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Almost fifty years ago, economic historians began to explore the potential of anthropometric measurements as indicators of health and wellbeing.[1] The vast majority of these studies have shown the average heights of both children and adults have increased substantially, especially since the start of the twentieth century, but the evidence regarding birth weights is more mixed. A number of studies have demonstrated that birth weights can fluctuate quite markedly under conditions of nutritional stress,[2] and some authors have argued that birth weights have increased significantly over time.[3] However, other authors have reached rather different conclusions. For example, Goldin and Margo argued that average birth weights at the Philadelphia Alms House 'compare[d] favorably with mid-20th century birth weight standards'[4] and similarly, Roberts and Wood concluded that the median birth weight of babies born in early-twentieth century New Zealand was 'nearly identical' to the values achieved in 1991.[5] Tanner also argued that 'the old birthweights are closely equivalent to present-day values', although he included the important caveat that this was after 'allow[ing] for the difference between heights of women in the nineteenth century and now'.[6] Schneider has argued that the relative stability of birth weights over time suggests either that 'fetal health has remained stagnant' or that 'the indicators used to measure fetal health … are not as helpful as research might hope'.[7]

Given the uncertainty regarding changes in birth weight, it is not surprising that scholars have started to look at other measures of intrauterine health, exploring the growth and development of the foetus and the plasticity of the placenta. Although scholars have devoted increasing attention to placental development in recent years, most of the information has been derived from comparatively modern populations. Our paper therefore breaks new ground by using data collected during the early years of the twentieth century to investigate foetal and neonatal health at *La Casa Provincial de Maternitat i Expòsits de Barcelona* (the Provincial House) between 1905 and 1920. If it is true that the placenta has the capacity to 'adapt' to adverse maternal conditions, changes in placental weight may help to unpick the birth weight 'puzzle'.

[1] Fogel and Engerman, *Time on the Cross* and Fogel *et al*., 'The Economics of Mortality.' For a review of the literature in anthropometric history see Floud *et al. The Changing Body*; Floud *et al. Health, Mortality*; Galofré-Vilà, 'Growth and Maturity'; and Hatton, 'How have Europeans'.
[2] See e.g. Antonov, 'Children Born'; Valastovsky, 'The Secular Trend'; Stein *et al*., *Famine and Human Development.*
[3] See e.g. Bakwin, 'Secular Change', p. 79; Gruenwald, 'Influence of Environmental'; Ward, 'Perinatal Mortality'; *ibid.*, 'Women's Health'; O'Brien *et al.*, 'Placental weights', p. 583.
[4] Goldin and Margo, 'The Poor at Birth', p. 360.
[5] Roberts and Wood, 'Birth Weight', p. 154.
[6] Tanner, *A History*, p. 260. For a similar claim about the stagnation of birth weights over the last 150 years, see also Cole, 'Secular Trends'.
[7] Schneider, 'Fetal Health Stagnation', p. 25. Rosenberg also observed that the average weight of newborns in three Norwegian cities only increased by around 200g between 1860 and 1980; Rosenberg, 'Birth Weight', p. 283.

By exploring the link between changes in placental weight and early-life mortality, we show that while in the short-run this 'adaptation' may enable the embryo and foetus to achieve a certain birth weight and to survive, it is not possible to compensate entirely for the effects of maternal undernutrition increasing the risk of dying. We also show that although there is some evidence to suggest that placental weights have declined over the course of the last century, this picture does not appear to have been true for all countries.

The paper continues as follows. In the next section, we review the development of the placenta and the role it plays in embryonic and foetal growth. In Section II we present our data and discuss it for selection and representativeness. Sections III-VI are our empirical sections exploring the short-term changes in neonatal markers, the birth outcome risks associated with early-life mortality and the long-term decline of placental weight across the twentieth century. Section VII concludes.

I. *The role of the Placenta in the Baby's Growth*

Before delving into the implications of historical changes in placental weight in Barcelona, it is first necessary to explain the development of the placenta from a biological perspective. As Gude *et al.* have explained, 'the placenta is the physical and functional connection between the mother and the developing embryo/foetus'. It transfers oxygen and nutrients to the foetus whilst removing carbon dioxide and other waste products. It can also release metabolic products into the maternal and foetal blood streams and protect the foetus against certain infections and maternal diseases, and it releases hormones into both the maternal and foetal circulations to affect pregnancy, metabolism, foetal growth, parturition and other functions.[8] It therefore plays a critical role in enabling the healthy development of the foetus and may also have significant implications for the onset of chronic disease in later life.[9] It has been described by one recent researcher as 'a mirror which reflects the intrauterine status of the foetus'.[10]

The relationship between nutrition and placental development is complex. If the placenta fails to develop properly, it will be unable to transfer nutrients to the foetus, thus impairing foetal growth.[11] However, other researchers have also argued that 'fetal growth [is] sacrificed to

[8] Gude *et al.*, 'Growth and Function', pp. 397, 406.
[9] Barker, 'In Utero Programming'.
[10] Kaur, 'Assessment of Placental Weight', p. 185.
[11] Salavati *et al.*, 'The Possible Role', p. 1.

maintain placental function' when the mother's nutritional status is compromised.[12] As a result, different researchers have reached contradictory conclusions regarding the relationship between placental weight and maternal nutrition. Stein and Susser argued that 'mothers from populations that suffer chronic malnutrition … tend to have babies of low birth weight and also to deliver lighter placentae', and Perry *et al.* found no evidence to support the view 'that a raised placental ratio [i.e. a raised ratio of placental weight to birthweight] is a marker for poor maternal nutrition'.[13] However, Godfrey and Barker argued that 'large placental weight and a high placental ratio are a consequence of maternal nutritional deficiency' and that 'large placental weight may be an indirect marker of suboptimal maternal nutrition'.[14] Together with other authors, they have also identified possible relationships between placental growth and anaemia,[15] gestational diabetes,[16] altitude,[17] maternal smoking,[18] and social class,[19] and Barker *et al.* have argued that maternal deprivation may also lead to changes in placental shape.[20]

Although Barker and his colleagues argued that the placenta expands to improve the flow of nutrients in situations where the mother's own nutrient supply has been compromised, there might also be some costs associated with this 'adaptation' and high placental weights are also associated with high neonatal mortality rates. McNamara *et al*. report that 'while low placental weight … is more common among stillbirths, high placental weight is associated with neonatal death and serious neonatal morbidity, including seizures, low 5-min Apgar score, and respiratory morbidity. These associations remained even after controlling for infant birth weight, suggesting an independent role for the placenta as a determinant of perinatal outcome'. Ananth and Wilcox observed that heavier placentas are also linked with obstetric complications such as placental praevia and abruption,[21] and Godfrey suggested that both high and low placental weight ratios could be associated with higher levels of coronary heart disease in later life.[22]

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[12] Heinonen *et al.*, 'Weights of Placentae', p. 399; see also Lau and Wong, 'Neonatal Implications', p. 726.
[13] Stein and Susser, 'The Dutch famine', p. 72; Perry *et al.*, 'Predictors of Ratio', p. 438.
[14] Godfrey and Barker, 'Maternal nutrition', p. 19. The 'placental ratio' (or 'placental weight ratio') is the ratio of placental weight to birth weight, as opposed to the ratio of birth weight to placental weight.
[15] *Ibid.*, p. 18.
[16] MacDonald *et al.*, 'Obstetric Conditions'.
[17] Krüger and Arias-Stella, 'The Placenta'.
[18] Heinonen *et al.*, 'Weights of Placentas'.
[19] Godfrey *et al.*, 'Effect of maternal Anaemia'.
[20] Barker *et al.*, 'Lifespan of Men'.
[21] McNamara *et al.* 'Risk Factors', p. 97; Ananth and Wilcox 'Placental Abruption'. The spread of antibiotics such as the Prontosil and Sulfa drugs in the mid-1930s, followed by Penicillin in the mid-1940s, sharply reduced maternal infections during pregnancy and perinatal mortality because infections were not diffused into the placenta.
[22] Godfrey, 'Role of the Placenta', p. S21.

In considering the relationship between birthweight and placental weight, it is important to note that they do not grow at the same rate. As Figure 1 depicts, the placenta grows at a relatively stable rate throughout pregnancy, whereas the foetal growth rate accelerates. By the 24th week of pregnancy, the placenta has achieved almost 40% of its average size at 39 weeks, whereas the foetus has only achieved approximately 18% of its 'final' size.[23]

[Figure 1 about here]

According to Burton *et al.*, the placenta develops at a fairly constant rate during the first trimester of pregnancy and growth is not dependent on maternal circumstances. However, at the end of the trimester, the placenta becomes linked to the maternal blood supply and starts to become much more dependent on maternal nutrition. They argue that 'adapting to the new conditions poses a major challenge to the placental tissues, and extensive remodelling takes place at … [this] time'. This means that events at the end of the first trimester may therefore play a particularly important role in determining the final size of the placenta and its functional capacity. However, they also argue that 'vascular or dietary compromise' during the remaining months can limit placental growth through its effects on protein synthesis.[24]

Even though the majority of recent studies have suggested that there has been little change in average birth weights over time, the evidence regarding trends in placental size is more mixed. In a study of the relationship between the size of mothers' pelvises and the health of their offspring in later life, Martyn *et al*. argued that there had been a decline in the incidence of pelvic deformity over the course of the twentieth century and that this had been associated with increases in placental size'.[25] However, in a subsequent paper, Barker *et al.* argued that the mean weight of the placentas of 1,999 men and women who had been born in Helsinki between 1934 and 1944 was 'above the median recorded in a recent series of deliveries in Europe',[26] whereas Pinar *et al.* concluded that the average size of placentas in the US had increased between the first half of the 1960s and the mid-1990s.[27]

[23] At the individual level, several studies have shown that there is a fairly close correlation between placental weight and birth weight. For example, in an analysis of data from their classic study of the Dutch Hunger Winter, Susser and Stein estimated that the correlation coefficient between birth weight and placental weight was 0.59, and Thomson *et al.* found that the correlations between placental weights and birth weights in different groups of Aberdeen women ranged from 0.56 (for first-born female children) to 0.59 (for girls born following the mother's second or third pregnancy). Susser and Stein, 'Third Variable Analysis', p. 111; Thomson *et al*., 'Weight of the Placenta', p. 866. In our own data, the correlation between placental weight and birth weight was 0.57.

[24] Burton *et al*., 'Influence of the Uterine', p. 303; see also Burton and Jauniaux, 'Pathophysiology', p. S746.

[25] Martyn *et al*., 'Mothers' Pelvic Size', p. 1268.

[26] Barker *et al*., 'Surface Area', p. 529.

[27] Pinar *et al*., 'Reference Values', p. 907.

If maternal deprivation does lead to increased placental growth, one might expect this to be reflected in the historical record in two ways. In the first place, we might expect to find that placental weight fluctuates, over a given period of time, in response to changes in external conditions. Second, we might also expect to see a long-term decline in placental weights as conditions have improved. By looking at changes in placental weights over a sixteen-year period in early-twentieth century Barcelona, we have a unique opportunity to explore each of these issues. We explore these two questions in turn after presenting the details in our data.

II. *The Provincial House of Barcelona: Selection and Data Representativeness*

The Provincial House was a charitable institution which aimed to address the problem of unwanted motherhood and assist all those who wished to give birth in secret. It was founded in 1853 by the Foundling House and the House of Maternity, and was originally located at 87 Ramellers Street in *El Raval*. It moved to the somewhat healthier surroundings of *Les Corts de Sarrià* in 1878 and a breastfeeding pavilion was added in 1890. This was followed by the establishment of the 'Ave Maria' or 'weaned' pavilion in 1891 and Ponent's Pavilion for children with infectious diseases in 1893. The institution also acquired a laundry in 1893 and a kitchen in 1899, and further improvements were made after 1900.

After the turn of the century, the Provincial House doctors began to record an increasing amount of information about the health of both mothers and children, but this was a gradual process.[28] Between 1905 and 1909 the age of the mother was recorded, along with the child's sex, birth weight, birth length, placental weight and data describing whether the infant was premature or stillborn (*nascuts morts*), whether they died during delivery (*morts al néixer*) or within 24 hours (*abans de les primeres vintiquatre hores de vida*).[29] After 1911 they started to keep regular records of the mother's occupation and place of birth, data on maternal height were added in 1914 and information about maternal weight in 1916. Although parity was not recorded consistently, midwives also commented on the mother's and baby's progress and any complications or treatments until the day of discharge, as well as the mode of feeding the infant (breast-fed by wet nurses or bottle-fed). The medical inspections of the mother and baby were

[28] Brossa and Goday, 'Mortalitat dels Nens Abandonats'.

[29] We combined information on stillbirths, born dead and death within the 24 hours of life because sometimes medical doctors instead of providing the time of death, just reported the word death (mort) or a big cross.

recorded in the same files (for details see Appendix A). Thus there was no need to rely on other documentation to perform linkages.

Although the Provincial House assisted women who wanted secrecy about their pregnancy, we have been able to locate the maternal registers which include details of the dates on which individual mothers were admitted, the dates on which they gave birth, and the dates on which they departed.[30] Although they did not report the names of the mother, the ledgers for 1908 and 1909 did show that 38 per cent of mothers were admitted within 30 days of giving birth, 67 per cent within 60 days and 90 per cent within 91 days. These figures are consistent with institution's Regulations. Although Article 87 allowed the medical staff to admit women at a relatively early stage of pregnancy 'in order to attend to moral or health interests', they were normally expected to submit to a diagnostic check on the state of pregnancy and 'to have entered the seventh month of gestation'. These issues are discussed in more detail in the Appendix (see Appendix B).

One of the ways in which we might seek to compare the Provincial House with the rest of the city is by looking at early-life mortality. As we have already noted, the institution recorded data showing the numbers of babies who were stillborn, those who died during delivery and those who died during the first 24 hours, and we can compare these with similar data for the city as a whole. However, it is important to recognise the limitations of this analysis, since we do not know for certain whether any differences between the two sets of data reflect changes in either the characteristics or the circumstances of the mothers who entered the institution or in the ways in which the institution supported their pregnancies.

Table 1 presents separate estimates comparing early-life mortality in the Provincial House with 'legitimate' mortality in the city as a whole and mortality among illegitimate babies and foundlings. Early-life mortality in the Provincial House was below the level of 'legitimate' mortality in the city as a whole up to 1914 and it remained below the city-wide figure for illegitimate and foundling births for almost the entire period.[31] Early-life mortality in the Provincial House rose after 1913 and exceeded the figure for legitimate births from 1915 onwards. The fact that early-life mortality in the Provincial House was so low at the start of the period suggests that the institution itself played an important role in supporting mothers during

[30] Unfortunately, we cannot link them to a particular birth, as in one day more than one birth could take place in the Provincial House.

[31] Similar to our argument, Muños Pradas and Nicolau-Nos 'Evolució i Desigualtats', p. 268, also argued that 'once survivorship is firm in the Casa de la Maternitat i dels Expòsits, which only happened after 1900, the observed rate of mortality is very close to the rate of mortality for the city [of Barcelona]'.

the final months of their pregnancies. However, as we have already suggested, it is impossible to know whether the relative deterioration in the life-chances of infants who were born inside the Provincial House reflected a change in the circumstances of the mothers who entered the institution or a change in conditions inside it.

[Table 1 about here]

Although the Provincial House started to provide information about mothers' geographical origins in 1911, it only began to record detailed information about the birthplaces of mothers who were born outside Catalonia in 1916 (see Appendix C). The data after 1916 show that although 27.9 per cent of the mothers were born in Barcelona and 20.8 in rural Catalonia (outside Barcelona), almost half came from nearby regions: 19.3 per cent from Aragó, 11.5 per cent from València, 3.1 per cent from Castella i Lleó, 3.3 per cent from Múrcia, 2.5 per cent from Andalusia and 9.6 per cent from other parts of Spain. 31 women (1.6 per cent) came from other countries and the birthplaces of 14 women (0.7 per cent) were either not recorded or impossible to read. Over the period 1911-20 the number of mothers born outside Catalonia increased. Although we do not know when these mothers migrated to Barcelona, the increase in non-Catalan mothers could be a reflection of the general pattern of migration into the city, as during the 1910s the number of people moving to Barcelona rapidly increased.[32]

We also possess information about the occupations of 77.9 per cent of the mothers who gave birth in the Provincial House between 1911 and 1920. Of those mothers whose occupations were recorded, 54.4 per cent can be categorized as servants or maids; 29.3 per cent as factory workers; 8.1 per cent as agricultural workers; 3.2 per cent as shopworkers; and 5.1 per cent as 'others'.[33] The average age of the mothers was fairly stable across time and ranged from 24.3 years (in 1908) to 25.5 (in 1915), with a mean value from 1911 to 1920 of 25.0. Even though the ages given by the mothers were probably self-reported, there is relatively limited evidence of age-heaping as controlling for age-misreporting gives a Whipple Index of 124.7, suggesting acceptable quality of age data. Finally, the first page of the maternal books also recorded the yearly aggregate figures of single, married and widowed mothers for the years 1916 to 1920.

[32] Silvestre shows that the flow of population included migrants from rural parts of Catalonia and from nearby regions such as Aragó and València. See Silvestre, 'Las Emigraciones Interiores', p. 234; and Silvestre, 'Internal Migrations'.

[33] The category 'servants' includes occupations such as servants and maids; the majority of those classed as 'factory workers' were employed in textiles, but the category also includes workers employed in other manufacturing industries; 'agricultural work' includes farmers, labourers or 'agriculturists'; 'shopworkers' includes any kind of shops; the category of 'others/not recorded' includes representatives of a large number of smaller categories such as artists, typist, catering workers, translators and students, together with those whose occupations were not recorded.

From a total of 1,923 mothers, 80.3 per cent were single mothers (being illegitimate births associated with single women), 17.8 per cent married and 2.0 per cent widowed.[34]

III. *Barcelona in the early decades of the 20th century*

By the start of the twentieth century, Barcelona was a major industrial and trading centre, but it also experienced significant disruption following the outbreak of the First World War.[35] As Vicens Vives noted, 'the First World War offered Spanish industry an exceptional opportunity to place itself on a competitive level with foreign countries. Because of the neutrality, maintained throughout the contest… not only the markets of the belligerent powers were opened… but also those from many other countries in America, Africa and Asia… [with] a wave of prosperity invading the country, enriching people and the State'.[36]

However, although the outbreak of war may have provided a short-term boost to Barcelona's fortunes, its impact on international trade routes meant that many of these benefits were short lived. As early as 1915, the *US Bureau of Labor Statistics* reported that 'the shutting off of exports has reduced employment and brought about hard times. In some places the difference between earnings and cost of living is so great that serious labor troubles are feared'.[37] As we document in the Appendix D, between 1914/15 and 1918/19, the price of meat in Barcelona increased by 41.6 per cent, the price of milk by 73.9 per cent, the price of chickpeas doubled and the price of potatoes increased by 183.3 per cent. However, our own data suggest that average wages rates rose by only 63.8 per cent (for males) and 69.7 per cent (for females) between 1914 and 1919 and Nadal concluded that 'any rise in nominal wages was insufficient to meet the needs of the working class'.[38]

We can gain a further insight into the main changes in real wage rates over the whole of the period between 1908 and 1920 from Figure 2. The figure suggests that the real wage rates of male workers rose between 1911 and 1913 before falling fairly consistently for the duration of the war. They rose again between 1918 and 1919 before falling again in 1920. The real wage

[34] It is unclear why between 1916 and 1920 the maternal books reported aggregate figures for 1,923 single, married and widowed mothers and recorded 1,919 individual births. We can speculate that the person who reported the aggregate figures double counted some mothers or that 4 medical reports were just lost.
[35] The impact of the war was greater in Barcelona than in any other region in Spain. Rosés and Sánchez-Alonso 'Regional Wage Convergence', Smith, 'Cataluña y la Gran Guerra' and Smith, *Anarchism*.
[36] Vicens Vives, *Historia Social*, p. 321. Exports to America and Africa rapidly expanded, as these markets were almost abandoned by the exports of the countries at war.
[37] *US Bureau of Labor Statistics*, *Foreign Food Prices*, p. 117.
[38] Nadal, *La Población Española*, p. 206-207.

rates of female workers followed a similar though not identical path. They also rose between 1911 and 1913 before falling more sharply during 1914 with little change between 1914 and 1916. There was an increase in real wage rates in 1917 followed by a further decline, with a smaller increase between 1918 and 1920.

[Figure 2 about here]

Barcelona also experienced a succession of major public health problems during the 1910s. Among other short-lived epidemics and problems of malaria, the outbreak of typhoid fever in 1914 was especially severe.[39] By the end of November 500 new cases were being reported daily in Barcelona with 80 new deaths being attributed each day to the typhoid epidemic, which affected more than 25,000 citizens (out of a population of 600,000) with 2,036 deaths in total (though unreported cases might have shifted this number upwards).[40] Additionally, although Barcelona appears to have been largely untouched by the first wave of the influenza epidemic in the spring and summer of 1918, it was badly affected when the second wave broke in the autumn of that year. According to Chowell *et al.*, the second and third waves led to an excess mortality rate from respiratory diseases of 7.44 deaths per thousand living. The overall mortality rate increased by 9.13 deaths per thousand over the same period.[41]

IV. *Short-term Responses in Placental Weight*

From the maternal books held at the Provincial House, we collected data for all the births which occurred in the Provincial House between 1905 and 1920. Unfortunately, the books of 1906 and 1910 were lost or stolen, so we do not have information for these two years. The total number of births in the remaining years was 4,331, and these accounted for just over two per cent of all the births occurring in the city during this period. Out of the recorded 4,331 births between 1905 and 1920, we excluded 305 children who were either stillborn, born dead or dead within 24 hours and 79 children who were either twins or triplets. We also excluded 18 children whose sex was unspecified or impossible to read and 99 children whose placental weights or birth weights were not recorded (see Appendix E). Our analysis is therefore based on the birth weights and placental weights of 3,830 live-born singleton births.

[39] Sabaté, 'Public Health in Catalonia'.
[40] Guardia *et al.*, 'Barcelona's Water Supply'. Mortality data are from the *Anuari Estadístic de la Ciutat de Barcelona*.
[41] Chowell *et al.*, 'Spatial-Temporal Excess', p. 7; see also Trilla *et al.*, 'The 1918 'Spanish Flu''.

One of the limitations of our data is that we do not know precisely how placentas were weighed. When the Provincial House doctors recorded placental weights, they used a record card which also provided space for the recording of observations regarding the umbilical cord, membranes and amniotic fluid, but there is no indication to suggest that these items were weighed separately. We have therefore assumed that the placenta was weighed *before* trimming, but we cannot be certain of this. However, we have checked for references to current practice in other near-contemporary sources and these also suggest that placentas were routinely weighed before trimming,[42] and Panti *et al.* have suggested that 'the standard method of weighing the placenta after trimming the placental disk of membranes and umbilical cord' probably dates from the early-1960s.[43]

Figure 3 compares the main changes in birth weight and placental weight, as recorded on the Provincial House record cards, for babies born in the institution between 1905 and 1920. Although birth weights were relatively low in 1905, they showed little change over the rest of the period. Placental weights fluctuated rather more markedly. There was relatively little change before 1911, but placental weights fell between 1911 and 1914 and then rose even more sharply between 1914 and 1917 to remain fairly constant between 1918 and 1920. Consequently, the BW:PW ratio rose between 1909 and 1914 (from 6.4 to 7.1), before falling to 6.1 in 1919.

[Figure 3 about here]

In order to examine the relationship between living conditions and placental weights, we have compared changes in placental weights with an inverted index of changes in both male and female real wage rates over the course of our period. As we have already noted, epidemiologists have argued that events towards the end of the first trimester have a crucial bearing on placental development so wages are shown with a half-year lag to give a better indication of wage rates at the end of the first trimester rather than the point of birth. Although the graphs in Figure 4 suggest that there was only a fairly weak relationship between placental weights and female wage rates, the relationship between placental weights and male wage rates was somewhat

[42] For example, in their account of the process for studying haemorrhagic lesions of the placenta and their relation to white infarct formation, McNally and Dieckmann explained that 'our routine method of examination of placentae is as follows: They are washed free of blood and placed in 10% formalin and allowed to remain in this solution about seven to ten days. They are then described *in gross* and cut in slices about 2 cm thick' (emphasis added). A few years, later, in one of the classic papers of the field, Traut and Kuder also stated that 'our placentas are examined routinely in the gross'. See McNalley and Dieckmann, 'Haemorrhagic lesions', p. 55; Traut and Kuder, 'The lesions of 1500 placentas', p. 552.

[43] Panti *et al.*, 'Relationship Between'; see also Salafia, 'Measures of placental growth', p. 997.

stronger and the figures as a whole provide some indication that changes in placental weights may have been related to changes in average living standards during the period as a whole.

[Figure 4 about here]

V. *Compensatory Reponses of Placental Weight*

While in the previous section we showed that changes in the placenta offer a way to explain the short-run disjuncture between shock and birth weight,[44] we next explore whether it is possible to compensate entirely for the effects of maternal undernutrition. If the placenta increases its size under conditions of maternal hardship this would be a form of adaptation necessary to compensate for the reduced flow of nutrients from the mother. Yet, this form of adaptation may not be able to compensate fully for the problems which make it necessary and may also generate additional risks of its own. Both of these factors may help to explain the association between placental weight and both early-life and adult mortality rates.

In order to account for compensatory issues, in Figure 5 we explore the relationship between the various anthropometric indicators (birth weight, birth length, placental weight, and the BW:PW ratio) and our measure of early-life mortality. Birth weight data show that very low values of the distribution account for most of the early-life deaths with a reverse J-shaped curve. This is consistent with modern medical studies which find that over 70 per cent of perinatal mortality occurs below the first centile of birth weight, demonstrating the higher risk of perinatal mortality associated with premature or small-for-gestational-age births.[45] There is also a small rise in early-life mortality above the ninth decile. This is probably because the large head and orientation of the baby constitute a major challenge for vaginal delivery owing to the fact that the fit between the foetal head and the pelvis is tighter than in other species. However, the relationship between placental weight and early-life mortality follows a U-shaped curve, indicating that early-life mortality was very high at low values of the distribution (below 350 grams) and at high values (over 650 grams). Finally, a low BW:PW ratio (either because the placenta is abnormally large or the foetus has failed to thrive) accounts for most early-life deaths.

[Figure 5 about here]

[44] McNamara *et al.,* 'Risk Factors'.
[45] Vasak *et al*., 'Human Fetal Growth'.

As we have already noted, the amount of information collected by the Provincial House increased over the course of our period. We possess additional information about the socioeconomic and demographic characteristics of the mothers and birth outcomes from 1916, and this enables us to provide a fuller description of the impact of maternal health and foetal development on the risk of early-life mortality with a Cox proportional hazards model (Table 2). The model includes variables deemed important to explain differences in birth outcomes such as the sex of the new-born, neonatal markers and maternal body dimensions. At the bottom of the table we also report on the proportionality tests to ensure that the predicted hazard rates are proportional.[46] Since Figure 5 also suggests that the relationship between mortality risk and birth outcomes in non-linear, we bin the birth outcomes and enter them as dummy variables in the Cox models.[47] Specifically, for birthweight we use bins for every 500 grams (i.e., 500-999, 1,000g-1,499, etc.), for placental weight every 50 grams, for the BW:PW ratio for every unit, for birth length every 20 cm, for maternal height every 15 cm, for maternal weight every 10 kg and for maternal pelvis size every 5 cm.

Unadjusted results for models 1-4 show that the risk of premature death declined as babies grew heavier and taller, and as placental efficiency (as measured by the BW:PW ratio) increased. Column 5 shows that the BW:PW ratio remains highly statistically significant even after controlling for maternal height, weight and pelvic size, and column 6 shows that placental weight becomes statistically significant after controlling for birth weight. This suggest that the BW:PW ratio variable is driving much of the association between *in utero* health and the risk of death and the 'dialogue' between the maternal environment, placental weight and birth weight. Although a baby's weight or placental weight reflects their genetic inheritance and maternal environmental factors (as measured by maternal height and weight, respectively), we can remove concerns on attenuation bias because the inclusion of maternal-specific characteristics that correlate with birth weight and placental weight, such as maternal height and weight, helps to ease the effect of genetics.[48]

[Table 2 about here]

[46] We also account for non-linearities and in alternative specifications bin the different early-life markers and enter them as dummy variables in the Cox models. We achieve the same overall findings (unreported here).
[47] We would like to thank Referee 2 for suggesting that we bin the birth outcomes and control for non-linearities in the Cox models in this way. We also explored with bins of different sizes and also without bins and the main results are maintained.
[48] We preferred maternal height over maternal BMI, as maternal weight fluctuations substantially over different ages.

VI. *Long-term trends in placental weight*

As we have already seen, a number of epidemiological studies have made conflicting claims with respect to changes in placental weights over time. Barker *et al.* suggested that average weights might have declined between the 1930s and 1940s and the end of the twentieth century, whereas Pinar *et al.* believed that they had increased.[49] What light can our data shed on this issue?

In order to address this question, in Table 3 we have compared the average weights of the placentas in our study with the results obtained from two separate analyses of an investigation into the impact of maternal weight on pregnancy outcomes which was undertaken in the early years of the twenty-first century at two hospitals in Granada. The placentas were weighed without trimming,[50] and both papers presented separate results for placentas associated with mothers who were of 'normal' weight (i.e. $18.5 \leq$ BMI <25), 'overweight' ($25 \leq$ BMI <30) or 'obese' (BMI ≥ 30). One of the papers included data for mothers with gestational diabetes and the second paper subdivided this group by weight group also. The average sizes of the placentas in different groups ranged from either 469 or 475 grams for mothers in the 'normal' weight group to between 531 and 571 grams (in the case of 'obese' mothers). Only one of the studies provided sufficient information to enable us to calculate a mean weight for the study population as a whole (488.25 grams) but neither study attempted to compare the characteristics of the study population with the maternal population more generally. Nevertheless, the results provide some evidence to suggest that average placental weights were lower than the average value of placental weights in the Provincial House a century earlier. We also performed a one-sample t-test showing that the mean value of placental weights in Granada between 2007 and 2010 (488.3 grams) was statistically significantly different from the historical mean in the Provincial House (505.3 grams).

[Table 3 about here]

We have also examined other available sources to explore changes over time using data from other parts of the world, but these results also need to be interpreted with caution. As we have already seen, one of the limitations of our data is that lack of clear evidence to show whether placentas were weighed without trimming, or whether they were weighed after the membranes

[49] Barker *et al.*, 'Surface Area', p. 6; Pinar *et al.*, 'Reference values', p. 907.

[50] We would like to thank Cristina Campoy for clarifying this issue through personal correspondence. Berglund *et al.*, 'Maternal, Fetal', p. 4. The authors of second survey stated only that 'placenta [*sic.*] were collected and weighted immediately after delivery' (Martino *et al.*, 'Effect of Body Weight', p. 62.

and umbilical cord had been removed. A number of recent papers have suggested that placentas were usually weighed without trimming up until the start of the 1960s but our own investigations suggest that different authors have followed different practices since that time. However, a small number of studies have attempted to compare trimmed and untrimmed placentas from the same sample, and it has been suggested that the average weight of trimmed placentas is roughly equivalent to 83.7 per cent of the average weight of untrimmed placentas.[51] We have therefore used this figure to 'convert' trimmed values to untrimmed values for the purposes of this comparison.

The results of this exercise are shown in Table 4, but they do not provide any clear indication of changes in either direction, either within countries or across countries. In the United Kingdom, the average weight of the placentas recorded by Simpson in the 1840s was lower than the figures reported by Thomson *et al.* in Aberdeen between 1948 and 1964 but both sets of figures were higher than those reported by Leary in Southampton at the end of the twentieth century. In the United States, the data reported by Costa for the period 1897-1935 were greater than the figures obtained by Warburton and Naylor *et al*. from the Collaborative Perinatal Study between 1959 and 1966, but they were substantially lower than the figures reported by Dombrowski *et al.* for Detroit in the 1980s, and also lower – though not by as much – than the figures reported by Pinar (for singleton births) in the 1990s. On the other hand, the figures reported by Butie *et al.* for the Swiss city of Basle between 1912/13 and 1923 were significantly greater than the figures reported by Burkhardt for both vaginal and caesarean deliveries in Zurich between 1995 and 2002, and the figures reported by Barker *et al*. in their studies of babies born in Helsinki between 1934 and 1944 were also higher than the figures reported by Heinonen *et al.* in Kuopio (approximately 400 km further north) sixty years later.

Overall, these figures suggest that, whilst placental weights may well provide a sensitive guide to the intrauterine environment, we still know relatively little about the ways in which they may, or may not, have changed over time. However, this picture may start to change if more historical series come to light,[52] especially if they are accompanied by more detailed information about the conditions under which they were weighed and the populations from which they were taken.

[Table 4 about here]

[51] Leary, 'Placental Weight', p. 277.
[52] For a recent example, see Butie *et al.*, 'Impact of World War I'.

VII. *Conclusions*

As this paper has demonstrated, there has been growing interest in recent years in the analysis of historical changes in birth weights and the majority of recent studies have supported the view that these have not changed significantly over time. A number of epidemiological studies have suggested not only that placental growth is a better measure of intrauterine conditions but also that the placenta may expand in size to compensate for maternal undernutrition. If so, this may help to explain the relative stability of birth weights.

We have attempted to address this problem by examining the pattern of change in placental weights in Barcelona's Provincial House between 1905 and 1920, and also by comparing these values with those obtained from more recent studies. We have provided some evidence to suggest that placental weights may have varied inversely with changes in real wages between 1908 and 1920, and we have also provided evidence to suggest that the average value of placental weights in the Provincial House was greater than the values observed in Granada at the start of the twenty-first century. Both sets of results are consistent with claims that the placenta does expand in response to adverse maternal circumstances. However, when these results are compared with studies from other parts of the world, no consistent pattern emerges.

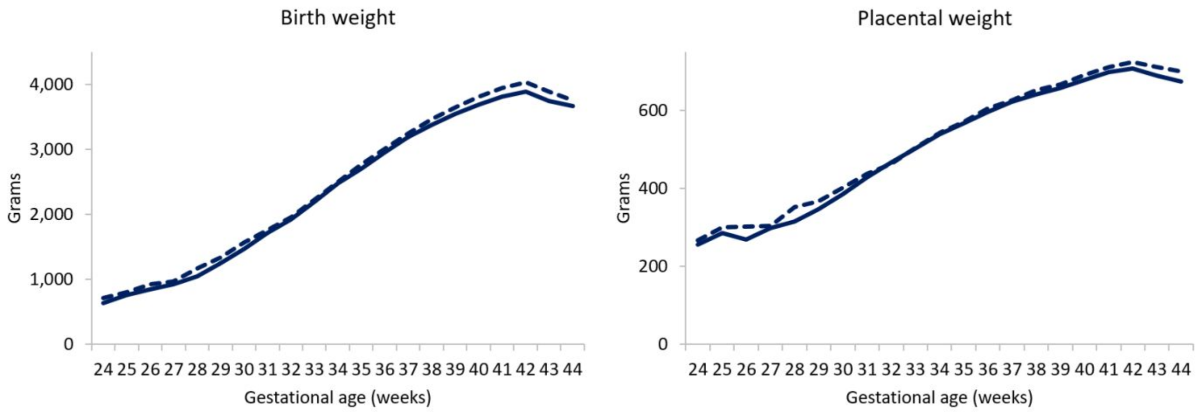
We have also explored the relationships between different markers of foetal health and a range of birth outcomes. Our results suggest that, even if increases in placental weight can be regarded as a form of 'adaptive response' to adverse circumstances, they are not cost-free. This is reflected in the fact that, within the Provincial House sample, both very low and very high placental weights were associated with increased risks of early-life mortality. These findings are similar to those reported in more recent studies, which also highlight the relationship between adverse foetal conditions, elevated placental weight ratios and adverse outcomes in later life.

This paper also has important implications for our understanding of the impact of economic and social conditions on foetal health in early-twentieth century Barcelona and, in particular, on the impact of wartime conditions on civilian health in a neutral country during the First World War. This is an important issue, as most studies of the impact of the war have tended to focus on combatant countries.[53] Our study has demonstrated that it may have also had a significant effect on ordinary life in a non-combatant country and, if the epidemiologists are

[53] See for instance, Winter and Robert, *Capital Cities at War*.

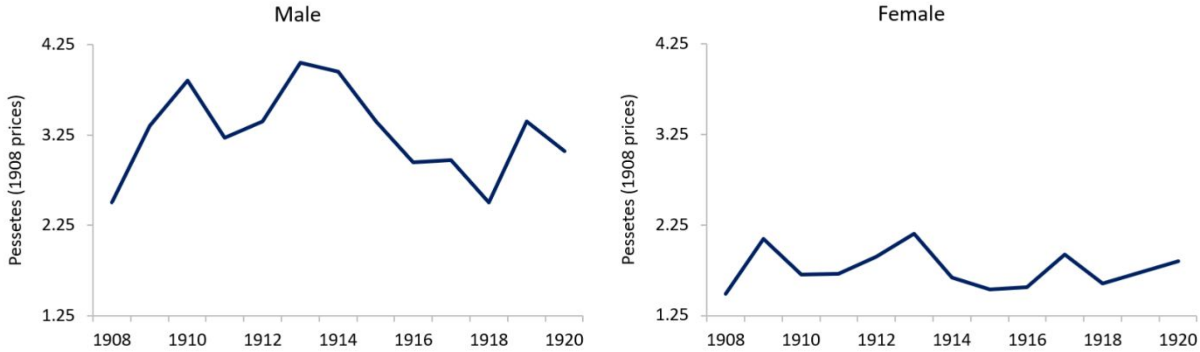
correct, the consequences for those who were born during the War are unlikely to have ended with the return of peace.

Figure 1. Growth curves for foetal and placental weight (50th centile) in boys (dashed line) and girls (solid line), 24-44 weeks



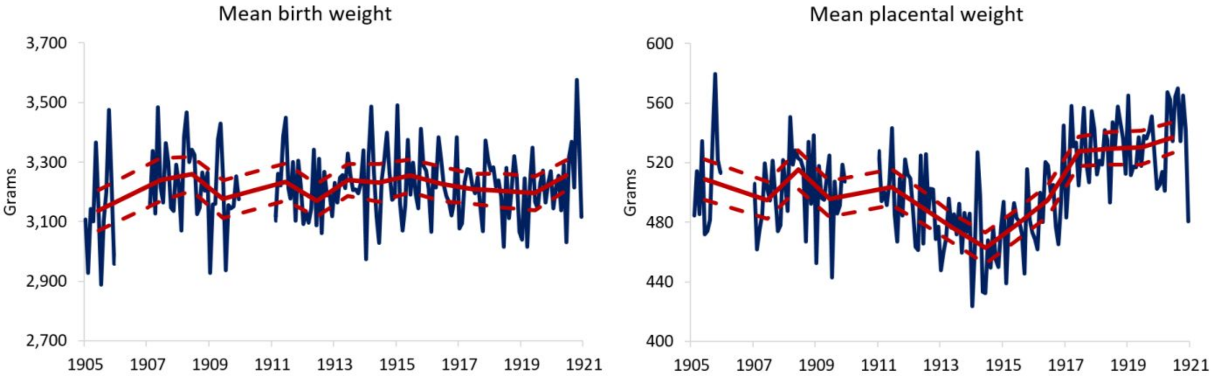
Sources: Thompson *et al.*, 'Placenta Weight', p. 717.

Figure 2. Real wages, 1908-20



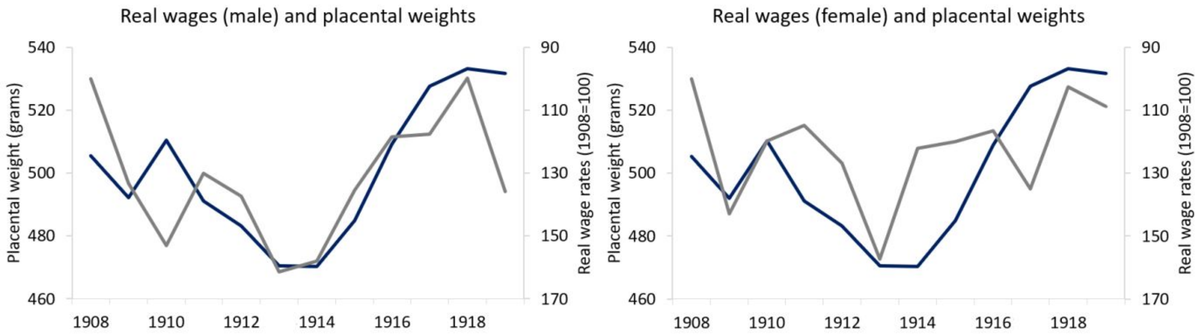
Notes and sources: The real wage series is based on average nominal wages for industrial workers in Barcelona between 1908 and 1920. These have been deflated by a price index based on the prices charged in Barcelona markets between 1905 and 1920 (see Appendix D). Prices and industrial nominal wages were collected by the *Instituto de Reformas Sociales*. Prices are reported in the *Boletín del Instituto de Reformas Sociales* (various issues) and wages in the *Memoria General de la Inspección del Trabajo* (various issues).

Figure 3. The development of birthweight and placental weight, 1905-1920.



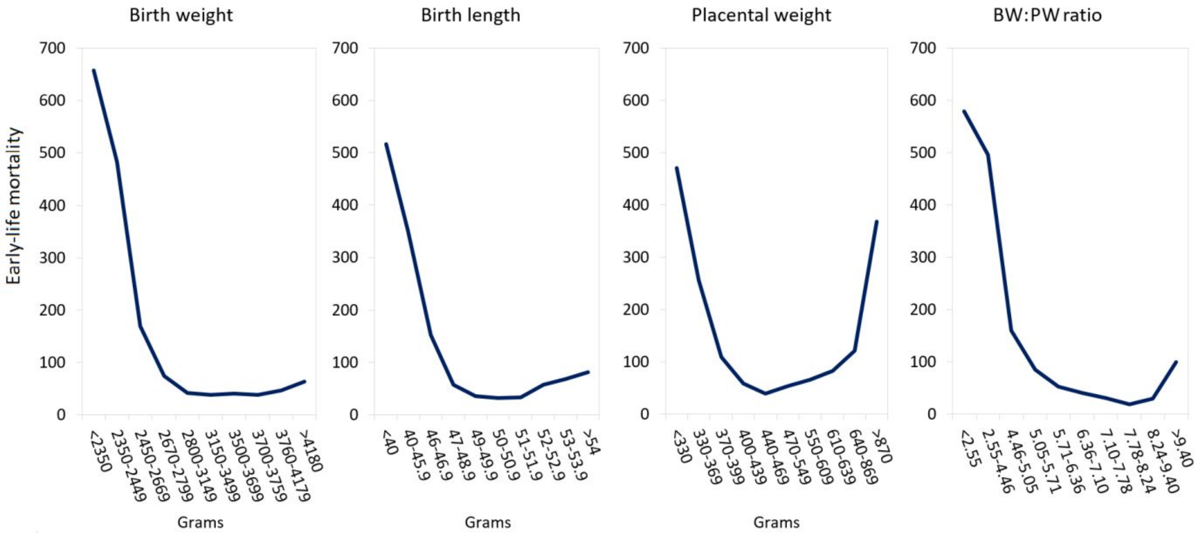
Notes and Sources: For data and sources see text. The dark blue line shows the monthly data and the marron line the yearly averages with their associated 95 percent confidence intervals.

Figure 4. Male and female real wages and placental weights, 1908-20



Sources: See text. *Notes*: The dark blue line shows placental weights and the grey line real wages. For placental weights, instead of the natural years (January to December), the years refer to July-June 1908/09, July-June 1909/1910, etc.

Figure 5. Early-life Mortality, Birthweight, Birth Length, Placental weight and BW:PW ratio.



Sources: Early-life data are from the Provincial House records (see text).

Table 1. Early-life mortality in the Provincial House and Barcelona

Year	Provincial House	Legitimate births in Barcelona	Illegitimate and foundling births' in Barcelona
1905	50.60	80.00	127.90
1906	54.00	68.10	120.40
1907	57.30	77.90	173.60
1908	49.80	77.60	151.80
1909	71.70	70.80	142.40
1910	60.70	72.50	118.50
1911	49.60	71.70	131.80
1912	45.00	72.80	141.50
1913	53.00	74.50	144.90
1914	81.00	73.10	135.60
1915	65.50	68.50	117.60
1916	92.30	63.30	122.20
1917	77.30	68.70	117.80
1918	107.00	73.20	108.50
1919	99.70	62.30	196.40
1920	83.60	56.60	173.70

Sources: For the Provincial House records see text. Data on legitimate, illegitimate and founding births in the city of Barcelona are from the *Statistical Yearbook of the city of Barcelona.* The early-life mortality indicator is the total number of babies who were stillborn, died during delivery and during the first 24 hours per thousand births.

Table 2: Cox proportional hazards models predicting risk of death

	(1)	(2)	(3)	(4)	(5)	(6)
Sex (Ref. boy)	0.875	0.972	0.785	0.839	0.801	0.797
	(0.185)	(0.205)	(0.170)	(0.180)	(0.174)	(0.175)
Birthweight (grams)	0.579***					0.562***
	(0.040)					(0.040)
Placental weight (grams)		1.046				1.133***
		(0.064)				(0.049)
BW:PW ratio			0.553***		0.552***	
			(0.047)		(0.046)	
Birth length (cm)				0.438***		
				(0.083)		
Maternal height (cm)					0.881	0.874
					(0.087)	(0.087)
Maternal weight (kg)					0.965	1.043
					(0.154)	(0.171)
Maternal pelvis size (cm)					0.740	0.815
					(0.179)	(0.199)
Number of subjects	1,278	1,278	1,278	1,278	1,278	1,278
Number of failures	91	91	91	91	91	91
Schoenfeld residuals	0.625	0.229	0.967	0.546	0.567	0.254

Sources and Notes: Neonatal, early-life and maternal data are from the Provincial House records (see text) and combine deaths during pregnancy, deaths during delivery and deaths occurred during the first 24 hours immediately after delivery. Standard errors are given in parentheses. To control for non-linearities, we bin the birth outcomes and enter them as dummy variables: for birthweight we use bins for every 500 grams (i.e., 500-999, 1,000g-1,499, etc.), for placental weight every 50 grams, for the BW:PW ratio every unit, for birth length every 20 cm, for maternal height every 15 cm, for maternal weight every 10 kg and for the maternal pelvis size every 5 cm. For the proportionality tests, we used the Schoenfeld residuals. These tests suggested that there is no evidence that the proportional-hazards assumption has been violated. Along with the global test we also check for covariate-specific tests and found similar results. In the different entries of the table, coefficients greater than 1 increase risk whereas coefficients less than 1 reduce risk, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3. Birth statistics: Provincial House and modern comparators

				Granada (2007-10)						Granada (2008-12)					
	Provincial House			‘Normal’ (N=59)		‘Overweight’ (N=29)		‘Obese’ (N=22)		‘Normal’ (N=≤128)		‘Overweight’ (≤54)		‘Obese’ (N=≤52)	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mothers															
Age	3,524	24.94	5.65	30.40	4.50	30.90	7.20	29.00	4.70	30.90	4.20	32.00	4.20	29.50	7.80
Height (cm)	1,964	152.06	6.60	162.90	5.70	162.50	6.40	162.70	6.20	163.90	n/a	174.66	n/a	161.91	n/a
Weight (kg)	1,322	59.45	7.60	70.59	n/a	82.65	n/a	93.71	n/a	72.00	8.80	82.20	n/a	94.80	n/a
BMI	1,301	24.23	2.75	26.60	2.60	31.30	2.40	35.40	2.40	26.80	n/a	26.95	n/a	36.16	n/a
Infants															
Birth weight (grams)	3,830	3,214.24	502.14	3,292.00	410.00	3,230.00	587.00	3,454.00	549.00	3,250.00	390.00	3,290.00	490.00	3,490.00	510.00
Placental weight (grams)	3,830	505.27	99.05	469.00	120.00	495.00	135.00	531.00	114.00	475.00	112.00	512.00	123.00	571.00	133.00
BW:PW ratio	3,830	6.36	1.11	7.02	n/a	6.53	n/a	6.50	n/a	6.84	n/a	6.43	n/a	6.11	n/a

Notes. In ‘Granada 2007-10’ maternal weight was calculated using maternal BMI at 34 weeks and in ‘Granada 2008-12’ maternal height was calculated using maternal BMI prior to gestation. The labels ‘normal’, ‘overweight’ and ‘obese’ refer to the mothers’ pregestational weights. *Sources:* Provincial House: see text; Granada 2007-10: Martino *et al.*, ‘Maternal Body Weight’, Tables 1, 3; Granada 2008-12: Berglund *et al.*, ‘Maternal, fetal and perinatal alterations’, Tables 1, 2

Table 4. Placental weights and birth weights, 1844/6-2017

Authors	Location	Period	Observations	Placental weight (g)	Birth weight (g)	Comments
Priestley and Storer	Edinburgh, UK	1844-6	325-337	591.80	3,102.50	Original measurements: Placentas (325): 1 lb, 4 oz, 14 dr[ams]; Birthweights (337): 6 lbs 13oz, 7 dr[ams]
Costa	Baltimore, USA (whites)	1897-1935	961	570.76	3,448.96	n/a
Costa	Baltimore, USA (blacks)	1897-1935	1,254-1,363	541.42	3,192.79	n/a
Costa	Baltimore, USA	1897-1935	1,254-1,363	554.15	3,298.72	n/a
Butie *et al.*	Basle, Switzerland	1912/13-1923	2,618	649.70	3,292.50	n/a
Barker *et al.*	Helsinki, Finland	1934-44	6,975	648.53	3,409	Barker and his colleagues also published several other studies using data from the Helsinki records. Where these studies include placental weights or birth weights, the figures tend to be similar to those reported here. See e.g. Barker *et al.* 'Trajectories of growth, p. 1804; Barker *et al.* 'The lifespan of man', p. 784; Eriksson *et al.*, 'Early growth and coronary heart disease', p. 950; Kajantie *et al.,* p. 470.
Stein and Susser	Netherlands	1944-6	3,108-3,245	600.75	3,306.65	3108 placentas; 3245 births in Rotteram, Groningen and Heerlen
Thomson *et al.*	Aberdeen, UK	1948-64	33,044	648.92	3,312.00	Singleton births
Naeye	USA	1959-66	26,529	520.01	-	NCPS data 'Trimmed' weight = 435.25g. For details of the original study, see Warburton and Naylor.
Naeye and Dixon	USA	1959-66	48,239	520.84	3,269.38	NCPS data; Single born neonates; information on trimming from Naeye 1987; 'trimmed' weight = 435.94g. For details of the original study, see Warburton and Naylor.
Warburton and Naylor	USA	1959-66	30,642	525.91	3,250.65	Info. re. trimming from Naeye 1984; 'trimmed' weight = 440.19g. In the original study, the average figures for 'white' mothers were 447.6g (trimmed placental weight) and 3,334.60g (birth weight), and the average figures for mothers described as 'Negro' were 429.93g (trimmed placental weight) and 3,135.45g (birth weight). (Equivalent figures for untrimmed placental weights are 534.76g and 512.58g respectively). The study excludes foetal deaths, multiple births, evidence of endocrine or metabolic disease, if reproductive histories from consecutive pregnancies of the same woman showed inconsistencies and deliveries below 36 weeks.
McLean *et al.*	Montreal, Canada	1978-86	6,379-7,000	671.03	3,527.30	6379 placentas and 7000 births
Dombrowski *et al.*	Detroit, USA	1984-91	2,215-2,324	654.50	3,331.56	The original study presented estimates showing placental weights and BW: PW ratios at each week of gestational age from 24-43 weeks but did not give numbers of births at each week. The current figures are therefore based on the unweighted mean value of the mean placental weight at 39 weeks and birthweights have been estimated from the reported value of the BW:PW ratio at 39 weeks. The authors noted that 81.4 per cent of babies in the original study were born to mothers of African-American origin. The total number of subjects in the study as a whole was 29,902.
Heinonen *et al.*	Kuopio, Finland	1990-99	16,616	620.74	3,522.89	Weighted average of results for AGA and SGA babies
Pinar	USA	1993-5	787	548.39	n/a	Singleton births only; 'trimmed' weight = 459.01g
Burkhardt	Zurich, Switzerland	1995-2002	8,463	501-560	2,846.59-3,589.74	Vaginal births. 50th centile values, gestational age 37-41 seeks; birth weights calculated from the reported values of the P:BW ratios at each week of gestational age for both vaginal and caesarean births.
Burkhardt	Zurich, Switzerland	1995-2002	2,678	579-642	3,289.77-4,115.38	Caesarian births. 50th centile values, gestational age 37-41 seeks; birth weights calculated from the reported values of the P:BW ratios at each week of gestational age for both vaginal and caesarean births.
Lao and Wong	Hong Kong	Not stated (c. 1999)	252	478.95	n/a	Study conducted on small-for-gestational-age babies
Thompson *et al.*	Norway	1999-2002	198,971	795.66	3,587.45	Although the authors stated that placentas ought to have been trimmed before weighing, they also noted that 'to what extent these guidelines are followed is unclear, though anecdotal information would suggest that they do not appear to be enshrined in obstetric practice'. The resulting figures may therefore be overestimates. The original estimate figure was 665.96g, based on the estimated median values for each week of gestational age from 24-44 weeks.
Ouyang *et al.*	Boston, USA	1999-2013	1,035	503.84	2,665.01	This sample included a high proportion of pre-term births (41% of total). The average weight of the placentas at term was 474.62g (trimmed) which corresponds to an estimated 'untrimmed' value of 567.05g.

Almog *et al.*	Canada	2001-7	20,307	787.83	n/a	These figures have been calculated using the median values of placental weights from weeks 24-44 of gestational age. The study used both singleton and twin births but did not disaggregate them. This is likely to have imparted an upward bias to the estimates since other studies have shown that placentas associated with twin births are much heavier (for example, Pinar *et al.* estimated that the average weight of placentas in singleton births was 459.01g (trimmed weight) whereas the average weight of the placentas in twin births was 745.63g (trimmed weight). In the present study, the original 'trimmed' weight as 659.4g.
Leary *et al.*	Southampton, UK	Not stated (c. 2002)	50	589.00	3,553.00	Placental weight and birth weight are medians. This study also reported trimmed weights (480g).
Salafia	North Carolina, USA	2002-4	628	548.00	n/a	Singleton births. This study also reported trimmed weights (452g).
Janthanaphan *et al.*	Songkhlanagarind, Thailand	2004	519	620.07	3,020.95	BW calculated from BW:PW ratio; subjects were at 36-40 weeks' gestational age. 'Trimmed' weight = 519g.
Panti *et al.*	Nigeria	2008-9	1,009	590.00	3,275.00	n/a
Cerosimo *et al.*	Rio de Janeiro, Brazil	2011-12	73-78	584.03	3,249.59	Separate data for adolescent and teenage vs. adult mothers; 73 placentas; 78 births
Kaur	Punjab, India	Not stated (c. 2016)	60	537.00	3,047.67	Data collected from 30 'anaemic' women and 30 'non-anaemic' women. For birth weights, separate figures were given for women with mild, moderate and severe anaemia but exact numbers were not given
O'Brien *et al.*	Dublin, Ireland	2017	276	634.57	n/a	50th centile values

Notes: We have assumed that placentas were weighed before trimming unless otherwise stated. Where we have obtained data from studies using trimmed placentas, these figures are shown in italics. The italicised figures have been converted to 'untrimmed' figures by dividing the trimmed figures by 0.837. The original trimmed figures are shown in the 'Comments' column. *Sources*: Almog *et al.*, 'Placenta Weight'; Barker *et al.*, 'Surface Area'; Burkhardt, 'Reference Values'; Butie *et al.*, 'Impact of World War I'; Cerosimo *et al.*, 'Comparison'; Costa, 'Race and Pregnancy'; Dombrowski *et al.*, 'Birth Weight-Length Ratios'; Heinonen *et al.*, 'Weights of Placentae'; Janthanaphan *et al.*, 'Placental Weight'; Kaur, 'Assessment of Placental'; Lao and Wong, 'Neonatal Implications'; Leary *et al.*, 'Contribution'; McLean *et al.*, 'Postterm Infants'; Naeye, 'Do Placental'; Naeye and Dixon, 'Distortions'; O'Brien *et al.*, 'Placental Weights'; Ouyang *et al.*, 'Placental Weight'; Panti *et al.*, 'Relationship'; Pinar, 'Reference Values'; Priestley and Storer *Obstetric Memoirs*; Salafia *et al.*, 'Measures of Placental'; Stein and Susser, 'Dutch Famine'; Thompson *et al.*, 'Placenta Weight'; Thomson *et al.*, 'Weight of the Placenta'; Warburton and Naylor, 'Effect of Parity.

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Growth Before Birth: The Relationship between Placental Weights and Infant and Maternal Health in early-twentieth century Barcelona

Data Appendix for Online Publication

Gregori Galofré Vilà and Bernard Harris

Appendix A: Data Sources

Our paper explores a novel dataset using the medical forms of the Provincial House (Casa Provincial de Maternitat i Expòsits, *Secció de parts*). These records are held in the *Arxiu Històric de la Diputació de Barcelona*.

Our data are based on the totality of births that took place in the Provincial House between 1905 and 1920 (with the exception of 1906 and 1910 as records were lost or stolen). However, while in the paper we explored some key variables available in the medical forms, including maternal characteristics and health details of the newborns, after 1916 medical doctors also recorded additional information. For instance, they also recorded the age at which mothers started to walk, age of menarche, main diseases experienced during growth, complications during pregnancy and blood pressure. They also collected the details of various dimensions of the baby's head, pulse and temperature at birth, length of the umbilical cord and monitored birth weight over the first days of life (first week or so). Thus, although not explored in this paper, we note the existence of additional data in the medical forms as they might be useful for future research. Although our analysis stops in 1920, the records are also available for subsequent decades.

Appendix B: The Provincial House

The Provincial House was a public charity organization that had to attend all women who requested it. Its origins can be found in the Spanish General Law of Charity of 20 June 1849 and its Regulation of May 14, 1852, which set the basic characteristics of the model of charity in Spain.

The Provincial House printed booklets that defined the legislation of the institution including rules concerning the Department of Maternity. The first booklet we have been able to locate was printed in 1890 and we checked the four booklets printed between 1890 and 1936 to understand how admission worked in the Department of Maternity. We noted that between 1890 and 1936 the number of regulations increased, but they followed the same philosophy throughout the different editions. We attributed the increase in the number of rules in each edition to new developments of the Provincial House with new pavilions and institutional needs.

After a pregnant woman made a request, she was inspected by a medical doctor who invited her to enter the institution. Article 85 of the booklet of the Provincial House of Barcelona printed in January 1936 stated that: 'The object of the Department of Maternity is to give asylum and assistance to pregnant women who claim this assistance'. Article 87 further adds that 'to be sheltered ... a woman who requests it, must satisfy the following two conditions: a diagnostic check of the state of pregnancy, to have entered the seventh month of gestation. In order to attend to moral or health interests, the Board may, with prior knowledge and optional opinion, grant the admission despite not meeting the second condition of the conditions expressed. This exception may be established and regulated by the Board with a general nature for first time single women'. Hence, although it seems likely that the majority of women were admitted during the final trimester of their pregnancy, a small number could have been admitted earlier for either 'moral' (most likely if she was carrying an illegitimate birth) or medical reasons (a difficult pregnancy).

Article 101 regulated the entry and exit in the Department of Maternity, saying that 'When a pregnant woman requests entrance... she is examined by a medical doctor, who will arrange for her to enter the Department of Maternity or one of the corresponding sections, after washing, receiving a change of clothes, disinfection and other appropriate hygienic precautions have been carried out, according to the state and circumstances of the interested party'. Yet, Article 89 is more ambiguous in acceptance. Since the capacity of the Provincial House was limited, there was a maximum number of beds which could be allocated ('the number of shelters ... will be set by the Board, in view of the capacity of the available premises'). In general, then, it seems that they continued to admit expectant mothers until full capacity was reached.

Although the Provincial House assisted women who wanted secrecy about their pregnancy, we have been able to locate the registers which included details of the dates on which individual mothers were admitted, the dates on which they gave birth, and the dates on which they departed.[1] In order to have a sense about the period between entry and delivery, and delivery and exit, we have transcribed the data for 1908 and 1909. We find that the vast majority of prospective mothers entered the institution within 6-10 weeks of giving birth. Specifically, the average number of days between admission and delivery was 45.8, with a standard deviation of 32.1. The average number of days between delivery and departure was

[1] Unfortunately, we cannot link them to a particular birth, as in one day more than one birth could take place in the Provincial House.

16.1, with a standard deviation of 14.8. Additionally, since women were expected to be in seventh month of pregnancy before entering the institution, we found that 90% of the cases were within the last 91 days of pregnancy. For the remaining mothers, under the Article 87 it was also possible to enter before the seventh month if the board of the Provincial House approved it. From the registers it was impossible to read the accurate day number or name of the month for less than 1 per cent of the cases. We also found that 38% of the women entered within the last 30 days of pregnancy and 67% during the last 60 days. It is therefore unlikely that many mothers joined the institution during the first trimester but they did enter early enough to benefit from better nutrition in the third trimester, which may have prevented a large birth weight effect.

Although for our study what happened to the mothers after giving birth is less relevant, data show that 73% of the mothers left the Department of Maternity after 14 days. Yet, despite exiting the Department of Maternity, it is possible that they moved to another Department of the Provincial House if they wanted to breast-feed their baby and some of them also worked as wet nurses.

Appendix C: Maternal characteristics

On maternal origin, Table A1 depicts the birthplace of the mothers attended at the Provincial House. This information was not recorded for pre-1911 years and was incomplete for the years between 1911 and 1915 when medical doctors mostly only recorded it if the birthplace was Barcelona. If we focus in the birthplace details for between 1911 and 1920, although we do not actually know when the mothers moved from their birthplaces to Barcelona, we find a decline in the percentage of mothers accepted in the Provincial House born in Catalonia after 1915, which is consistent with the influx of migrants experienced in Barcelona in the 1910s.[2]

[2]Silvestre, J., 'Las Emigraciones Interiores...', *Revista de Estudios sobre Despoblación y Desarrollo Rural* 2 (2002), pp. 227-248.

Table A1. Maternal place of birth

Year	Barcelona	Other Catalonia	Outside Spain	Spain	Not recorded
1911	156	28	29	3	66
1912	187	19	32	2	49
1913	179	18	30	1	74
1914	145	16	19	2	65
1915	140	13	19	2	162
1916	109	80	190	6	5
1917	117	84	203	8	2
1918	106	95	174	5	3
1919	97	64	193	7	0
1920	106	76	180	5	4

On maternal occupation, Table A2 depicts the occupational structure in our sample. We find that there was no significant change in the occupational structure of the Provincial House population over time. From the cases occupation was recorded between 1911 to 1920 (77.9 per cent), 54.4 per cent of the mothers were described as servants and maids and 29.3 per cent factory workers. Despite some short-run fluctuations, the hierarchy of the occupational structure in our data is maintained throughout the 1910s and it is unknown if the short-run movements in the data are due to selection effects or to changes in the female labour market as a whole.

On maternal height, Table A3 depicts the details of maternal height and weight. Height was only recorded after 1914 and weight after 1916. There was a small decline in average height between 1914 and 1915 (from 152.54 cm to 151.82 cm) followed by a small increase up to 1918, and then a further decline. The average weight of the mothers fell by approximately 0.7 kg between 1916 and 1917 but changed very little between 1917 and 1919, although there was a further fall between 1919 and 1920. However, none of these changes was especially significant and differences are within the 95% confidence intervals (unreported here). In the data we also observe that maternal height as measured by birth cohorts was fairly constant for the mothers born between 1880 and 1900, with a mean value of 152.0 cm and a standard deviation of 0.6 (unreported here). We also find that maternal height and weight were normally distributed (unreported here).

Table A2. Maternal occupation

Year	Servant	Factory	Farming	Shops	Other	Unrec.	Total
1911	127	61	15	10	16	53	282
1912	137	63	18	9	12	50	289
1913	135	66	15	5	9	72	302
1914	74	35	12	6	2	118	247
1915	62	39	11	5	6	213	336
1916	166	106	40	14	12	52	390
1917	209	114	25	4	26	36	414
1918	165	107	28	9	21	53	383
1919	158	84	26	9	22	62	361
1920	196	94	22	13	8	38	371

Table A3. Maternal height and weight

	Height (cm)		Weight (kg)	
	N	Mean	N	Mean
1914	154	152.5	n/a	n/a
1915	284	151.8	n/a	n/a
1916	353	152.2	69	60.3
1917	394	152.5	396	59.6
1918	349	152.4	356	59.3
1919	321	151.6	324	59.4
1920	322	151.2	329	58.6

Table A4. Maternal age

Year	N	Mean	Year	N	Mean	Year	N	Mean	Year	N	Mean
1905	n/a	25.4	1910	n/a	n/a	1915	327	25.1	1920	369	25.5
1906	n/a	n/a	1911	250	24.6	1916	362	25.5			
1907	n/a	25.0	1912	286	24.7	1917	413	25.3			
1908	n/a	24.3	1913	297	24.8	1918	381	24.6			
1909	n/a	24.5	1914	245	24.7	1919	359	24.9			

Using data from Martínez-Carrión *et al.*[3], we also find that the heights in the province of Barcelona were fairly similar to that of nearly provinces. In 1913 the average male height in the province of Barcelona was 162.6 cm, which was similar to nearby provinces outside Catalonia such as in Osca (162.1 cm), 162.5 cm in Saragossa, 161.8 cm in Terol, 162.3 cm in Castelló and 163.5 cm in València. Similarly, the average male weight in Barcelona was 60.7 kg, 61.9 kg in Osca, 61.4 kg in Saragossa, 60.9 kg in Terol, 61.5 kg in Castelló and 60.7 kg in València. We also explored the birth weights and placental weights of the babies from Catalan and non-Catalan mothers and only found small differences between the two groups (again, a t-test suggests that differences are not significant).

On maternal age, in Table A4 we report that the average age of the mothers ranged from a minimum of 24.3 years (in 1908) to 25.5 (in 1915), with a mean value from 1911 to 1920 of 25.0. Deviations from the mean are unlikely to affect our findings as after controlling for maternal socioeconomic and health status, maternal age ceases to have an effect on birth weight.[4] Maternal age was probably self-reported but we note that there is relatively limited evidence of age-heaping as controlling for age-misreporting gives a Whipple Index of 124.7, suggesting acceptable quality of age data.

Appendix D: Birth outcomes

On the number of births, as Table A5 depicts, out of the recorded 4,331 births, we excluded 305 children who were either stillborn, born dead or dead within 24 hours (column 10) and 79 children who were either twins or triplets (column 9). We also excluded 18 children whose sex was unspecified (column 8) and 99 children for whom either placental weight or birth weight was lacking (column 7). Our analysis is therefore based on the birth weights and placental weights of 3,830 live-born singleton births.

On birth outcomes, Table A6 depicts the main trends in average birth weights and placental weights for boys and girls. Both male and female birth weights were relatively low in 1905, and they showed little change over the rest of the period. Although birth weights were relatively low in 1905, they showed little change over the rest of the period. Placental weights fluctuated rather more markedly. There was relatively little change before 1911, but then placental weights fell between 1911 and 1914 and then rose even more sharply between

[3] Martínez-Carrión, J. M. *et al.*, 'Parámetros Antropométricos', *Nutrición Hospitalaria* 33 (2016).

[4] Borja, J. D., and Adair, L. S., 'Assessing the Net Effect', *American Journal of Human Biology*, 15 (2003).

1914 and 1917. There was little change between 1918 and 1920. Over the period as a whole, the average birth weight of the babies in our sample was 3,214 grams (boys weighed 3,263 grams and girls 3,162 grams) and the average placental weight was 505 grams (503 grams for boys and 507 for girls).

We also wondered whether changes in the developments of birth weight or placental weight were not due to sex ratios. For instance, Beltrán Tapia and Gallego-Martínez have pointed out that childhood sex ratios in nineteenth-century Spain were abnormally high, with an excess of female mortality.[5] However, when we plot the development of placental weight by sex, we find little differences by gender and both sexes responded equally to the same maternal health conditions (unreported here).

To strengthen our argument that selection on maternal characteristics was not driving the neonatal patterns we observe across time, we estimated five additional regression models for birth weight and placental weight controlling for maternal characteristics and one-year time dummies. The results of this test show that the year dummies can effectively replicate the trend we describe and are statistically significant (unreported here). The limitation of this analysis is that we are restricted to the period 1916-20 when maternal characteristics are available in the data.

Appendix E: Prices & Wages

As we explain in the paper, Barcelona experienced a short-lived improvement in economic conditions at the start of the First World War, followed by a significant decline. This was reflected in trends in a number of different price series. From the *Boletín del Instituto de Roformas Sociales* we collected nominal prices from a variety of commodities from markets in Barcelona. Table A7 shows that the prices of a number of staple items, including bread, meat, cod and potatoes, began to increase either immediately before the war or during its early stages, whilst the prices of other goods, such as rice, sugar, milk, petrol and olive oil increased later. The prices of wine and chickpeas were more volatile, although these also showed an upward trend. From the *Instituto de Reformas Sociales* (*Memoria General de la Inspección del Trabajo*) we also collected data on nominal wages from industrial workers in Barcelona (for males and females). Nominal wages have been deflated by a price index based on the prices charged in Barcelona markets (as defined in the paper).

[5] Beltrán Tapia, F. J., and Gallego-Martínez, D., 'Where are the Missing Girls?', *Explorations in Economic History*, 66 (2017).

Table A5. Number of births in different categories, 1905-20.

	Single births										
	Male			Female							
Year	BW	PW	BW & PW	BW	PW	BW & PW	BW & PW	No sex	+1 birth	deaths	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1905	108	81	81	109	94	94	44	2	4	12	237
1907	121	114	114	89	83	82	15	2	2	12	227
1908	102	98	98	128	122	122	10	1	4	6	241
1909	120	116	116	111	108	108	7	0	4	16	251
1911	130	128	128	129	126	126	5	1	10	12	282
1912	122	121	121	147	146	146	2	0	7	13	289
1913	141	140	140	141	141	141	1	0	4	16	302
1914	110	110	110	113	113	113	0	0	4	20	247
1915	161	159	159	147	142	142	8	2	4	21	336
1916	168	166	165	160	159	159	6	3	14	43	390
1917	213	213	213	164	164	164	0	1	4	32	414
1918	177	177	177	159	159	159	0	4	6	37	383
1919	164	164	164	154	154	154	1	2	6	34	361
1920	191	191	191	143	143	143	0	0	6	31	371

'BW' stands for birth weight, 'PW' stands for placental weight, and '+1 births' for multiple births. As we report in the paper, we do not have data for 1906 and 1910.

Table A6. Main descriptive statistics of BW and PW, 1905-20

	Male					Female				
		BW		PW			BW		PW	
	N	Mean	SD	Mean	SD	N	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1905	81	3,226.0	440.3	515.8	111.4	94	3,052.4	589.6	497.5	98.7
1907	114	3,267.5	529.1	488.3	85.9	82	3,206.4	556.5	506.8	104.9
1908	98	3,290.9	448.9	514.0	101.8	122	3,217.5	472.5	516.2	101.0
1909	116	3,153.5	562.4	491.0	91.2	108	3,147.7	485.1	499.7	105.1
1911	128	3,284.4	520.2	503.3	103.0	126	3168.7	513.8	502.6	92.0
1912	121	3,230.1	454.4	475.0	86.7	146	3114.3	444.7	499.9	97.6
1913	140	3,316.7	453.8	478.8	84.2	141	3170.4	459.4	472.1	77.1
1914	110	3,297.5	479.0	458.7	87.8	113	3178.5	487.5	464.6	81.8
1915	159	3,298.7	492.1	478.0	98.4	142	3170.6	505.1	479.0	92.5
1916	165	3,273.0	556.6	496.8	99.8	159	3181.3	504.9	490.5	97.1
1917	213	3,247.7	496.7	520.5	97.8	164	3156.7	501.2	537.2	105.4
1918	177	3,265.1	539.0	523.9	107.8	159	3156.3	441.3	533.0	89.9
1919	164	3,260.4	476.1	525.4	97.7	154	3138.9	574.4	533.6	103.8
1920	191	3,258.0	488.5	539.4	97.9	143	3202.9	490.3	529.6	98.5

As we report in the paper, we do not have data for 1906 and 1910

Table A7. Barcelona prices, 1901-1920. Pessetes per kg.

	Bea	Bre	Chi	Ric	Cod	Bee	Bul	But	Egg	Mil	Pig	Shee	Cha	Cha	Pet	Soa	Oli	Win	Pot
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1900	0.50	0.40	1.25	0.57	1.00	2.15	2.00	2.25	1.30	0.40	2.25	2.20	0.10	0.07	0.85	0.70	0.60	0.30	0.25
1901	0.50	0.40	1.25	0.57	1.10	2.10	2.00	2.25	1.30	0.40	2.25	2.15	0.10	0.07	0.85	0.75	1.50	0.25	0.15
1902	0.50	0.40	1.30	0.60	1.10	2.10	2.00	2.25	1.25	0.40	2.25	2.15	0.10	0.07	0.80	0.75	1.60	0.25	0.20
1903	0.56	0.40	1.30	0.60	1.15	2.15	2.00	2.20	1.25	0.40	2.30	2.20	0.10	0.07	0.80	0.70	1.60	0.25	0.20
1904	0.56	0.40	1.35	0.63	1.15	2.20	2.00	2.20	1.30	0.40	2.40	2.20	0.15	0.07	0.90	0.70	1.55	0.25	0.20
1905	0.63	0.40	1.35	0.63	1.15	2.30	2.25	2.20	1.25	0.40	2.50	2.25	0.15	0.07	0.85	0.75	1.55	0.30	0.20
1906	0.63	0.40	1.40	0.63	1.15	2.35	2.25	2.25	1.25	0.40	2.50	2.35	0.15	0.07	0.85	0.75	1.60	0.30	0.20
1907	0.63	0.40	1.40	0.63	1.20	2.35	2.25	2.30	1.30	0.40	2.60	2.30	0.15	0.07	0.80	0.75	1.60	0.30	0.25
1908	0.60	0.40	1.40	0.63	1.20	2.40	2.30	2.20	1.30	0.40	2.60	2.25	0.15	0.07	0.85	0.75	1.60	0.25	0.20
1909	0.60	0.40	1.45	0.63	1.25	2.40	2.30	2.20	1.50	0.40	2.65	2.30	0.15	0.07	0.80	0.75	1.50	0.25	0.20
1910	0.70	0.40	1.45	0.63	1.25	2.60	2.50	2.15	1.50	0.40	2.65	2.35	0.15	0.07	0.80	0.75	1.60	0.30	0.20
1911	0.70	0.40	1.45	0.63	1.25	2.70	2.50	2.10	1.50	0.40	2.65	2.35	0.15	0.07	0.80	0.75	1.25	0.65	0.20
1912	0.69	0.40	1.50	0.65	1.25	3.00	2.58	2.00	1.61	0.40	2.68	2.27	0.15	0.07	0.80	0.75	1.66	0.25	0.17
1913	0.77	0.44	1.50	0.64	1.25	3.00	2.50	2.00	1.67	0.40	2.75	2.25	0.15	0.07	0.86	0.75	1.60	0.25	0.20
1914	0.75	0.45	1.50	0.62	1.34	3.00	2.50	2.00	1.78	0.40	2.75	2.25	0.15	0.07	0.90	0.75	1.60	0.25	0.17
1915	0.81	0.50	1.50	0.68	1.53	3.00	2.50	2.00	1.87	0.40	2.91	2.27	0.15	0.07	0.90	0.75	1.60	0.30	0.22
1916	0.75	0.50	1.50	0.71	1.86	3.08	2.66	2.33	1.92	0.50	3.00	2.50	0.18	0.13	0.90	0.91	1.62	0.30	0.25
1917	0.83	0.56	1.50	0.75	2.74	3.37	3.15	2.85	2.46	0.50	3.29	2.66	0.21	0.19	1.03	1.19	2.03	0.30	0.25
1918	0.83	0.60	1.50	0.75	3.50	3.62	3.50	4.00	3.10	n/a.	4.12	3.37	0.30	0.37	1.50	1.37	2.05	n/a.	0.25
1919	1.02	0.62	1.50	0.90	3.87	4.80	4.16	4.26	3.37	n/a.	4.57	4.80	0.27	0.27	1.90	1.12	1.90	n/a.	0.36
1920	1.37	0.70	1.50	0.95	3.62	4.25	4.80	4.38	3.75	n/a.	4.00	4.80	0.32	0.25	1.27	1.25	2.33	n/a.	0.28

Data are from the Statistical Yearbooks of the City of Barcelona, several issues and egg prices are shown in *pessetes* per dozen. Column (1) shows Beans, (2) Bread, (3) Chickpeas, (4) Rice, (5) Atlantic cod (fish), (6) Beef meat, (7) Bull meat, (8) Butter, (9) Eggs, (10) Milk, (11) Pig meat, (12) Sheep meat, (13) Charcoal, (14) Charcoal, (15) Petroleum, (16) Soap, (17) Olive oil, (18) Wine, and (19) Potatoes.