

Analysis of the Historical Evolution of Sex Ratio at Birth in Spain

Análisis de la evolución histórica de la razón de masculinidad al nacer en España

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Key words

Mother's Age

- Father's Age
- Spain
- Standardization
- Solar Radiation
- Races
- Sex Ratio at Birth
- Vitamin D

Palabras clave

Edad de la madre

- Edad del padre
- España
- Estandarización
- Radiación solar
- Razas
- Razón de masculinidad al nacer
- Vitamina D

Abstract

This study analyzes sex ratio at birth in Spain from the late 19th century to the present. A detailed examination has been performed for the period between 1975 and 2019, considering over 20 million birth records. In addition to verifying the low reliability of the birth records during the early 20th century, we have also found that, in contrast to general beliefs, this ratio is not consistent. Our data suggest that parental age and race, birth order and intensity of solar radiation, all clearly influence this indicator.

Resumen

Presentamos un análisis de la razón de masculinidad al nacer en España desde finales del siglo XIX hasta la actualidad. Se hace una explotación muy detallada para el período 1975-2019 sobre la base de más de 20 millones de fichas de nacimientos. Además de constatar la escasa fiabilidad de los registros de los nacimientos en las primeras décadas del siglo XX, hemos determinado que, al contrario de lo generalmente aceptado, esta ratio no es constante. Nuestros datos muestran que la edad y la raza de los progenitores, el orden de nacimiento, el estado civil de las madres y la intensidad de la radiación solar tienen una clara influencia en dicho indicador.

Citation

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INTRODUCTION

The human sex ratio at birth (SRB) is the ratio of the number of male live births, expressed as a percentage. Some scientists believe that this relationship is a biological constant, equaling approximately 105-106 male births per 100 female births (Ein-Mor *et al.*, 2010). This minor bias towards the male sex at birth was first documented in the early 18th century by Englishman, John Graunt. Since then, many studies of the human population have confirmed it. A study by Chahnazarian (1986) on births occurring between 1962 and 1980 in 24 European countries reveals an SRB of 105 to 107, with a median of 105.9. This last figure is commonly used as a reference figure to calculate deviations in sex proportions. In contrast to common beliefs, the SRB in Spain is not a consistent figure, but rather, one that varies considerably, depending on certain factors.

Numerous biological, demographic, environmental and sociological factors may influence SRB, such as family size, age and employment of parents (Novitski, 1953), birth order, race (Khoury, Erikson and James, 1984), frequency of intercourse, latitude, diet type, famine, exposure to environmental toxins (Schacht, Tharp and Smith, 2019; Terrell, Harnett and Marcus 2011), stress (Grech, 2018), socio-economic aspects (Grech, 2018), illnesses, wars (Hesketh and Xing, 2006) and even earthquakes¹.

Despite the numerous studies performed globally on this topic, in Spain it has been almost completely ignored, with the exception of two studies: one by Gutiérrez-Adán, Pintado and Fuente, (2000) and another by Braglia and Nicolini (2018). The former analyzes SRB during a very short period of time (1981-1997) suggesting that changes in ma-

ternal age have led to variations in this ratio. The latter considers the potential link between increases in SRB in Spain and the potential existence of selective female abortion practices.

The importance of the study of SRB is unquestioned. Many demographic phenomena are affected by this ratio, including marriage rate, the quantity and extension of immigration and mortality rate. A community's social life may be highly affected by the sex distribution. This ratio affects the time needed to double a population size (which is greater when the ratio is higher). It is also relevant in the understanding of infant morbidity (male children are more likely to become ill and have higher rates of infant mortality) and it has been used to assess the impact of environmental factors on the endocrine system and the reproductive health of humans, etc.

Diverse articles on SRB and the sex proportion of infants, suggest the potential existence of female infanticide practices and negligence in the care of young girls in Spain prior to 1950 (Echavarri, 2022; Beltrán and Marco-Gracia, 2021; Beltrán and Gallego-Martínez, 2020; Braglia and Nicolini, 2018). Articles have been published which consider this ratio, declaring that in certain communities, immigrants living in Spain currently engage in selective female abortion practices (González, 2018; Castelló *et al.*, 2019).

SOURCES

This study is based on data obtained from the following sources:

- Births in Spain according to sex and mother's origin (provinces and capital cities)²:

¹ Some excellent literature reviews on the causes of the SRB appear in the works of Chahnazarian (1988), Guilmo (2015), James and Grech (2017) and West and Grech (2020).

² Until 1927, the provinces of Santa Cruz de Tenerife and Las Palmas formed part of a single province (Canary Islands). In this work, we have maintained this territorial unit throughout the study period (1858-2019).

- a) 1858-1974: Books on natural population movement, National Institute of Statistics (INE). Data available in the Document Collection of the INE, accessible at https://www.ine.es/inebase_historia/inebase_historia.htm
 - b) 1975-2019: Microdata from the “Statistical bulletin of births”, National Institute of Statistics. Data available at <https://www.ine.es/>. For this period, we have had access to information from microdata related to over 20.5 million births.
- Mean age at maternity between 1922 and 1974 in Spain was obtained from the Human Fertility Collection of the Max Planck Institute for Demographic Research (<https://www.fertilitydata.org/cgi-bin/country.php?code=esp>). The mean age at maternity and paternity between 1975 and 2019 was calculated based on the parents’ ages, collected from microdata of the “Statistical bulletin of births”.
 - The population by age and sex in Spain from 1857 to 2011: Spanish census surveys, the National Institute of Statistics (INE).
 - Historic data on births, classified by sex, for various European countries, have been obtained from the distinct official statistics offices of these countries, all of which may be accessed via the web: France, Sweden, Switzerland, Belgium, Finland and Italy.
 - Data on marriage rates in Spain from 1976 to 2019 come from microdata of the “Statistical bulletin of matrimonies” and are available in the previously cited website of the INE.
 - Data on Global Horizontal Solar Radiation from 1975 to 2021 have been provided by the State Agency of Meteorology of Spain. We present the annual mean values observed in all available seasons.

GRAPH 1. *Historical evolution of absolute number of births in Spain according to the mother's origin*



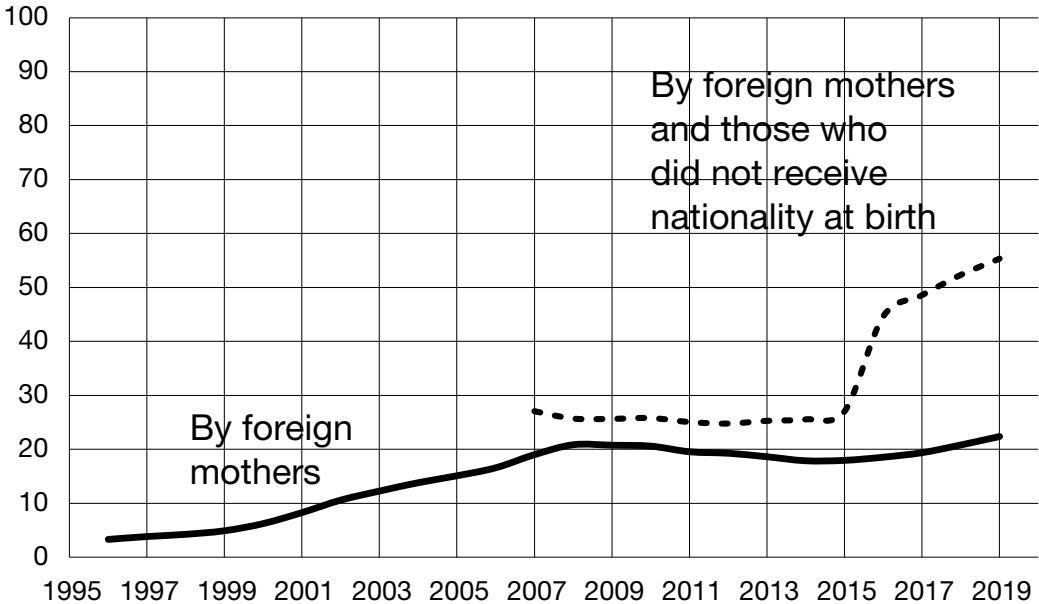
Source: See the “Sources” section.

HISTORICAL EVOLUTION OF THE NUMBER OF BIRTHS

Given that SRB is calculated from the relationship of sexes of live births, we will offer a brief explanation of the historical evolution of the number of births in Spain. Since the mid-19th century and until the late 20th century, approximately 600 000 and 700 000 children were born each year in Spain (see Graph 1). Coinciding with the arrival of democracy, a period of uninterrupted decline began, continuing until the present day. Only with the arrival of a large number of immigrants did

these figures experience a brief upturn between 1995 and 2015. The proportional weight representing births to foreign mothers has continued to grow since 1995. Graph 2 reveals that in 2019, more children were born to foreign mothers (or those originally from other countries who acquired Spanish nationality through the naturalization process) than to Spanish mothers. This major demographic transformation experienced in Spain in less than three decades justifies the fact that, in this study, we consider the geographic origin of the mothers, since skin tone may be a factor conditioning SRB.

GRAPH 2. *Percentage of births in Spain with foreign mothers*



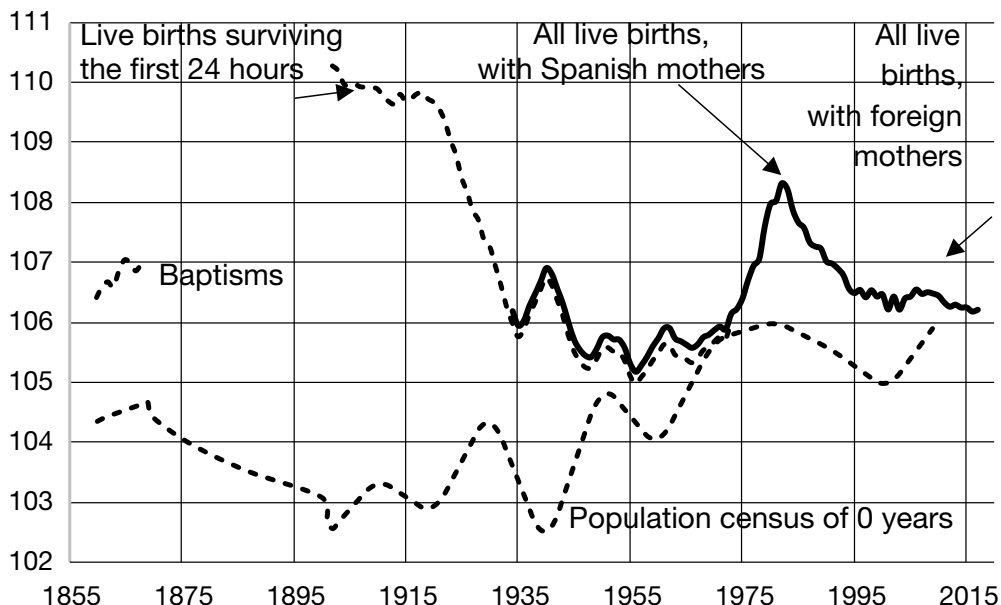
Source: See the "Sources" section.

HISTORIC EVOLUTION OF SRB

It is impossible to calculate SRB prior to 1932 in Spain since this was the year when statistics from the Natural Population Movement included sex of live births surviving the first 24 hours and those who, being born alive, died within 24 hours of birth. Between 1900

and 1931, we can estimate SRB based on the sex of those surviving the first 24 hours (in Graph 3 we can see that the SRB calculated in this manner did not differ considerably from the rate found when considering all live births). For the period between 1858 and 1870, SRB can be calculated based on baptisms celebrated throughout Spain.

GRAPH 3. *SRB in Spain, according to different sources and population types, over those making the calculation (moving average of 5 years)*



Source: See the “Sources” section.

The SRB for live births surviving the first 24 hours during the first decades of the 20th century is notably high, with values approaching 110 males per 100 females. Distinct authors have warned of the poor quality of the Civil Registry at the end of the 19th century and the first decades of the 20th century (Nicolau, 2005: 107; Reher and Valero-Lobo, 1995: 90; Livi-Bacci, 1968: 232-233). All of this suggests that the overall under-recording of the total number of births affected females more intensely than males. That is, parents were more likely to comply with their legal duty to register the birth of their male children as compared to that of their daughters. This would explain the surprisingly high values of SRB over these early decades of the 20th century.

Although Beltrán and Marco-Gracia (2021) noted the possible existence of selective female infanticide practices in some parts of Spain in the past (1750-1950), according to national data available since the

mid-19th century, we have discarded this possibility for the country as a whole. Furthermore, if considering SRB between 1858 and 1870 (calculated based on information on baptisms), we find values that are in line with the expected (106-107). That is, when attempting to baptize their children, parents did not discriminate according to the child’s sex. They engaged in the church ceremonies with all of their children, both male and female. However, with regard to the administrative obligation of registering their children in the Civil Registry, they were less diligent with their daughters.

Likewise, in the case in which a generalized female infanticide practice did take place with newborns, a much higher SRB would be expected for the population of 0-year-olds included in the Spanish censuses from the early 20th century (see Graph 3).

Between 1900 and 1930, a total of 10 provinces revealed abnormally high levels

of SRB, from 110 to 127 males per 100 girls. Most of these were located in southeastern Spain (Albacete, Alicante, Almería, Granada, Jaén, Málaga and Murcia) but others were situated in distinct locations of the country (Canary Islands, Lerida, Orense and Asturias). However, the SRB values for these 10 provinces between 1858 and 1870 (calculated over the base of baptism data) were much lower and closer to the mean of the Spanish set.

The province of Murcia is an especially noteworthy case. Between 1858 and 1870, its SRB (calculated from data on baptisms) was 106.5, that is, a value within the reasonably expected values. However, over the first three decades of the 20th century, its SRB increased at an extraordinary rate: 124.2, 127 and 123.5, respectively (recoded based on information collected from the Civil Registry). In the decade of 1930-1939, however, its ratio once again declined to 108.7.

The data on SRB in the capital cities of the provinces also revealed some major inconsistencies. The number of capital cities having suspiciously high data is greater than in the provinces. In the specific case of the city of Murcia, the SRB values reached disparately high figures: 1900-09: 178.0; 1910-19: 188.3 and 1920-29: 157.6.

We fail to accept the idea that the girls who were not registered in the Civil Registry had been murdered by their parents at birth, unless the generalized practice of filicide had somehow become a socially acceptable. According to the prior historical analysis, we can only conclude that the use of data on births was inappropriate during this period (1900-1930), according to information from the Civil Registry. Therefore, we must be extremely cautious when making conclusions from studies based on this data.

Furthermore, the rapid and gradual decline in SRB during the brief period between 1920 and 1936 is more likely to have resulted from the perfecting of the Civil Registry data collection as opposed to a profound change in val-

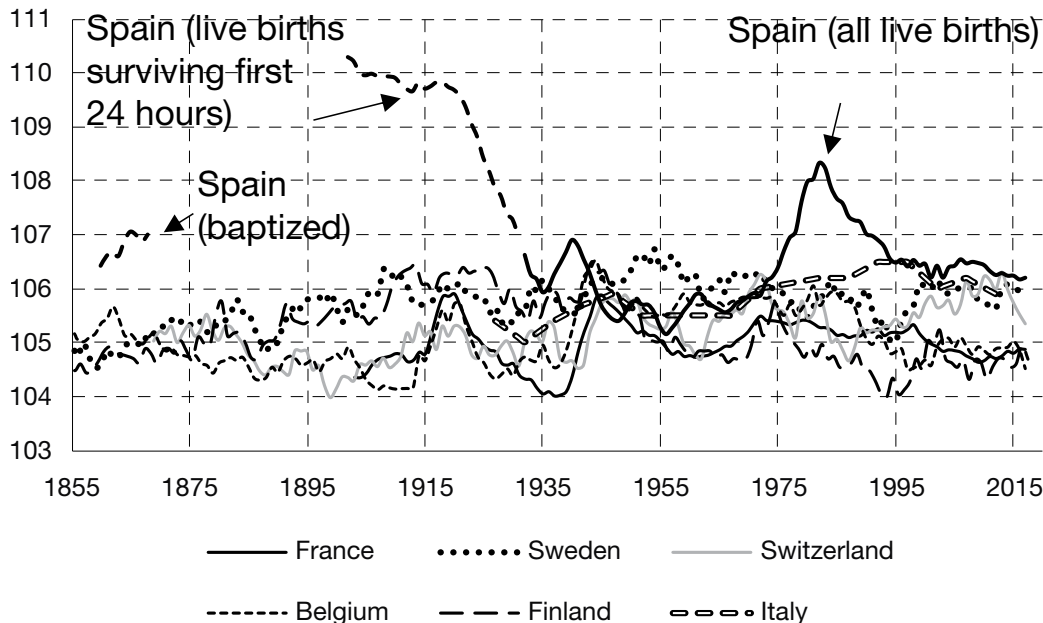
ues of parents who had previously engaged in filicide of their female offspring. Ultimately, we believe that this exaggerated SRB during the first quarter of the 20th century was due to strictly administrative causes (poor quality of the birth registry, especially that of girls). Blanes (2007: 63) quantified the under-registration of births by sex during the first decade of the 20th century at 3.1 % of the males registered and at 7.3 % of the females. These values went on to decrease considerably, and by the 1940s, they were situated at 0.4 % and 0.5 %, respectively.

If we focus on the evolution of the SRB as of 1932 (when data becomes available for all newborns and the effectiveness of the Civil Registry improved considerably), we find that, far from being consistent, this value fluctuated between 105 and 109.

As of 1958, the SRB began a steady increase, reaching a value of 109.2 in 1981. This value, based on 533 000 births, is quite different from the levels considered to be normal in countries where selective abortion of girls is not practiced. If we compare the evolution of SRB in different European countries (see Graph 4), we find that this fluctuation generally ranges from 104 to 106 points.

Both in Spain during its Civil War period (1936-1939), and other countries during the Second World War (1939-1945), a minor increase in SRB was found to take place. Distinct studies have noted a small but significant increase in the birth of males in Europe and the US during both the first and Second World War, and in the US during the Korean and Vietnam Wars. However, studies of the wars in the Balkans and the Iran-Iraq Wars have not reproduced these findings. Distinct biological explanations have been offered for this, such as the increase in stress in males which may affect the viability of XY sperm as compared to XX sperm. However, this alteration in sex proportion at birth as related to wars continues to be unresolved (Hesketh and Xing, 2006).

GRAPH 4. SRB in distinct countries (moving average of 5 years)



Source: See the “Sources” section.

Graph 4 reveals that even as of 1932, when statistics on birth registers are more reliable, SRB values in Spain have always been amongst the highest of the European countries.

The high SRB values in Spain during the 1975-1995 period are especially striking. The high quality of data from the Civil Register during these years is beyond doubt and there has been no confirmation of selective newborn female infanticide (or selective abortions based on sex, upon approval of the decriminalization law of 1985), making it necessary to investigate the causes of this boom in SRB values during this period.

THE MEAN AGE OF MATERNITY AND PATERNITY

Parental age is one of the main variables that has been frequently mentioned in numerous studies as a potential determi-

nant of SRB (Novitski, 1953). Chahnazarian (1988) created an extensive table of results from 30 studies performed on this topic. The conclusions derived from these results suggest that birth order and father’s age correlate negatively with SRB. On the other hand, mother’s age appears to have no relationship with SRB, when controlling for father’s age and birth order.

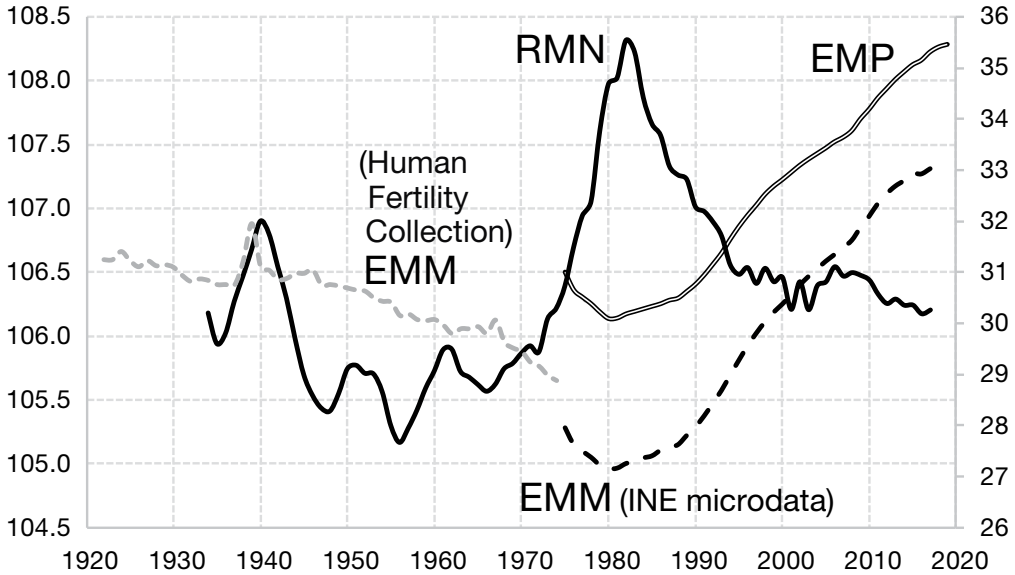
In graph 5, we see that, for the Spanish case, a clear temporal overlap exists between the historical evolution of mean ages of maternity (EMM) and paternity (EMP) with SRB³. When the EMM and EMP decrease, an increase is found in SRB, and vice versa. Is it possible that the boom in SRB occurring between 1975-1995 was due to the decrease in EMM and EMP taking place during these years? By merely observing these

³ The exceptionality in the relationship taking place between 1935-1940 may be due to the effect of the Civil War, as mentioned previously.

data, it appears that younger mothers and fathers had higher possibilities of giving birth to males as compared to females. This

apparent relationship requires a more thorough analysis of the relationship between SRB and EMM and EMP.

GRAPH 5. Historic evolution of SRB (left axis) and the mean age at maternity (EMM) (Spanish mothers) and paternity (EMP) (right axis). The moving average of 5 years is expressed in the SRB



Note: The mean age at paternity refers to male partners of the Spanish mothers. These men may be either Spanish or foreigners.

Source: See the "Sources" section.

Microdata from the INE on births taking place in 1975 offer the possibility of performing a very detailed analysis to calculate SRB while controlling for parent's age and geographic origin, as well as birth order.

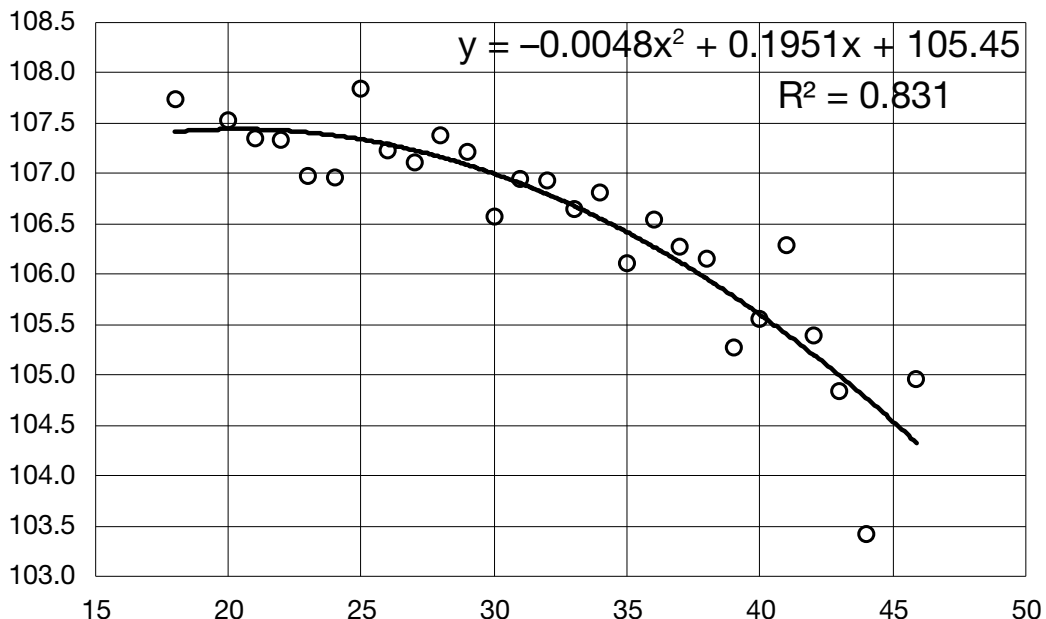
The strong relationship between parental age and SRB is evident in graphs 6 and 7. In both graphs, we observe that, both the mother and father's age individually explain up to 83 % of the variability in SRB⁴. Furthermore, the slope of the function is relevant, suggesting that changes in age of ma-

ternity/paternity may considerably affect the SRB values.

The ages of the mothers and fathers when having their children are highly correlated since most of the women choose to carry out their reproductive function with male partners of similar ages. In Table 1, we see that almost half of the births in Spain between 1975 and 2019 were of parents having an absolute age difference of 2 or less years. Almost 3/4 of the births were from parents having an age difference of 4 or less years. In other words, young women tend to have children with young men and the more mature women tend to have children with older partners.

⁴ In both graphs, the equation for a second order polynomial relationship are included, given that it has the greatest adjustment.

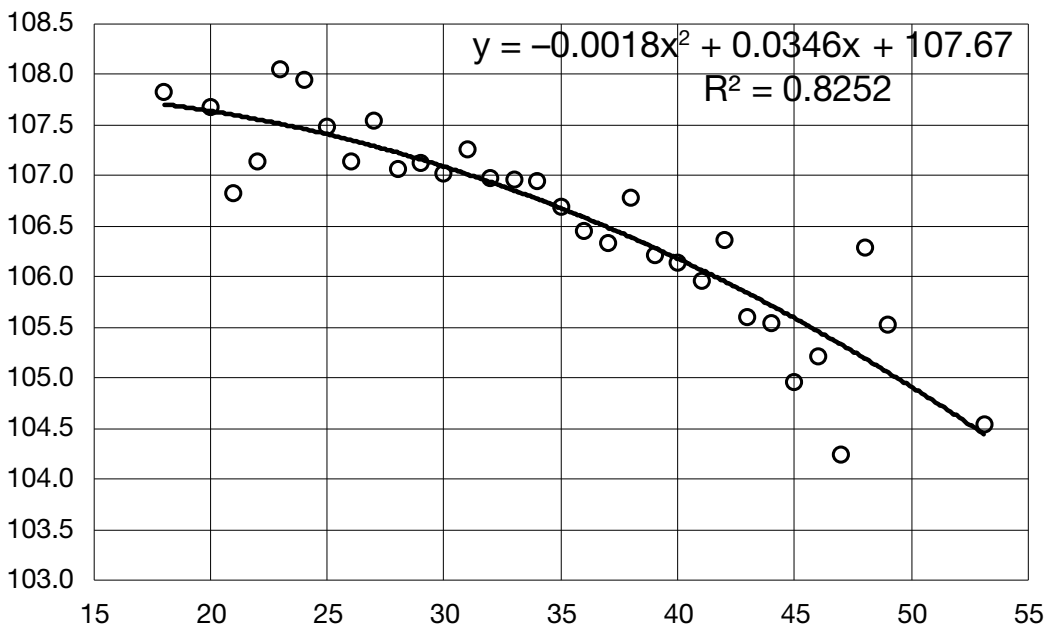
GRAPH 6. Relationship between age at maternity and SRB (Spanish women, 1975-2019)



Note: The ages 15 to 19 and 45 to 49 are represented in a grouped manner.

Source: See the "Sources" section.

GRAPH 7. Relationship between age at paternity and SRB (partners of Spanish mothers during the 1975-2019 period)



Note: The ages 15 to 19 and 50 to 54 are represented in a grouped manner.

Source: See the "Sources" section.

TABLE 1. Percentage distribution of births taking place in Spain (1975-2019) classified according to absolute difference in age of the parents (Spanish mothers and their partners)

Years of difference in age between parents (absolute values)	% births	% accumulated births
0	11.6	11.6
1	20.1	31.7
2	17.3	48.9
3	14.3	63.2
4	10.7	73.9
5	7.7	81.6
6	5.4	87.1
7	3.8	90.9
8	2.6	93.5
9+	6.5	100.0

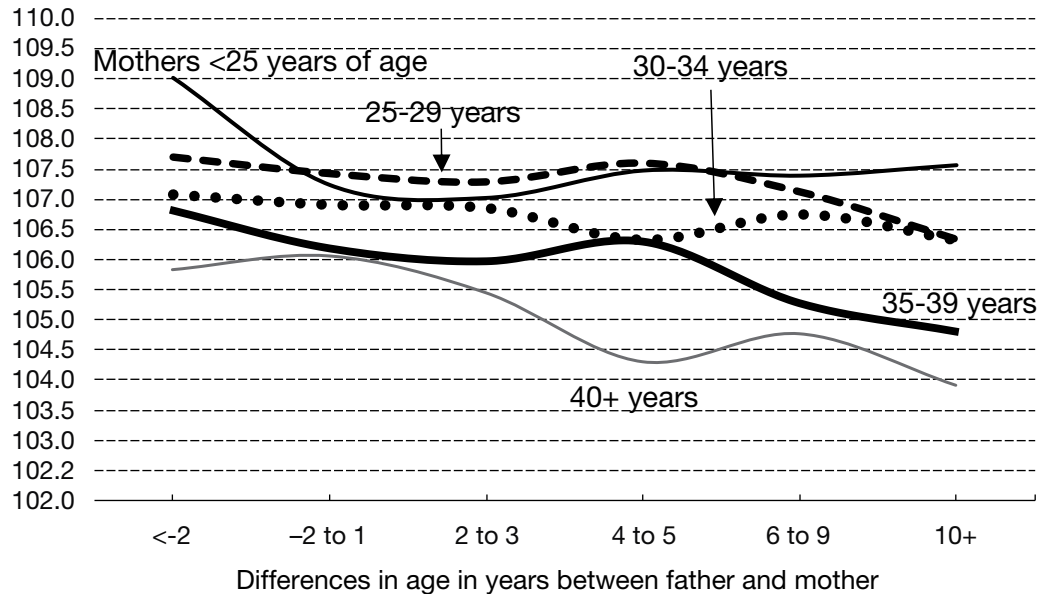
Source: See the "Sources" section.

Given the previous data and the intense correlation between the age of the father and the mother, it is impossible to deter-

mine if it is the age of just one or both of the parents which conditions the SRB values. To determine the contribution of the age of each of these, it is necessary to calculate SRB while maintaining the age of the other constant. This was done in graphs 8 and 9. In the first, the levels of SRB are presented, maintaining the mother's age constant and varying the differences in age between the parents. It may be observed that in all of the groups of mothers (and especially the older mothers), the younger their male partner, the higher the SRB. In Graph 9, it is shown that the younger the mother, the higher the SRB.

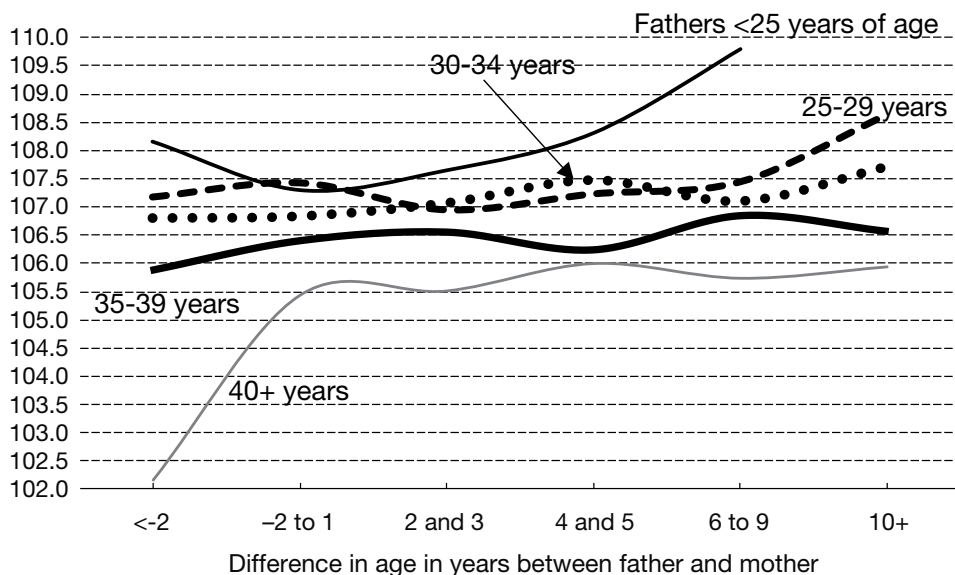
With the data from graphs 8 and 9, we can conclude that the age of both parents has a marked influence on SRB. Apparently, there are biological reasons affecting both sexes and establishing a law that, the younger the parents, the higher the SRB.

GRAPH 8. SRB according to age group of mother and age differences between father and mother (Spanish mothers, 1975-2019 period)



Source: See the "Sources" section.

GRAPH 9. *SRB according to the father's age group and differences in age between the father and the mother (partners of Spanish mothers, 1975-2019 period)*



Source: See the “Sources” section.

BIRTH ORDER OF CHILDREN

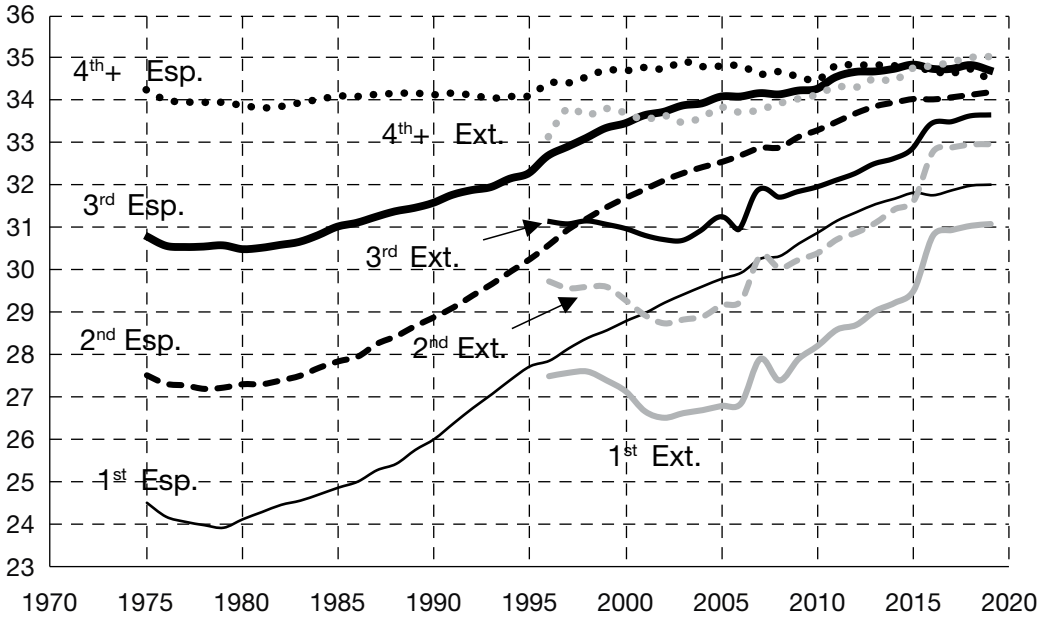
Another variable that tends to be examined in studies on SRB is birth order of children. In Graph 10, we can observe that, as expected, the larger the birth order, the larger the EMM (first order children always have younger parents than their siblings). Likewise, we also verify that the EMM of all women (both first time mothers and those who have previously had children) has not ceased to increase over time.

A doubt arises as to whether the negative relationship between parental age and SRB, as observed in graphs 6 and 7, is actually due to a biological factor related to age or to birth order. It is very important to clarify this, since the decline in the total fertility rate in Spain since the mid-1970s was accompanied by a great reduction in weight proportional to the higher

birth orders. If, between 1975-1979, 30 % of the births were third order or higher, from 2015-2019 these represented approximately 9 % of the total (calculations based on microdata of the INE’s “Statistical bulletin of births”).

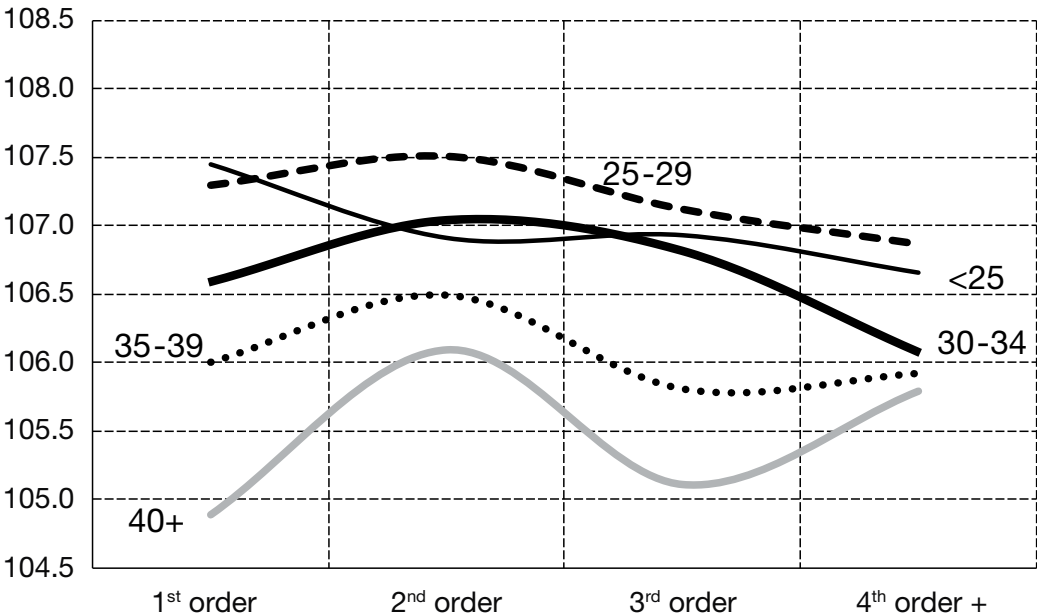
Given the close relationship between a) birth order and b) mother’s age (higher birth orders have older parents), it is necessary to analyze SRB while holding these variables constant. We have done this in Graph 11. It may be concluded that, once controlling for the mother’s age, the impact of birth order on SRB is minor. It has been seen that, when maintaining age constant, the younger mothers (<35 years of age) reveal a minor decrease in SRB as the birth order increases. On the other hand, for the older mothers (40+), having had prior children increases their likeliness of giving birth to a male.

GRAPH 10. Mean age at maternity according to birth order and mother's origin (Spanish mothers (Esp.) and foreign mothers (Ext.))



Source: See the "Sources" section.

GRAPH 11. SRB according to the mother's age and birth order (Spanish mothers, 1975-2019)



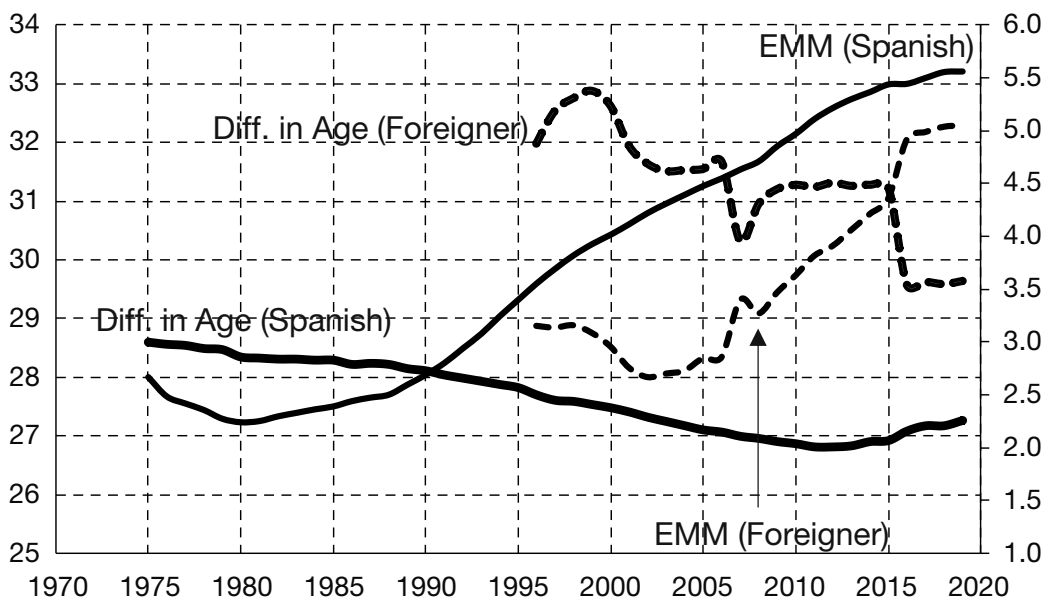
Source: See the "Sources" section.

VARIATIONS IN PARENTAL AGE PATTERNS

Given that we have confirmed the strong relationship between ages of both parents with the SRB values, below we present a detailed analysis on the changes observed in these ages. In Graph 12, we observe that, since information has been available (1975 for Spanish mothers and 1996 for foreign mothers), the EMM has not ceased to

increase, being a bit lower in the foreign mothers. Therefore, as this occurs, we also observe that the age difference between parents has not ceased to decline. If, in the mid-1970s the mean age difference between the father and mother was approximately 3 years, during the second decade of the 21st century, it was just over 2. In foreigners, this mean difference has decreased much more, from over 5 years in the late 1990s to 3.6 years in 2019.

GRAPH 12. Evolution of the mean age at maternity (left axis) and of the difference in age between the father and the mother (right axis) according to the mother's origin (Spanish and foreigners)



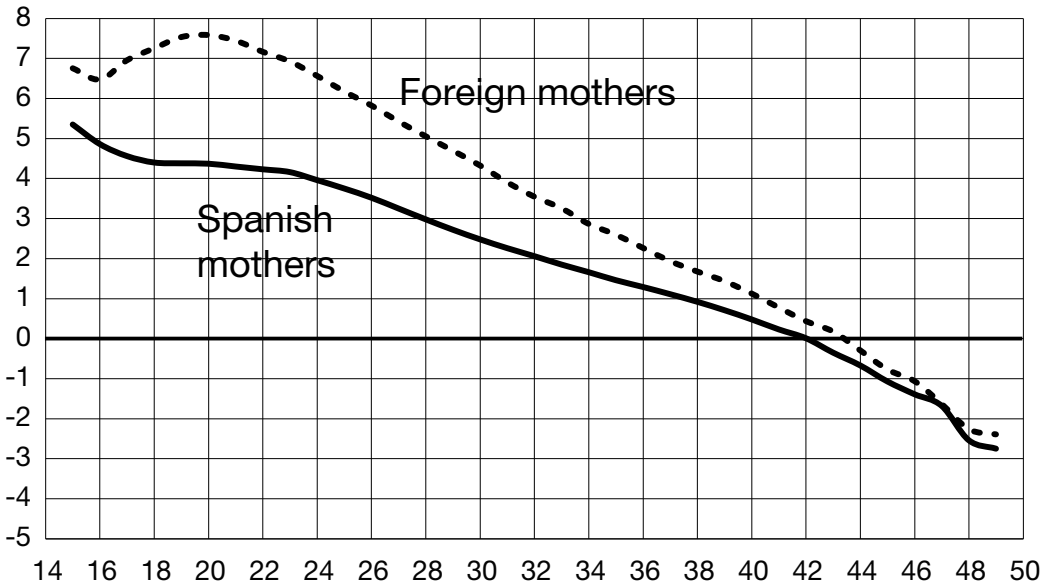
Source: See the "Sources" section.

Graph 13 details the difference in age between parents for each of the mother's ages. It is clearly seen that the age difference between the younger parents is notably greater than that between the older ones (especially so in the case of foreign mothers). And as of 40 years of age, the mothers were older than their partners.

Graph 14 shows the changes observed in the mean age difference between the fa-

ther and the mother at three distinct times of the 1975-2019 period. We can conclude that: 1) the difference in age between the younger fathers and mothers (<30 years of age) has always been greater than that of the older mothers (30+ years of age); 2) over time, the younger Spanish mothers (<30) have had children with increasingly older men, whereas the older mothers (30+) have had children with increasingly younger men.

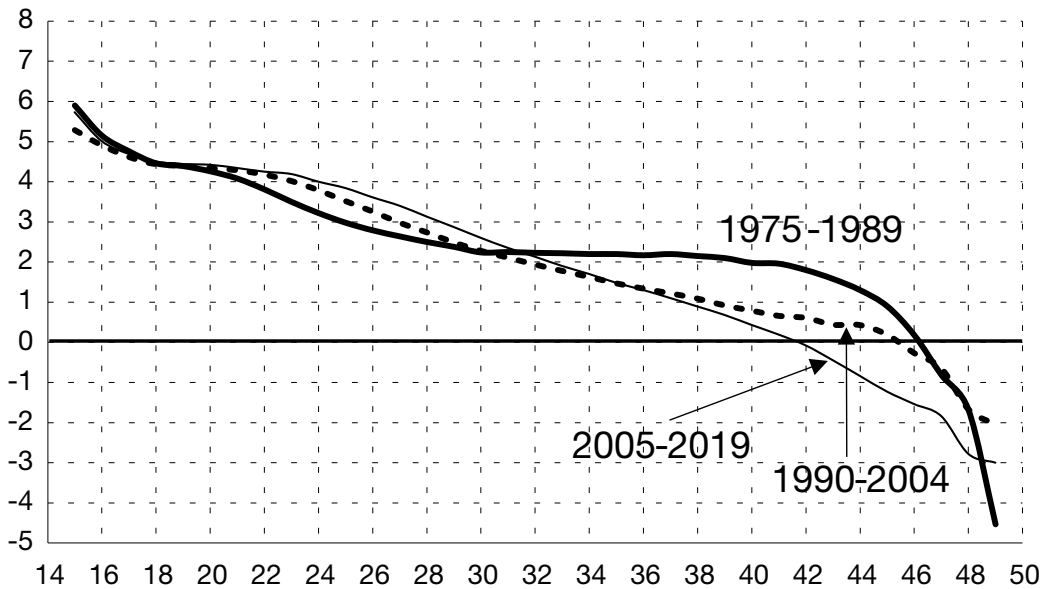
GRAPH 13. Mean age difference between the father and mother at the time of birth during the 1996-2019 period in Spain, according to the mother's age and origin



Note: Fathers may be of any nationality and ethnic group.

Source: See the "Sources" section.

GRAPH 14. Variations in the mean of the age difference between the father and mother at the time of birth over three periods, according to the mother's age (only Spanish women)



Source: See the "Sources" section.

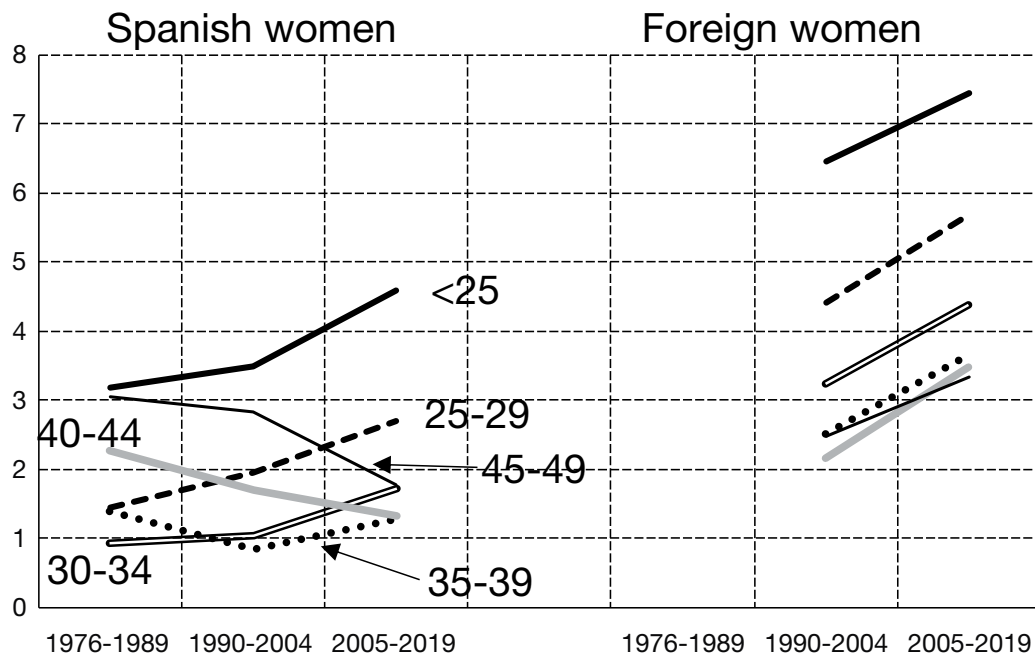
There may be two reasons for this:

Sperm quality decreases with age, resulting in a decline in natural fertility. The fact that older mothers have children with men who are closer to their age (or even younger) than younger mothers, may be due in large part to the fact that the quantity and

quality of Western men’s sperm is on the decline, and this may have a larger effect on older males (Levine *et al.*, 2017).

Graph 15 shows that with the passage of time, younger women tend to marry older men and older women tend to marry younger men.

GRAPH 15. Mean of age difference between husband and wife according to woman’s age at the time of heterosexual marriage (only single women at the time of matrimony)



Source: See the “Sources” section.

Microdata from the INE regarding matrimony statistics registered in Spain since 1976 allow us to confirm the ever-changing age pairings⁵. In Graph 15, we can see that since

1976, there has been a clear trend in younger Spanish women (<35 years) to marry younger men, whereas the older women (40+) tend to select increasingly younger partners.

The behavior of foreign women regarding matrimony differs slightly from that of Spanish women. The two most noteworthy aspects are: 1) they marry older men than the Spanish women and 2) with the passage of time, all of them, regardless of their age group, marry increasingly older men. Several years have passed since information has been available on the matrimonyes of foreign

⁵ Over recent decades, the number of males born from unmarried partners has increased greatly, and logically, these are not included in the matrimony statistics. However, the temporal evolution of the EMM of married women and that of unmarried women has been very similar. In both groups, the EMM has increased with equal intensity (e.g., the EMM of the married women in the 1980-1984 period was 24.5, whereas that of the unmarried women was 23.3; in the 2017-2019 period, these values were 32.4 and 30.7, respectively).

women. It would be interesting to consider the evolution of this demographic behavior. Little doubts exist as to whether this change in pairing behavior has influenced the EMM and thereby, the SRB of their offspring.

ANALYSIS OF THE INFLUENCE OF PARENTAL AGE ON SRB WHEN STANDARDIZING THE AGE DIFFERENCE BETWEEN PARENTS

Until now, it has been possible to verify that:

- a) The age of the mother and the father has a notable effect on SRB (see graphs 8 and 9).
- b) Younger women tend to have children with younger spouses and older women tend to have children with older men (see Table 1).
- c) Age differences between parents are not the same for all ages, with greater differences existing between younger parents as compared to older ones (see Graph 13).
- d) During the 1975-2019 period, major changes took place in the ages of the parents (see Graph 14).

Ultimately, the SRB calculated for each individual age of the mothers included in graphs 6 and 7 are also affected by the variable distribution of age difference between parents. To neutralize the effect of the changing distribution of age differences between parents on SRB that we have detected (see Graph 14) and to exclusively assess the effect of the mother's age on this SRB, we have standardized the age differences between the parents as follows:

1. Mothers have been grouped in the following age brackets: 15-19, 20 and 21, 22 and 23, 24 and 25... 36 and 37, 38 and 39, 40-49⁶.

⁶ It was necessary to make these groupings since, in each of them, it was necessary to calculate the SRB

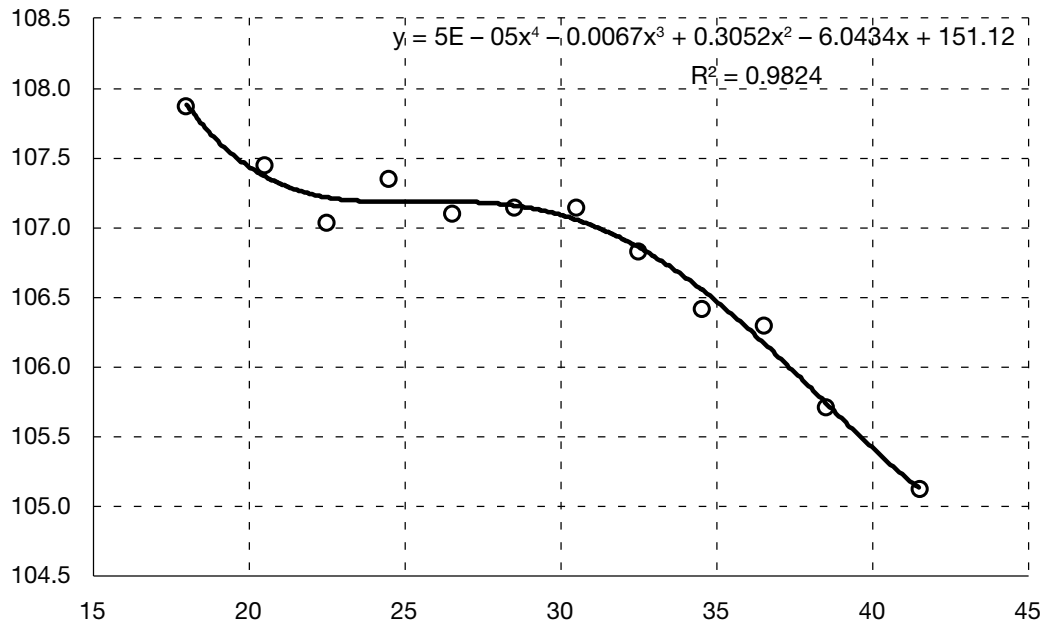
2. We have classified each group of mothers in six subgroups according to age differences between the father and mother: <-2, -2 to 1, 2 and 3, 4 and 5, 6 to 9 and 10+.
3. SRB has been calculated for each of these six subgroups of mothers specified in the previous point.
4. After estimating the six SRB in each of the mothers' age groups, we have calculated its simple mean. In this way, we give the same weight to all of the SRB of the six subgroups. In other words, we assume that in all of the groups of mothers, the age differences between the parents is the same and we neutralize the changing weight that each of these may have over the passage of time.

Once this standardization has been carried out, and the effect of the age difference between parents has been neutralized, the relationship obtained between mother's age and SRB is shown in Graph 16. The adjustment obtained when neutralizing the age of the fathers is very high. Similarly, we have applied this same standardization process to the fathers (partners of the Spanish mothers). The results may be seen in Graph 17⁷. Ultimately, these data confirm the close relationship existing between parent age and SRB levels.

of 6 sub-groups, as specified in point 2 below. Grouping the mothers together in this way assures that each subgroup has a sufficiently high number of births and thereby, reduces the variability of the SRB values considerably. Guilimoto (2015: 189) reported that, as with any proportion, the distribution by sex is subject to the effects of a binomial law in which the precision of the measure depends on the inverse of the square root of the number of observations. That is, the larger the number of available cases (births), the lower the variation.

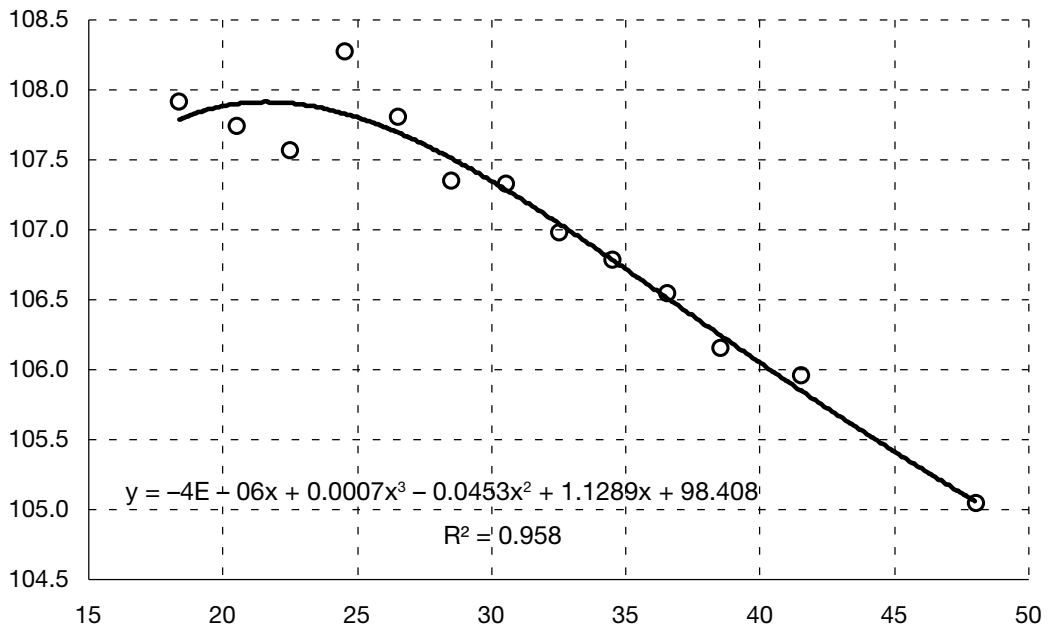
⁷ The groupings by age made for the fathers are as follows: 15-19, 20 and 21, 22 and 23, 24 and 25... 36 and 37, 38 and 39, 40-44 and 45+.

GRAPH 16. Relationship between age at maternity and SRB (Spanish mothers, 1975-2019 period). For each mother's age, the age difference between the parents has been standardized



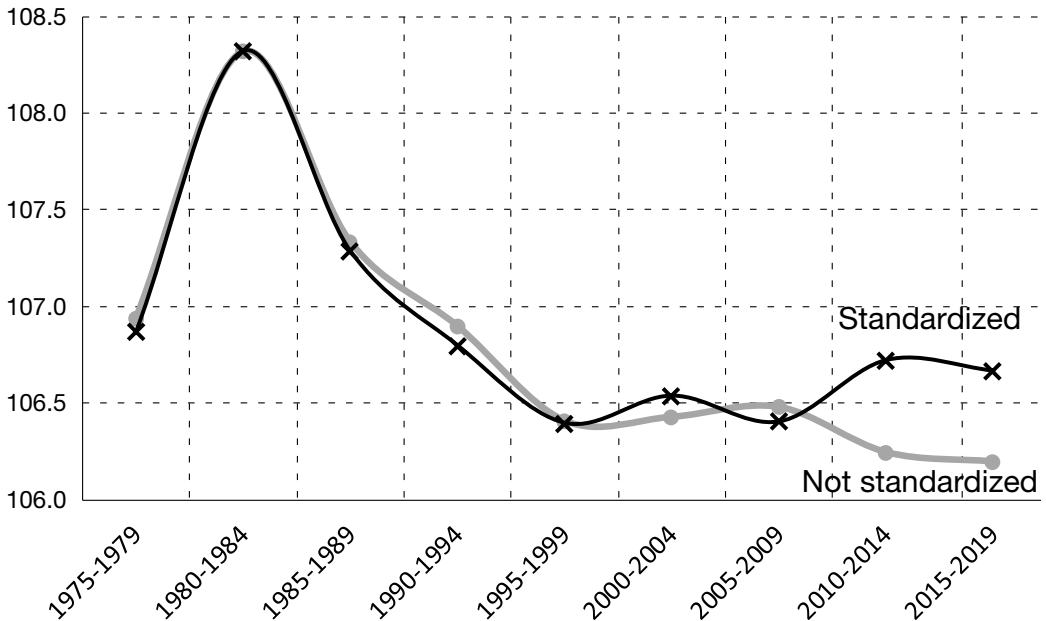
Source: See the "Sources" section.

GRAPH 17. Relationship between age at paternity and SRB (partners of the Spanish mothers, 1975-2019 period). For each father's age, the age difference between the parents has been standardized



Source: See the "Sources" section.

GRAPH 18. Evolution of the SRB without standardizing and standardized according to mother's age (Spanish mothers, 1975-2019 period)



Note: Proportional weights in the different age groups used in the standardization: <20: 0.086; 20-24: 0.233; 25-29: 0.280; 30-34: 0.250; 35-39: 0.123; 40-44: 0.026; >44: 0.002.

Source: See the "Sources" section.

STANDARDIZATION OF SRB ACCORDING TO AGE OF THE MOTHERS

While there is no doubt that the parents' age influences SRB, and we have verified that the EMM and EMP have varied over time (see Graph 5), can we therefore conclude that the boom in SRB values observed between 1975 and 1995 was due to the evolution of the EMM and the EMP?

In Graph 18, we see the evolution of the SRB values without standardization and when standardizing the age of the mothers during the 1975-2019 period⁸. We have verified that, when neutralizing the effect of

changes in mother's age through standardization⁹, few changes are observed in the index value (except in the last decade). This suggests that the changes in the EMM observed in the 1975-1995 period, although still considerable, are not a main cause of the SRB boom and, therefore, other variables should be found to explain this intense and noteworthy fluctuation.

WEEKS OF GESTATION

According to James (2003) and Cagnacci *et al.* (2003), a positive association exists between SRB and gestation period. On the con-

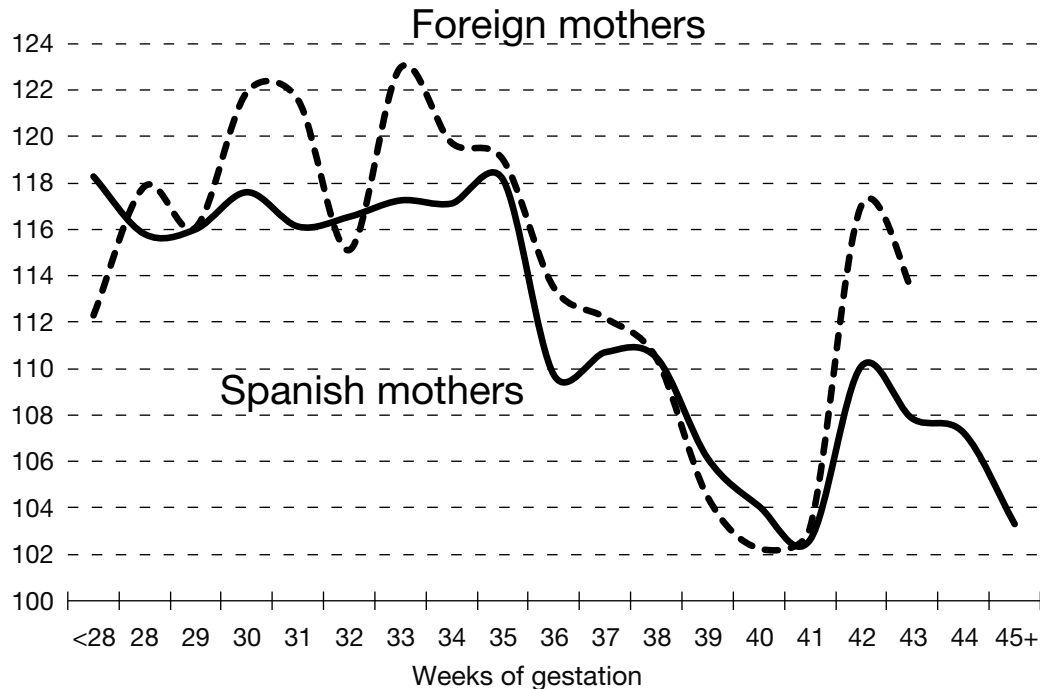
⁸ To familiarize themselves with the standardization technique, we suggest that readers consult the Vinuesa Angulo *et al.* (1994: 52) manual.

⁹ Proportionate weights in the age groups that have been used in the standardization: <20: 0.086; 20-24: 0.233; 25-29: 0.280; 30-34: 0.250; 35-39: 0.123; 40-44: 0.026; >44: 0.002.

trary, data handled by Orzack *et al.* (2015) suggest the opposite. Graph 19 shows that, in Spain, births taking place with less than

28 weeks of gestation have a notably higher SRB than those that are longer. As of 34-35 weeks, there is an evident decline in SRB.

GRAPH 19. SRB according to number of weeks of gestation and type of mothers (1980-2019)



Source: See the “Sources” section.

SOLAR RADIATION

Some medical studies have demonstrated that the level of Vitamin D in the block of women prior to conception may be positively associated with a higher SRB. Sufficient levels of this vitamin may mitigate inflammatory processes that may affect the mothers and may influence implantation and the survival of male embryos (Purdue-Smithe *et al.*, 2019 and 2021). Vitamin D is synthesized in the skin from cholesterol, thanks to a chemical reaction that is naturally activated by type B, short wave ultraviolet rays (UVB), which contain solar light.

According to the atlas of solar radiation created by the State Meteorology Agency, the provinces of *Green Spain* receive an average solar radiation that is much lower than the southern and southeastern provinces and the Canary Islands¹⁰. To verify if the solar radiation (and therefore, the levels

¹⁰ The mean daily global radiation (kWh/m²/día) from the 1983-2005 period in the selected provinces of southern Spain and the Canary Islands was greater than 5, whereas that of the provinces of Green Spain were lower than 4.1 (State Meteorology Agency, “Atlas of Solar Radiation in Spain using data from the SAF on Climate of EUMETSAT”, http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/atlas_radiacion_solar).

of Vitamin D) may influence the SRB values, we have contrasted data on births from the 1975-2019 period for these two groups of provinces:

- a) Green Spain: La Coruña, Lugo, Orense, Pontevedra, Asturias, Cantabria, Vizcaya, Guipúzcoa and Álava.
- b) South and Canary Islands: Huelva, Seville, Cádiz, Málaga, Granada, Almería, Murcia, Alicante, Jaén, Córdoba, Santa Cruz de Tenerife and Las Palmas.

Table 2 shows that, upon standardizing the mother's age, the SRB is slightly higher in the provinces receiving more solar radiation and those in which, it is likely that the women will have higher levels of Vitamin D in their blood. Although the differences are minor, they are statistically significant given the volume of information that has been used (almost 6 million births in the Southern provinces and 2.5 million in the Northern provinces).

TABLE 2. *SRB by age of mothers in the two geographic areas (Spanish mothers, 1975-2019)*

Green Spain	106,68
Southern peninsula and Canary Islands	106,92
North-South difference	-0,24

Note: Weighing according to mother's age: <25: 0.319; 25-29: 0.280; 30-34: 0.250; 35-39: 0.123; 40+: 0.028.

Source: See the "Sources" section.

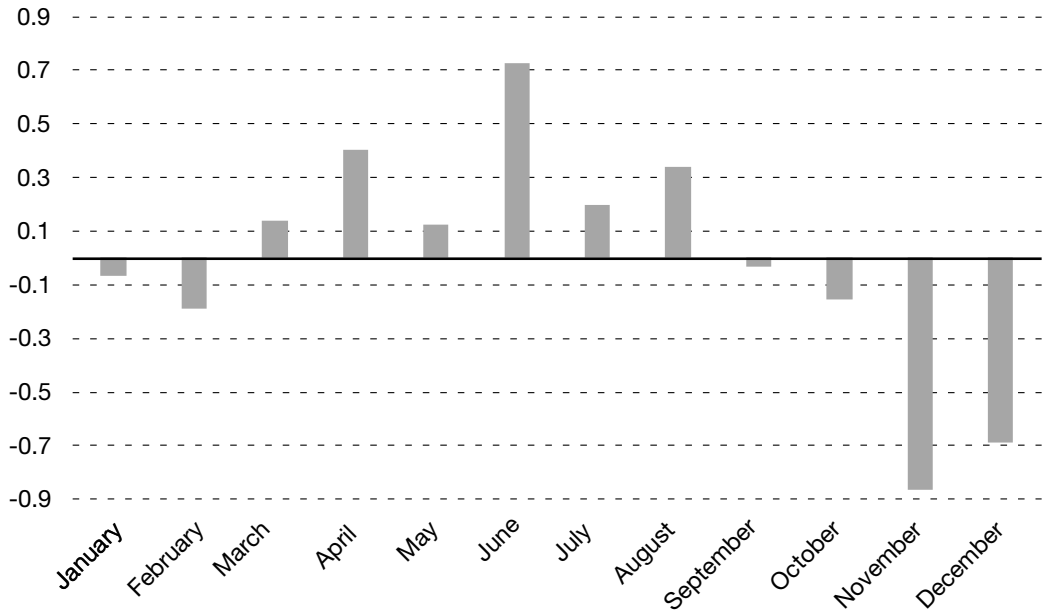
Graph 20 reveals that SRB is not homogenous across the different months of the year. The proportion of males is greater amongst those born between March and August (mean of 107.2) as compared to those born between September and February (mean of 106.6). If we are to consider that various weeks are necessary for the human body to increase its levels of

Vitamin D from solar radiation, we should pay attention to the two months prior to the time of conception. Therefore, the two months prior to conception for those born between March and August correspond to the months from April to September, precisely the months of the most solar irradiation in Spain.

November and December are the months having the lowest SRB. Children born in these last two months of the year were conceived in February and March, therefore the two months prior to their conception coincide with the months of December and January, which, according to the State Meteorological Agency of Spain, are the two months with the lowest radiation of the year.

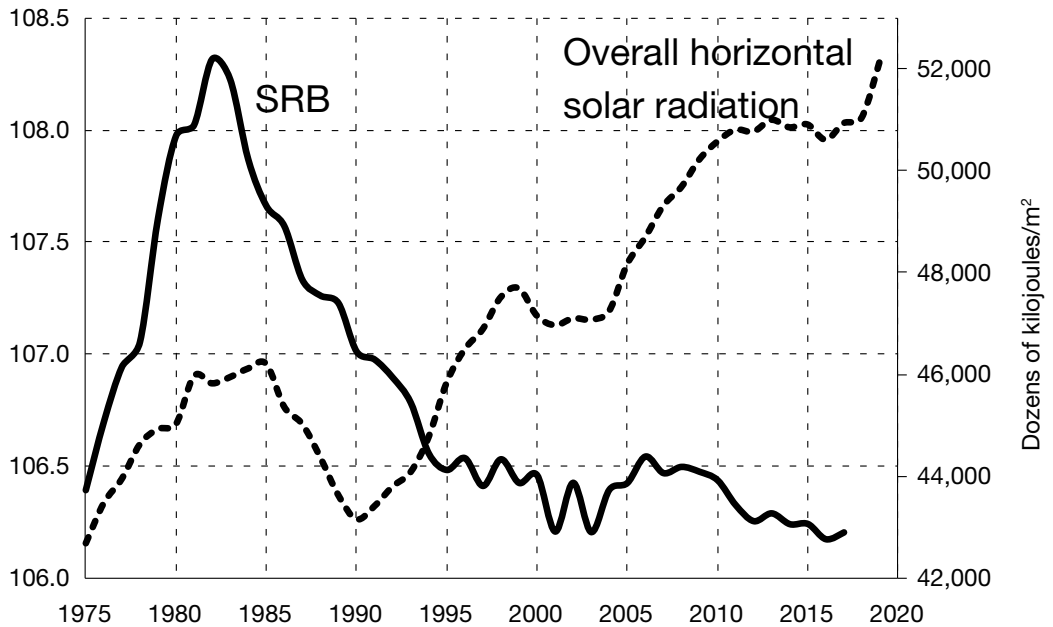
Graph 21 reveals that the boom in SRB values in the 1975-1995 period coincided with a notable increase in overall solar radiation in Spain. It may be surprising to find that, as of 1990, as solar radiation once again increased, the SRB followed a downward trend (although more moderate). This may be due to the fact that as of the 1990s, the use of sun cream became widely popularized in Spain to prevent skin cancer. This practice, together with the growing number of individuals working in offices and factories and enjoying their free time in interior locations (gyms, theaters, cafeterias, etc.) and without the need for sun exposure, as well as the limited intake of foods that are high in Vitamin D, may have influenced the alarmingly low levels of this vitamin in the overall Spanish population (and worldwide) which has been detected for decades now (Navarro Valverde and Quesada Gómez, 2014). It appears that, once again, the studies carried out by Purdue-Smithe *et al.* (2019 and 2021) highlighting the important role of Vitamin D in determining the SRB levels. But clearly, more studies are necessary to ratify this hypothesis.

GRAPH 20. Deviation of SRB for each month with respect to the mean (Spanish mothers, 1975-2019)



Source: See the "Sources" section.

GRAPH 21. SRB (Spanish mothers) (left axis) and overall horizontal solar radiation horizontal in Spain (right axis) (moving average of 5 years)



Source: See the "Sources" section.

TABLE 3. Standardized SRB classified according to mother's geographic origin (Spain, 1996-2019)

Poland	109.4
China, India and the Philippines	108.8
Northern Africa	108.1
Caribbean	107.2
Eastern Europe	106.7
Spain	106.6
Western Europe	106.0
Asia	106.0
Latin America	105.8
Sub-Saharan Africa	105.3

Note:

- Sub-Saharan Africa: All African countries except for those cited in the Northern Africa group.
- Asia: Asian countries, except for China, India and the Philippines.
- Caribbean: Centro-American countries and Mexico.
- Spain: Born of Spanish mothers.
- Eastern Europe: Countries forming part of the former Soviet bloc, except for Poland.
- Western Europe: Also includes the United States, Canada, Australia and New Zealand.
- Latin America: Only South American countries.
- Northern Africa: Mauritania, Western Sahara, Morocco, Tunisia, Algeria, Libya and Egypt.

Source: See the "Sources" section.

RACIAL/ETHNIC DIFFERENCES

Almost all the above analyses have mainly focused on the historic study of SRB of children born to "Spanish mothers". This means that we have almost exclusively considered white parents. Table 3 includes SRB values according to geographic origin of immigrant mothers which, *grosso modo*, coincide with ethnic groups having distinct skin tones. While some of the high values may be related to the selective female abortion practices of certain immigrant communities¹¹,

it is clear that SRB varies notably amongst the different ethnic/racial groups. The population from Sub-Saharan Africa has considerably lower SRB levels as compared to the others, suggesting a biological explanation that may be linked to skin tone in the determination of this ratio. These results coincide with those obtained in other studies (Chahnazarian, 1988; Khoury, Erikson and James, 1984). Given the short time period and limited number of births occurring in Spain to populations having other skin tones (not white), it is not currently possible to make a more detailed analysis of this variable's effect on SRB, although it appears to have a significant relevance given the growing number of births in Spain to foreign mothers with different skin tones.

CIVIL STATUS

Numerous scientific articles have suggested that maternal stress is a relevant factor that increases the possibility of suffering natural abortions, especially of male fetuses (Grech, 2017). Extraordinary phenomena (earthquakes, terrorist attacks, famines, etc.) are socio-economic factors that have been linked to lower levels of SRB (Grech, 2018).

If we are to agree that unmarried mothers suffer from higher levels of stress (anxiety, anguish, fatigue, exhaustion) and socio-economic problems, we may assume that their levels of SRB would be lower¹². The results presented in Table 4 leave few doubts that, in fact, married women in Spain have higher SRB levels than their unmarried counterparts.

¹¹ González (2018) and Castelló *et al.* (2019) highlighted that in the Chinese and Indian communities residing in Spain, this type of fetal selection takes place.

¹² Not all single mothers experience their pregnancy on their own. Many of these women are in stable couple relationships and, therefore, their stress levels may be comparable to those of the married women.

TABLE 4. *SRB according to birth order and civil status. Spanish mothers, 1975-2019*

	Birth order			All*
	1	2	3+	
Married	107.07	107.23	106.40	107.09
Unmarried	106.75	105.56	106.36	106.54
Difference	0.32	1.67	0.04	0.54

* SRB standardized by mother's age.

Source: See the "Sources" section.

LEVEL OF URBANIZATION

Distinct studies have suggested that environmental pollution may be responsible for the recent decline in the SRB in western countries (Schacht, Tharp and Smith, 2019; Terrell, Hartnett and Marcus, 2011). Given that information pollution levels was not available to us for the municipalities, it may be reasonable to assume that, overall, the larger population centers have higher pollution levels (more vehicles, more homes using heating, industries, etc.). Based on the data from Table 5, we cannot reach any conclusions regarding the potential impact of pollution levels on SRB in Spain.

TABLE 5. *SRB according to size of mother's municipality of residence (Spanish mothers, 2007-2019)*

< 10,000 inhabitants	106.3
From 10,001 to 20,000	106.5
From 20,001 to 50,000	106.4
From 50,001 to 100,000	106.2
>100,000	106.4

Source: See the "Sources" section.

CONCLUSIONS

Before using any database, it is important to analyze the consistency and reliability of the same. From the analysis of historical in-

formation available on births in Spain, we must make repeated warnings given that for decades now, other researchers have questioned the quality of the data on births taking place between 1900-1930 and, therefore, any study that is based on the same should be considered with great skepticism.

The first conclusion that may be reached from this study is that SRB in Spain, far from being constant, has varied over time for distinct reasons. The considerable information available (especially since 1975) appears to suggest that the mean age of maternity (EMM) and paternity (EMP) are relevant variables that condition SRB. We have confirmed the biological law that the younger the parents, the greater the probability of their having a male child.

We have verified that in the 1975-2019 period, major changes took place in age patterns of parents, which may have influenced SRB. However, having standardized the indices by maternal age, the fluctuations were not eliminated, suggesting that other factors are involved.

We verified that, when controlling for maternal age, birth order had only a small effect. The data from Spain confirms the hypothesis of Purdue-Smithe *et al.* (2019 and 2021) relating a higher intensity of solar radiation (and its influence on Vitamin D generation in the blood) with higher levels of SRB. Additional research, however, must be performed to verify these findings. The length of the gestation period and the racial/ethnic variety of the parents appear to have a relevant effect on SRB levels. We also suspect that increased stress experienced by unmarried mothers may affect SRB. No differences were found based on the size of the mother's municipality of residence.

Sociological interest in the conclusions of this study has been considerable, most likely due to its extensive applicability to other studies. For example, research to detect selective female abortion practices in

groups of female immigrants living in Spain should consider the variables mentioned here. Variety in skin tone and the disparity of parental ages observed in the distinct immigrant communities¹³ are aspects that should be considered when establishing the existence (or not) of selective sex-based abortion practices.

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¹³ Between 1996 and 2019, Spanish mothers had a mean EMM of 31.4 years, and, on average, they were 2.2 years younger than their male partners. For mothers originally from India, these data were 28.9 and 5.2, respectively. Data for mothers originally from China were 28.7 and 2.6, respectively.

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