	2 538.3	2 538.3	2 538.3	2 538.3	2 538.3	2 538.3	2 538.3	2 538.3
Proteins	132.3	94.5	132.3	153.4	153.4	132.3	132.3	138.5
Fat	51.8	46.6	51.8	32.7	32.7	51.8	51.8	44.6
Iron	55.2	47	55.2	50.3	50.3	55.2	55.2	54.2
Thiam.	2.6	3.2	2.6	2	2	2.6	2.6	2.4
Niacin	20.5	16.2	20.5	45.5	45.5	20.5	20.5	21.3

Vit. B12	μg	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Folate	μg	3 661.3	3 661.3	1 160.5	3 661.3	3 267	3 661.3	3 661.3	3 661.3	3 661.3	3 503.8
Vit. C	mg	40.5	40.5	56.4	40.5	40.5	40.5	40.5	40.5	40.5	40.5

Notes: The table reports the composition of the balanced-nutrition (bn) food basket as well as the intake of nutrients for an average person. The figures refer to an average person. The minimum requirements for an average person are 2,538 kcal calories, 52 g of proteins, 33 g of fat, 19 mg of iron, 1.3 mg of thiamine, 16 mg of niacin, 0.7 μg of vitamin B12, 188 μg of folate and 41 mg of vitamin C per day.

Source: Our own calculations, based on the linear programming model.

FIGURE 1. COST OF FOOD (GRAMS OF SILVER PER DAY)



Notes: The figure depicts two series of the cost of food per day for one adult in grams of silver. The fixed basket refers to the optimal food basket at median prices of 1800-1873. Changing baskets refer to optimal food baskets for every decade at median decade prices. To calculate the cost of food for a five-year period, I first calculated the cost of food for each year and then computed the average cost for each five-year period.
 Source: Our own calculations based on the linear programming model.

TABLE 3. COMPARISON OF FOOD BASKETS

	<i>Balanced-nutrition basket (BN basket)</i>	<i>Based on historical diets</i>						
		<i>Gootenberg (1990)</i>		<i>Arrollo-Abad (2014)</i>		<i>Zegarra (2020)</i>		
		A	B	A	B	A	B	
<i>Consumption per year</i>								
Bread	kg	0	104.8	80.6	49.1	37.8	10.9	8.4
Maize	kg	0	0	0	0	0	0	0
Rice	kg	0	62.8	48.3	58.9	45.3	73.7	56.7
Noodles	kg	0	0	0	0	0	0	0
Quinoa	kg	0	0	0	0	0	0	0
Beans	kg	0	42	32.3	49.1	37.8	28.2	21.7
Chickpeas	kg	239.4	0	0	0	0	0	0
Butter beans	kg	0	0	0	0	0	0	0
Potatoes	kg	15.1	0	0	0	0	42.5	32.7
Beef	kg	0	56	43.1	98.2	75.5	43.2	33.2
Mutton	kg	16.8	56	43.1	0	0	19.3	14.8
Chicken	kg	0	56	43.1	0	0	4.8	3.7
Lard	kg	0	20.8	16	11.8	9.1	10.8	8.3
White sugar	kg	0	0	0	0	0	1.4	1.1
<i>Cost of food (grams of silver per day)</i>		1.29		3.24		1.81		1.44

Notes: The table compares the balanced-nutrition basket (BN basket) and baskets derived from historical diets. For the BN basket, the figures refer to an average person. When using historical diets, the figures refer to a male adult (A) and an average person (B). I converted the baskets for a male adult from Gootenberg (1990), Arroyo-Abad (2014) and Zegarra (2020a) to baskets for an average person. To make the conversion, I rely on the ratio of calorie requirements of a male adult with respect to the calorie requirements for an average person.

Sources: Gootenberg (1990), Arroyo-Abad (2014), Zegarra (2020a) and our own calculations based on the linear programming model.

WAGES AND WELFARE RATIOS FOR LOW-INCOME FAMILIES

Welfare ratios are useful to determine whether families are able to cover their basic needs. The welfare ratio is calculated as the ratio of total family income divided by the cost of subsistence, where the cost of subsistence includes the cost of food and other basic goods and services. I rely on the balanced-nutrition basket to compute the food cost. I call our welfare ratios “balanced-nutrition welfare ratios” or, simply, BN welfare ratios. If the welfare ratio is greater than 1.0, then the family income is higher than the cost of subsistence. If the welfare ratio is less than 1.0, then the family income is lower than the cost of subsistence.

The subsistence cost includes the cost of food, as well as the cost of fuel, clothing, housing, and other basic items. I rely on the fixed basket (estimated with the median prices of 1800-1873) to calculate the cost of food. I add the cost of fuel, clothing, soap, candles, oil and housing. To estimate the requirement of fuel, I rely on the relation between the quantity of wood and the quantity of food in the budget of artisans in the late 1860s, as reported by Pardo et al. (1870). I then assume that an average person required 1.79 M BTU of fuel per year.¹⁵ In addition, I assume that an average person required 3 meters of cotton, 1.3 kg of candles, 1.3 kg of soap, and 1.3 liters of oil per year.¹⁶ I assume that a family is composed of four members, so the subsistence cost of a family is four times the cost of an average person. In the case of Lima, considering that children and adolescents represented almost half of the population, the assumption of four members (two adults and two children) in a family is reasonable.¹⁷ In addition, I assume that a family rented a room in a *callejón*. A *callejón* (in plural, *callejones*) was a building composed of an alley and several rooms, inhabited by poor families.

Information on salaries of low-skilled workers comes from primary and secondary sources.¹⁸ Wages refer to laborers, doormen, mailmen and servants.¹⁹ The appendix describes the data sources. For doormen, mailmen and servants, information refers to annual salaries. Information on laborers' salaries is available from the 1800s. For doormen and servants, information on salaries is available from the late 1820s; for mailmen, wages are available from the late 1830s. For laborers, information refers to payments for a day of work or *jornales*. I assume that laborers could work between 250 and 365 days per year. Several studies have assumed that laborers worked 250 days per year (Allen, 2001, 2009). Other studies, however, have questioned this assumption (Stephenson, 2018). For Lima, I do not count with information on the number of working days per year. However, since annual incomes of servants were around 250 times the *jornal* (payment for a day of work) of laborers in most of the period and annual incomes of doormen and mailmen were around 365 times, it is reasonable to assume that the number of working days of laborers ranged between 250 and 365.

A possible weakness of the data is that wages refer to government workers. Salaries in the private sector could be different from government salaries. The government may take time to adjust salaries to market conditions. Scattered evidence, however, suggests that, at least in the

¹⁵ Allen (2009) assumes that a male adult requires 2.0 M BTU in pre-1900 Europe.

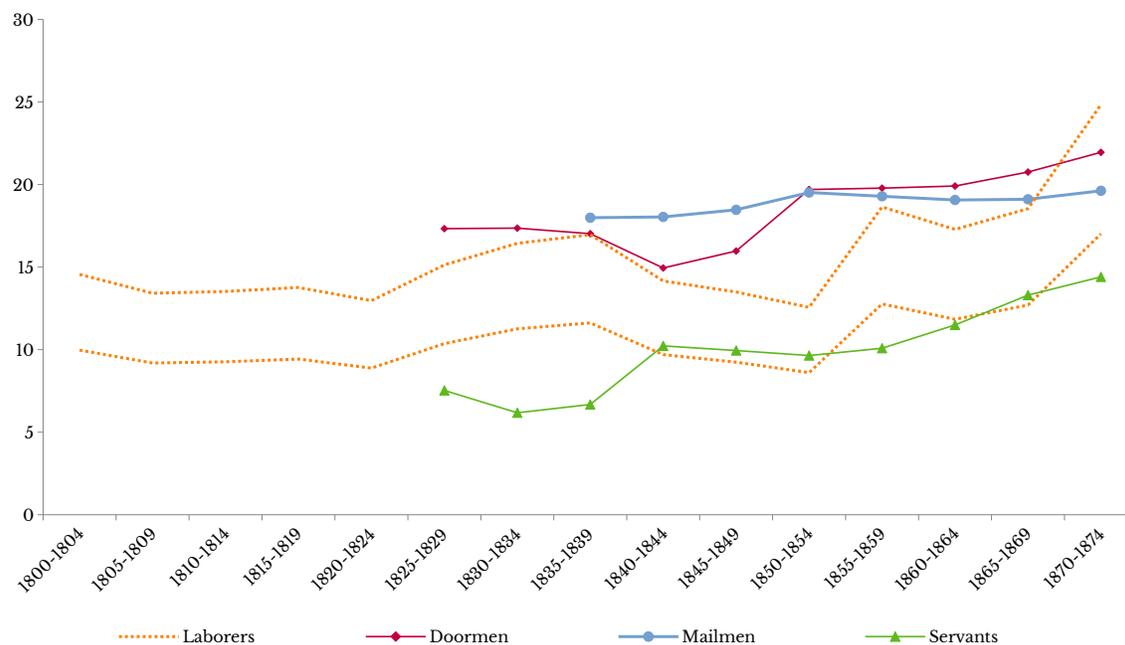
¹⁶ Allen (2009) makes similar assumptions for a male adult.

¹⁷ For other cities in the region, the family size could be different. Not taking into account those differences would introduce biases in the estimation of welfare ratios (Morales and Thul, 2018).

¹⁸ I previously used the same data set from the 1820s (Zegarra, 2020a).

¹⁹ Some studies usually only focus on salaries of masons, which may not be representative of unskilled workers (Morales and Thul, 2018).

FIGURE 2. DAILY WAGES IN THE CITY OF LIMA (GRAMS OF SILVER)



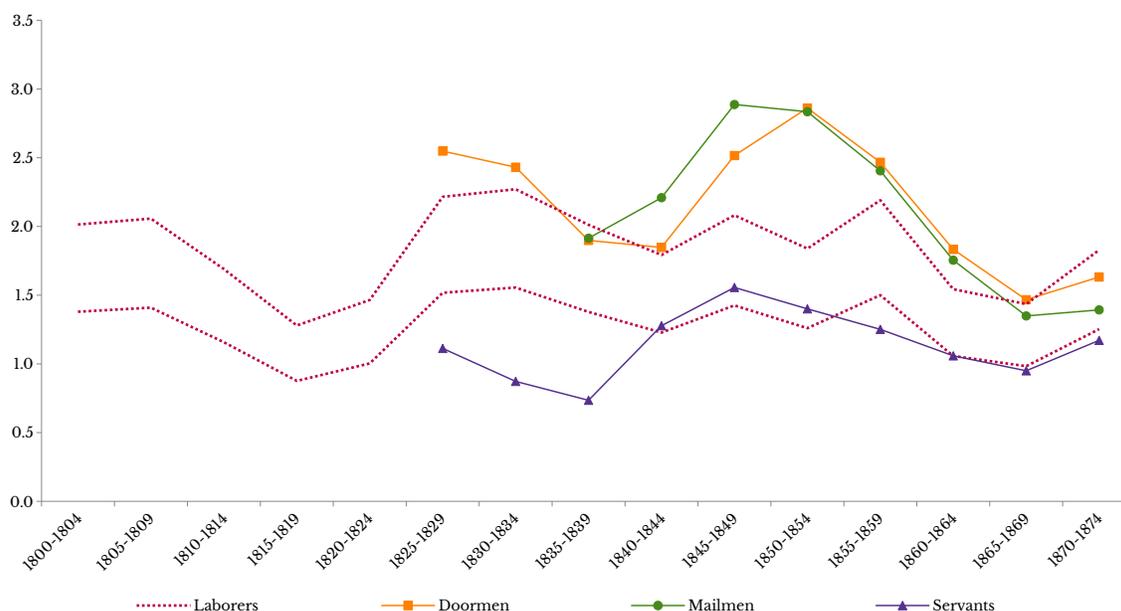
Notes: The figure depicts the average daily wage for laborers, doormen, mailmen and servants. For laborers, I report the lower and upper levels. The lower level is calculated under the assumption that laborers worked 250 days per year. The upper level is calculated under the assumption that laborers worked 365 days per year.

Sources: Our own calculations, based on information from the Municipality of Lima and the National Archives of Lima. See the appendix for more information.

long term, government salaries reflected market conditions. For instance, contemporary observers indicate that laborers earned around one peso per day in the late 1860s. The data also shows that laborers earned around one peso per day in 1867-68.

Figure 2 depicts the evolution of daily nominal wages in grams of silver. For doormen, mailmen and servants, the daily wage was calculated as the annual labor income divided by 365. For laborers, I calculated the daily wage as D times the *jornal* (payment for a day of work), where $D = \{250/365, 1\}$. In the 1800s, 1810s and 1820s, laborers earned between 10 and 15 grams of silver per day. Daily wages of laborers then increased to 11.6-17 grams of silver in the late 1830s, but later declined to 8.6-12.6 grams of silver in the early 1850s. In the following decades, daily wages of laborers increased, becoming 17-24 grams of silver in the early 1870s. Meanwhile, daily salaries of doormen declined from 17 grams of silver in the 1830s to 15 grams of silver in the early 1840s, but then increased in the following decades. In the early 1870s, daily wages of doormen were 22 grams of silver. Wages of mailmen were similar to those of doormen in the 1850s, 1860s and 1870s. In the case of servants, daily wages were around 6.5 grams of silver in the 1830s. Salaries then remained around 10 grams of silver per day in the 1840s and 1850s, but increased in the 1860s and 1870s. In the early 1870s, daily salaries of servants were around 14.5 grams of silver.

FIGURE 3. WELFARE RATIOS IN THE CITY OF LIMA (FIXED FOOD BASKET)



Notes: The figure depicts the welfare ratios for laborers, doormen, mailmen and servants. For laborers, I report the lower and upper levels. The lower level is calculated under the assumption that laborers worked 250 days per year. The upper level is calculated under the assumption that laborers worked 365 days per year. The food basket is the fixed BN basket.

Our own calculations, based on information from the Municipality of Lima and the National Archives of Lima. See the appendix for more information.

Welfare ratios are calculated as the total earnings of a family divided by the cost of subsistence. I assume that only one male adult worked per family and that workers did not receive in-kind compensation for their work.²⁰ Figure 3 depicts the evolution of the BN welfare ratios (balanced-nutrition welfare ratios). Laborers had a welfare ratio of 1.4-2.1 in the 1800s. The ratio then declined in the 1810s and 1820s. In the early 1820s, the ratio ranged between 1.0 and 1.5. The welfare ratio then increased to 1.6-2.3 in the early 1830s. During the Guano Era, the welfare ratio declined to 1.2-1.8 in the early 1850s and 0.9-1.5 in the late 1860s. In the case of doormen, the welfare ratio was around 1.9 in the early 1830s, then increased to 2.8 in the early 1850s and later declined to 1.5 in the 1860s and 1.6 in the 1870s. Living standards of mailmen were similar to those of doormen. In the case of servants, the welfare ratio was relatively low. It was below 1.0 in the 1830s, increased to 1.6 in the late 1840s, but then declined in the 1850s and 1860s. In the late 1860s, the welfare ratio of servants was around 1.0.

²⁰ Several studies rely on similar assumptions. However, I must acknowledge the possible biases of these assumptions. First, women could also work for a salary (Calderón-Fernández, García-Montero and Llopis-Agelán, 2017; Humphries and Weisdorf, 2015). Second, workers could receive in-kind compensation in addition to their salaries (Djenderedjian and Martirén, 2020).

In order to estimate welfare ratios, this study uses a linear programming model that guarantees the intake of basic nutrients. Alternative food baskets could yield different welfare ratios. I then estimate welfare ratios using historical diets. In particular, I use the food baskets from Gootenberg (1990), Arroyo-Abad (2014) and Zegarra (2020). I adjusted the food baskets, so they reflect the consumption of an average person. I rely on our information on prices and wages and on our assumptions on family size, number of people who worked and number of working days.²¹ Figure 4 depicts the series for laborers, assuming that laborers worked 250 days per year. All series point out at similar trends: an increase in the 1830s and a significant drop in the 1850s and 1860s. Nominal salaries did not change much during the Guano Era in spite of the increasing inflation. Since nominal wages did not increase as rapidly as prices, real wages declined.

Nevertheless, there are important differences in the magnitudes of the welfare ratios between this study and other studies. The BN welfare ratios are usually higher than the ratios estimated using historical diets. When using the basket from Gootenberg, for example, the welfare ratio is less than 1.0, far less than the BN welfare ratios. Using the baskets of Arroyo-Abad (2014) and Zegarra (2020), the welfare ratio would be below the BN ratios most of the time. A comparison of the BN ratios with those for Gootenberg clearly illustrates the differences between linear programming and historical diets. As indicated previously, the basket from Gootenberg refers to the typical diet of artisans. The estimates of BN welfare ratios suggest that the labor income of a low-skilled worker allowed him to cover the basic nutrients of his family. In contrast, the results for the Gootenberg's basket show that the same labor income did not allow the worker to afford the consumption habits of an artisan's family. To afford those consumption habits, low-income families would need another person (such as the wife) to work for a salary.

The BN estimates suggest that living standards did not improve during the Guano Era. Other estimations of welfare ratios also suggest that the living standards of low-income families did not increase during this period of macroeconomic bonanza (Gootenberg, 1990; Arroyo-Abad, 2014; Zegarra, 2020a). In addition, the evidence on the height of low-income Limenians supports the hypothesis that living standards did not improve during the Guano Era. In particular, Twrdek and Manzel (2010) collected information on the height of convicts in Lima and found that height did not increase during the Guano Era. Since those convicts belonged to the low-income segments of society, the evidence suggests that low-income families did not improve their nutrition during the Guano Era in spite of the macroeconomic bonanza.

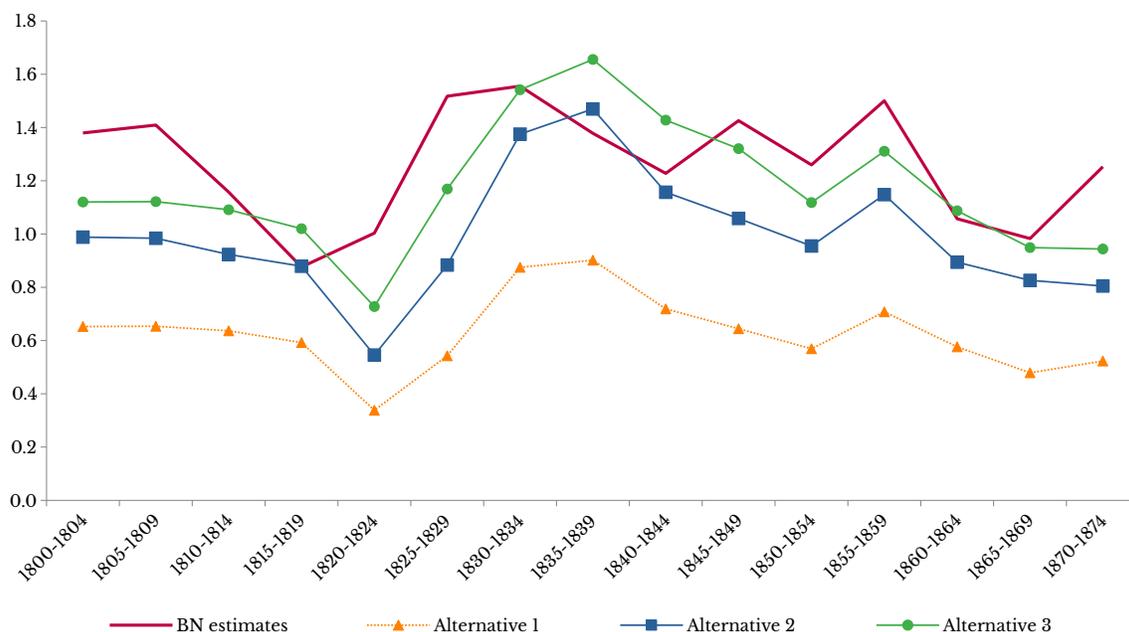
How can one explain the decline of the living standards of low-income families in Lima during the Guano Era, a period of economic bonanza?

The Guano Era was a period of substantial economic growth in Lima. From a theoretical point of view, it is possible that the growth of the economy led to the increase of living standards of all inhabitants, including low-income families. For instance, laborers and servants could have faced a higher demand for their services, which would increase real wages.

Real wages, however, declined. One possible explanation for the decline of real salaries during the Guano Era is that there were nominal rigidities. Under nominal rigidities, nominal salaries do not increase as rapidly as prices and so real wages decline in the presence of inflation. If the expansion of the economy led to the increase of earnings of high-income families, the higher demand for services could have led to higher prices. One might expect workers to require higher nomi-

²¹ Notice that Arroyo-Abad (2014) and Zegarra (2020) did not make the assumptions on family size. Those studies rely on Allen's assumption that family costs are equal to three times the costs for a male adult.

FIGURE 4. WELFARE RATIOS LABORERS IN LIMA, USING ALTERNATIVE FOOD BASKETS



Notes: The figure depicts the welfare ratios for laborers using alternative food baskets. For all series, I assume that laborers worked 250 days per year. One series refers to our estimates, using the fixed basket. Alternative 1 relies on the food basket of Gootenberg (1990). Alternative 2 relies on the food basket of Arroyo-Abad (2014). Alternative 3 relies on the food basket of Zegarra (2020a). Non food costs are the same for all series.

Source: Our own calculations based on the linear programming model, Gootenberg (1990), Arroyo-Abad (2014) and Zegarra (2020a).

nal wages to face higher prices. If nominal wages did not change rapidly, real wages would have declined. Nominal rigidities are usually associated with the existence of contracts or institutional restrictions. Nominal rigidities may explain a short-term decline in real wages during inflationary periods. However, it is hard to make a theoretical argument for a negative relationship between inflation and real wages in the long term.

The increase of terms of trade could also explain at least partly the decline of real wages in Lima during the Guano Era. Standard trade theory states that terms of trade may be correlated with the wage/rental ratio. In particular, the Heckscher-Ohlin model states that an increase in terms of trade may lead to a decline in the wage/rental ratio in land abundant economies and an increase in the ratio in labor abundant economies. For economies that export raw materials, a period of economic bonanza, associated with an increase in terms of trade, could be associated with the decline in the wage/rental ratio. Terms of trade increased in Peru during the Guano Era. The increase in terms of trade may have increased the demand for production factors in export sectors, in particular, in the sectors producing guano, nitrate, sugar and cotton. Since those sectors

were intensive in land and capital, the increase in terms of trade may have increased the overall demand for capital and land and may have reduced the overall demand for labor. The reduction in the demand for labor in turn would have reduced real wages.

Immigration of workers could also explain the decline in real wages in Lima. Peru experienced a massive immigration of Chinese coolies in 1849-74, especially in the late 1860s. By 1876, around 50 000 Chinese citizens lived in the coast of Peru, representing around 4% of the total population. Since most Chinese immigrants were unskilled workers, immigration could have increased the supply of low-skilled labor and so could have reduced real wages.

Therefore, in the short run the decline in real wages during the Guano Era could be partly explained by higher inflation. In the long term, however, one would expect real wages to depend on changes in the demand for labor and supply of labor. The increase in terms of trade and immigration of Chinese workers could explain the long-term decline in real wages of unskilled workers during the Guano Era.

INTERNATIONAL COMPARISON

An international comparison of welfare ratios is useful to determine the differences in living standards across cities and the possible determinants of living standards.

Comparison with other Latin American cities

No study has used linear programming to estimate welfare ratios for other Latin American cities. I then cannot determine whether welfare ratios in Lima were relatively high or low for Latin American standards. However, a comparison of the trends of welfare ratios across cities can provide useful insights. In particular, such comparison may provide some insights about the relationship between real wages and economic growth.

The evidence for 19th century Lima indicates that economic growth is not necessarily associated with an increase in living standards. Does the evidence for other Latin American economies point out in the same direction?

In the 19th century, economic growth in some Latin American countries was associated with increasing terms of trade, massive immigration and expansion of the frontier. As stated by the Heckscher-Ohlin model, increasing terms of trade in Latin America (a land-abundant region) and massive immigration would lead to a reduction in the wage/rental ratio (Arroyo-Abad, 2013; Williamson, 1999). The increasing terms of trade would lead to a lower demand for labor. In addition, immigration may have led to a greater supply of labor. Real wages could have declined due to the lower demand for labor and the greater supply of labor. However, the expansion of the frontier could reduce or counteract the effect of terms of trade and immigration on real wages. These were certainly not the only factors affecting real wages in 19th century Latin America. In some countries, civil wars also affected capital stock, the labor supply, productivity and therefore real wages.

In Argentina, the economy expanded from 1840. As the economy grew, real wages grew in Buenos Aires in 1825-1849 (Gelman and Santilli, 2018). Real wages in Buenos Aires continued increasing in the 1880-1900 (Cuesta, 2012). The growth of the economy occurred at a time of increasing terms of trade. According to Arroyo-Abad (2013), terms of trade and factor endowments affected the wage-rental ratio. Terms of trade could have reduced real wages; but the

expansion of the frontier and the consequent increase in land stock counteracted the negative effect of increase terms of trade on real wages in the 19th century. In the early 20th century, real wages remained stagnant. In the 1900s and 1910s, the increase in terms of trade and immigration probably contributed to the stagnation of real wages (Williamson, 1999).

In Brazil, real wages increased in the 19th century. For instance, real wages in the Southeast of Brazil increased by almost 200% in 1830-1900. The growth of the economy may have led to the increase in the living standards of the poor in the 19th century. In the early 20th century, however, the situation changed. Real wages declined by 30% between 1905-1909 and 1920-1924. The increase in terms of trade and massive immigration probably contributed to the decline in real wages (Williamson, 1999).

In the case of Mexico, real wages declined in 1760-1810 and remained relatively stagnant in 1810-1860 (Challú & Gómez-Galvarriato, 2015). In the late 19th century, real wages increased. The pacification of the country, the integration of Mexico with the international economy and the introduction of new technologies probably contributed to the increase of real wages (Challú & Gómez-Galvarriato, 2015). Decreasing terms of trade and the expansion of the frontier probably also contributed to the increase in real wages in the late 19th century (Arroyo-Abad, 2013).²²

The evolution of real wages in 19th century Lima is consistent with the findings for other Latin American economies for the late 19th and early 20th centuries. The expansion of the economy in the region in this period did not necessarily lead to the improvement of living standards. The expansion of the frontier could have contributed to the increase in living standards. However, if the expansion of the economy was associated with increasing terms of trade and massive immigration, real wages could have declined.

Comparison with European cities

Previous studies have compared living standards of Latin America and Europe. Some portray an unfavorable depiction of living standards in Latin America (relatively low living standards); others provide a favorable portrayal. Some studies show that welfare ratios in Latin America were below those in London in the 18th and 19th centuries.²³ London, however, may not be representative of Europe: some studies indicate that Londoners had far higher welfare ratios than other Europeans (Allen, 2001, 2009).²⁴ In addition, some estimates suggest that in the 18th century Spanish America had higher welfare ratios than Leipzig (Arroyo-Abad et al., 2012), and that in the 19th century Buenos Aires and Mexico had higher welfare ratios than Milan and around the same ratios as Amsterdam and Leipzig.

²² However, there is no consensus on the evolution of living standards in Mexico in the 18th and 19th centuries. At times, the evidence for height contradicts the findings for real wages. Real wages declined in 1760-1810 (Challú and Gómez-Galvarriato, 2015). However, according to Dobado-González and García-Hiermaux (2017), there is no “evidence regarding the notion of ‘Great Decline’ in Mexico heights between 1730 and 1840” (p. 161). In addition, height declined in the second half of the 19th century (López-Alonso, 2012) in spite of the increasing real wages.

²³ For the 18th century, see Allen et al. (2012) and Arroyo-Abad et al. (2012). For the 19th century, compare the results in Allen (2009) with those in Challú and Gómez-Galvarriato (2015), Gelman and Santilli (2018), Arroyo-Abad (2014, 2013) and Zegarra (2020).

²⁴ Recently, however, some studies have questioned the finding that London had higher living standards than other European cities (Humphries, 2013).

One problem with those welfare-ratio estimates is that they have been estimated using historical diets. One might wonder whether historical diets are comparable across countries. If they are not, then one should not rely on those ratios to determine the differences in living standards between Latin America and Europe.

Until now, no study has made a comparison of welfare ratios of Latin America and Europe using linear programming. Recently, I used linear programming to estimate welfare ratios in six European cities (Zegarra, 2021). For four of those cities (London, Amsterdam, Paris and Strasbourg), I estimated welfare ratios for the 19th century. For other two cities (Munich and Leipzig), there is only information for the 17th and 18th centuries.

In comparison to those London, Amsterdam, Paris and Strasbourg, the welfare ratio of laborers in Lima in the 19th century was not low (see figure 5). Actually, laborers in Lima had similar welfare ratios as laborers in the four European cities, including London, in the 1800s. The capacity of working families in Lima to cover their basic needs was similar to those cities in Europe. From the 1810s, the welfare ratio in London followed an upward trend. Since the welfare ratio in Lima did not maintain an upward long-term trend during this period, in the 1860s London had a far higher welfare ratio than in Lima. Therefore, over the 19th century, there occurred a divergence in living standards between Lima and London. Nevertheless, living standards in London were not the same as in other cities. Welfare ratios in Amsterdam, Paris and Strasbourg did not follow an upward long-term trend in 1800-1870. As a result, living standards in Lima were similar to those cities during this period.

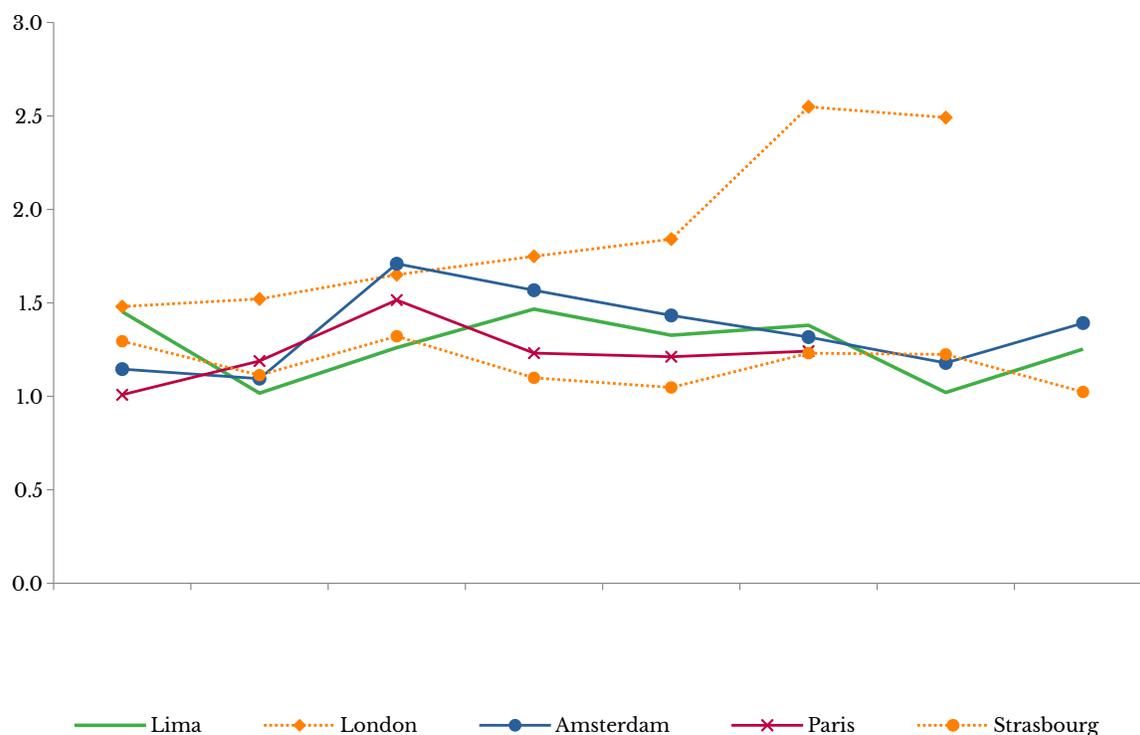
Therefore, our results provide a favorable depiction of living standards in Lima. Living standards were not relatively low in 1800-1870, at least not in comparison with important European cities. One would need further research for other Latin American cities to determine whether in general living standards in Latin America compared favorably to Europe in the 19th century.

CONCLUSIONS

Two methodologies can be employed to determine the food basket and estimate welfare ratios. Most studies have relied on historical diets to determine the food basket. This study relies on a linear programming model to determine the least cost basket that granted a balanced-nutrition diet to Limenians. According to the results of this study, the balanced-nutrition welfare ratio in Lima was usually above 1.0, so families were able to cover their basic needs.

The results show that the welfare ratio in Lima declined during the Guano Era. This finding is consistent with other studies that also indicate that the living standards of the poor declined during the Guano Era, in spite of the macroeconomic bonanza (Arroyo-Abad, 2014; Gootenberg, 1990; Twrdek and Manzel, 2010; Zegarra, 2020a). The results for Lima support the hypothesis that living standards do not necessarily increase in response to economic growth. Similarly, in other Latin American countries, real wages did not necessarily increase in response to the growth of the economy in the late 19th and early 20th centuries. In Peru, a land abundant economy, the increase in terms of trade may have contributed to the decline in real wages. The immigration of Chinese coolies and domestic inflation may have also contributed to the decline in the living standards of the poor.

FIGURE 5. WELFARE RATIOS IN LIMA AND EUROPE



Notes: The figure depicts welfare ratios of laborers for several cities. For Lima, I depict the lower level of the welfare ratio, estimated with the 250-day assumption.

Source: For European cities, Zegarra (2021). For Lima, our own calculations.

Nevertheless, in spite of the decline in real wages during the Guano Era, living standards in Lima were not relatively low for international standards. Lima had around the same welfare ratios as Amsterdam, Paris and Strasbourg in the mid-19th century. Although London had higher living standards than Lima, Limenians enjoyed similar living standards as working families in important European cities.

APPENDIX

Chemical composition of foods

This section explains the methodology to calculate the chemical composition of foodstuffs. I assume that wheat was purchased as bread. I adjust the information from the composition tables to obtain the actual consumption of nutrients per purchased kilogram of food. To estimate the chemical composition of bread, I rely on the chemical composition of wheat whole-meal flour at 100%. To calculate the composition of nutrients in a kilogram of bread, I assume that one kilogram of flour yielded 1.28 kilograms of bread (Allen, 2001). In addition, I take into account that some vitamins were lost due to baking. Denote θ_k as the relative loss of nutrient k due to the baking

of wheat flour and β_k as the quantity of nutrient k in a kilogram of raw wheat flour. Under the assumption that no portion of flour was discarded when making bread, the quantity of nutrient k in a purchased kilogram of wheat bread is calculated as $\alpha_k = \frac{(1-\theta_k)\beta_k}{1.28}$.

Recent composition tables are not appropriate for our historical analysis especially for bread (Gazeley & Horrell, 2013). Information on calories, proteins, fat and iron for wheat whole-meal flour at 100% comes from McCance and Widdowson (1946); information on other nutrients comes from Paul and Southgate (1978). Information on the loss of vitamins due to baking comes from Paul and Southgate (1978). According to our calculations, wheat bread yielded around 2,600 kcal/kg. This figure is not very different from the assumption on bread's calorie content made by Allen (2001): Allen assumed that bread yielded 2,450 kcal/kg of calories.

I also collected information on nutrients and edible portion for the following items: fresh maize (choclo), maize flour, polished rice, spaghetti, quinoa, common beans, dried chickpeas, dried butter beans, dried broad beans, dried green peas, potatoes, sweet potatoes, yucas, dressed carcass beef, raw dressed carcass pork, dressed carcass lamb, dressed carcass chicken, anchovies, dried meat, whole egg, milk, semi-hard cheese, lard, white sugar, brown sugar, salt, tea, cocoa, vinegar, pumpkins, onions, carrots, lettuce and tomatoes. All of those foodstuffs were employed for the estimation of nutrients intake for historical diets, and some of those foodstuffs were employed for the linear programming model.

I take into account that a portion was discarded. Meats, for example, were purchased with bones, but bones were discarded. For maize, maize flour, potatoes, sweet potatoes, yucas, chickpeas, butter beans, broad beans, green peas, pumpkins, brown sugar and vinegar, information on nutrients and edible portion comes from Ministerio de Salud (2009, 2014) and INCAP (2017). For rice, spaghetti, beef, mutton, pork, chicken, eggs, milk, cheese, lard, white sugar, salt, tea, cocoa, onions, carrots, lettuce and tomatoes, nutrients come McCance and Widdowson (1946) and Paul and Southgate (1978). For quinoa and anchovies, nutrient information comes from Ministerio de Salud (2009, 2014) and USDA. For dried meat, information comes from Latham (2002) and USDA. For common beans, information comes from FAO (2017). Cooking led to the loss of nutrients. Indian dietary requirements, however, already take into account possible losses of nutrients during cooking (Allen, 2017; Rao, 2009).

Denote j as the food purchased in the market $\alpha_{k,j}$ as the consumption of nutrient k in a kilogram of food j . Then $\alpha_{k,j} = e_j \beta_{jk}$, where e_j is the edible (non-discarded) portion of the food j , and β_{jk} is the quantity of nutrient k in a kilogram of food j .

Price data

Most data on prices comes from Gootenberg (1990). I complemented this source with Mancera (1992), Pardo et al (1870), Fuentes (1858) and Salinas (2013). Gootenberg collected information on prices from primary sources. For bread, information is missing for most years. I then calculated the ratio price of bread/price of wheat. To fill the blanks, I relied on interpolation. Using wheat prices and the estimates of the ratio price of bread/price of wheat, I estimated the price of bread. For noodle prices, I relied on a similar methodology as for bread in order to fill the blanks. Maize prices are missing for most of the period. I filled the blanks by using the ratio price of maize/price of maize flour. The ratio price of maize/price of maize flour was interpolated to fill the blanks. For rice, quinoa, beans, chickpeas, lima beans, potatoes, beef, mutton, poultry, lard and sugar, I also relied on interpolation to fill the blanks.

Information on the rent of rooms in callejones comes from Armas (2007) and Reyes (2004). To fill the blanks, I rely on interpolation and on the evolution of land prices from Zegarra (2020b).

Wage data

Data on wages refer to low-skilled workers, in particular laborers, doormen, mailmen and servants. All workers are government workers. Laborers worked in public works. Doormen, mailmen and servants worked for the public administration.

For laborers, I collected daily payments or jornales from primary sources. For doormen, mailmen and servants, I collected yearly payments from secondary sources. Jornales of laborers were collected from the Historical Archives of the Municipality of Lima and the National Archives of Peru. The Municipality of Lima invested on public works. Budgets and other documents include information on the total payments of salaries, the number of workers and the number of days. Information was not available for all years. I filled the blanks by using interpolation.

For doormen, mailmen and servants, information comes from annual budgets and other legal documents. Annual or bi-annual budgets for the national government report the annual wage of most workers, from the President of the Republic to doormen, mailmen and servants, the least paid among public workers. Budgets of the national government were obtained from the encyclopedic *Anales de la Hacienda Pública*. In particular, budgets were obtained from *Anales de la Hacienda Pública*, vol. i for 1821-1826, vol. ii for 1829, vol. iii for 1839-1840, vol. iv for 1846-1849, vol. v for 1850-1855, vol. vi for 1861-1862, vol. vii for 1863-1868, vol. viii for 1869-1872, ix for 1873-1874 and vol. x for 1875-1876. I complemented the information with laws and decrees that also included information on wages. These laws and decrees come from Oviedo (1872) for 1835-1838, 1840 and 1845.

TABLE 4. 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)
Bread	2 601.6	69.5	17.2	23.8	3.1	41.6	0	222.7	0
Maize	460	13.2	3.2	3.2	0.6	5.8	0	184	19.2
Maize flour	3 610	69.3	38.6	23.8	2.5	19	0	250	0
Rice	3 610	62	10	4.5	0.8	15	0	290	0
Noodles	3 780	136	10	12	1.4	20	0	130	0
Quinoa	3 430	136	58	75	4.8	14	0	1 840	5
Beans	3 052.6	209.2	15.1	62.9	2	72.7	0	4 100	26.6
Chickpeas	3 620	192	61	83	3.8	28	0	5 570	54
Butter beans	3 310	204	12	67	2.8	32	0	3 940	75
Broad beans	3 400	238	15	130	3.9	40	0	4 230	86
Green peas	3 510	217	32	26	2.5	34.3	0	2 740	35
Potatoes	853.6	18.5	0.9	4.4	0.8	14.7	0	149.6	123.2
Sweet potatoes	738.6	17.7	1.8	3.9	0.7	4.9	0	96.8	197.6
Yucas	1 263.6	6.2	1.6	3.9	0.3	5.9	0	210.6	239.5
Beef	2 340.6	131.1	201.7	15.8	0.4	31.5	8.3	83	0
Mutton	2 797.2	122.6	256.2	11.8	0.8	33.6	16.8	33.6	0
Pork	2 501.2	100.6	233.1	6.7	4.3	30.3	7.4	22.2	0
Chicken	532.4	90.2	18.9	3.1	0.4	34.3	4.4	52.8	0
Fish	1 560	191	82	30.4	0.1	0	6.2	90	87
Dried meat	2 250	253	120	41	2	32	15.9	20	0
Eggs	1 308.3	109.5	97	17.8	0.8	0.6	25.8	222.5	0
Milk	660	33	37	0.8	0.4	0.8	3	50	15
Cheese	3 040	244	229	2.1	0.4	0.6	14	200	0
Lard	9 210	0	890	1	0	0	0	0	0
White sugar	3 940	0	0	0.4	0	0	0	0	0
Brown sugar	3 240	0	0	32	0	0.8	0	10	0
Salt	0	0	0	3	0	0	0	0	0
Tea	1 080	196	20	152	1.4	75	0	0	0

Cocoa	3 120	185	217	105	1.6	17	0	380	0
Vinegar	210	0	0	5	0	0	0	0	0
Pumpkins	148.4	4.8	0.5	4.8	0.2	0	0	84.8	2.7
Onions	223.1	8.7	0	2.9	0.3	1.9	0	155.2	97
Carrots	220.8	6.7	0	5.4	0.6	5.8	0	144	57.6
Lettuce	77	7.7	2.8	5.1	0.5	2.1	0	238	105
Tomatoes	140	9	0	4.3	0.6	7	0	280	200

Notes: The table reports the content of nutrients per kilogram.

Sources: Our calculations based on McCance and Widdowson (1946), Paul and Southgate (1978), Allen (2001), Ministerio de Salud (2009, 2014), INCAP (2017) and FAO (2017).

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Otras fuentes.

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