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ORIGINAL PAPER

Key forces behind the decline of fertility: lessons from childlessness in Rouen before the industrial revolution

Sandra Brée[1] · David de la Croix[2]

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Abstract To better understand the forces underlying fertility decisions, we look at the forerunners of fertility decline. In Rouen, France, completed fertility dropped between 1640 and 1792 from 7.4 to 4.2 children. We review possible explanations and keep only three: increases in materialism, in women's empowerment, and in returns to education. The methodology is one of analytic narrative, bringing together descriptive evidence with a theoretical model. We accordingly propose a theory showing that we can discriminate between these explanations by looking at childlessness and its social gradient. An increase in materialism or, under certain conditions, in women's empowerment, leads to an increase in childlessness, while an increase in the return to education leads to a decrease in childlessness. Looking at the Rouen data, childlessness was clearly on the rise, from 4% in 1640 to 10% at the end of the eighteenth century, which appears to discredit the explanation based on increasing returns to education, at least for this period.

Keywords Demographic transition · Childlessness · Quality-quantity trade-off · Forerunners · Women's empowerment

JEL Classification J13 · N33 · O11

✉ David de la Croix
david.delacroix@uclouvain.be

Sandra Brée
breesandra@gmail.com

[1] Centre for Demographic Research, Université catholique de Louvain, Louvain-la-Neuve, Belgium

[2] IRES and CORE, Université catholique de Louvain, Louvain-la-Neuve, Belgium

1 Introduction

The decline of fertility to close to or below replacement levels is one of the major trends seen in the last century. It started in the West and has extended progressively to the whole world (Reher 2004). Cultural factors aside, key explanations for the drop in fertility include enrichment (in terms of income and education), decreased mortality, and better contraception. It is, however, difficult to disentangle the effect of each of these causes, as they are all endogenous and simultaneously determined. Figure 1 illustrates this point for the US.[1] It shows the inverse of fertility together with income per person, education, survival, and effectiveness of contraception. All the series increase together. Did people have fewer children because they were richer and more educated, or were they richer and more educated because they had fewer children? The simultaneity between income/education and fertility is not the only example. Child mortality is also related to wealth and fertility: Obviously, richer societies are able to use their resources to make mortality decrease. Moreover, having fewer children allows parents to devote more resources to the survival of each child.[2] As for contraception, modern techniques emerged as a consequence of more affluent societies investing in medical progress.

Understanding fertility in the context of economic growth is, therefore, difficult. That is why, in this paper, following Livi-Bacci (1986), we propose to look at a case of fertility decline that happened before the Industrial Revolution, in a period when there was still little change in income and mortality, and when modern contraception was not available. By doing so, we hope to identify deep-rooted factors underlying and/or conditions needed to produce a decline in fertility. We focus on one case—Rouen in the seventeenth and eighteenth centuries—for which, thanks to the amount of work done by Bardet (1983), we have a wealth of information allowing us to control for a wide variety of factors.

We look for one dominant explanation for the fertility decline, which would line up with what can be observed both across time and social classes. The methodology is one of analytic narrative, bringing together descriptive evidence with a theoretical model. We proceed in two steps. First, we list the possible explanations for the decline in fertility. For many of them, we can directly observe whether or not they are good candidates. For example, there was no increase in income during the period; hence, the explanation cannot be enrichment. At the end of this first step, we are left with three remaining candidates for which there is little direct information to be gleaned from the data: rise in the return to education, women empowerment, and rise in materialism.

Second, we develop a theoretical model to infer the logical implications of these three explanations for fertility, childlessness, and education of children. In the model, households decide whether and how much to consume a superior good, such as participating to cultural life, and they also decide about how many children to

[1] Very similar pictures could be presented for other developed countries.

[2] This trade-off between the number of children and their survival was recognized as early as 1837: "ces essaims d'enfans ne rendent que plus impossibles les soins indispensables pour leur assurer pleine vie." (D'Ivernois 1836).

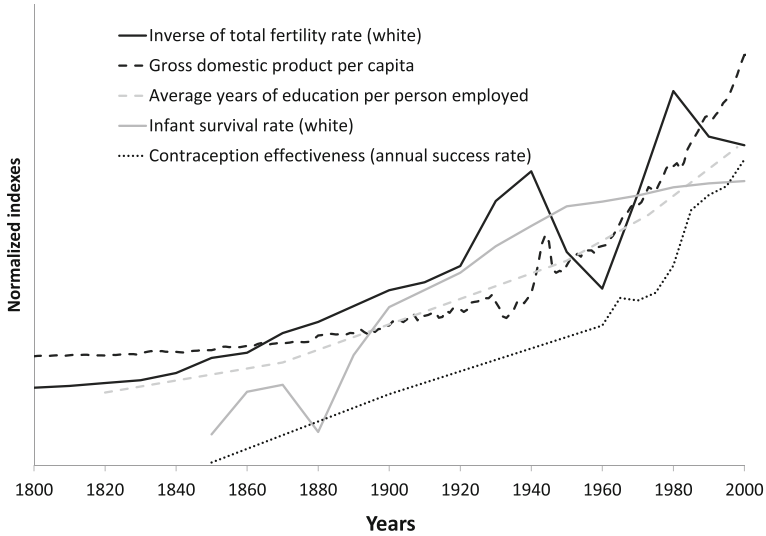

Fig. 1 Trends in fertility, income, education, mortality, and contraception (USA, 1800–2000). *Sources*: Fertility rates and mortality rates are from Greenwood et al. (2005). Gross domestic product per capita is from Maddison (2010) and average years of education are from Maddison (2001). Contraception effectiveness is from Greenwood and Guner (2010)

give birth to, and about the education to give them. Depending on their income, households can be in different situations. One is a Malthusian regime, where there is neither superior good consumption. Another regime is interior, with positive spending on all three goods. A last situation is one where the household decides not to have children, all income being directed then to the superior good consumption. Comparative static analysis allows to determine how the proportion of households in each regime changes with the exogenous variables of the model. For example, we show that if an increase in materialism (the superior good becomes cheaper/more accessible) was the main driving force behind the decline in fertility, one should also observe an increase in childlessness, and a widening of the fertility gap between the lower and upper social classes. On the contrary, a rise in the return to education implies a drop in fertility but also a drop in childlessness, as fewer people would stay in the child-free regime. As we do not observe such a drop in the data, we can conclude that the rise in the return to education cannot be the dominant explanation for fertility trends observed in Rouen before the nineteenth century, as childlessness sharply increased over the period.

In Sect. 1, we describe the historical context of the city of Rouen and the demographic study by Bardet (1983). Section 2 reviews the list of possible explanations for the decline in fertility in Rouen and rejects some out of hand based on direct evidence. Section 3 subjects the remaining explanations to an analytical framework, which allows us to derive the implications of each hypothesis and compare them to the data. Section 4 concludes.

2 Rouen: context and fertility decline

For a very long time, Rouen was the second most populated city in France, after Paris.[3] During the Early Modern Period, the Atlantic trade kept the port busy. Traders and Explorers from Rouen were found far away (Cavelier de La Salle (1643–1687), from Rouen, discovered the Mississippi and gave its name to Louisiana). Beyond trade, Rouen was also an important administrative center, with its own parliament. Although it did not have a university, Rouen remained an intellectual center throughout the period. Diderot's Encyclopédie claims that Rouen is, after Paris, the city in the kingdom of France which has produced the most famous people in the sciences and fine arts. A sample list is provided, ending with one (childless) woman, Catherine Bernard (1662–1712).

Rouen provides an impressive source of old civil registers in a single city, including those for 37 parishes, two hospitals, and many other institutions that kept registers. Bardet (1983) studies this wealth of information and provides a very complete picture of the evolution of the city over the two centuries preceding the French Revolution.[4] In the preface to Bardet's book on Rouen, Pierre Chaunu claims that Bardet's work took history out of empiricism, by providing a corpus of information linking together a wealth of coherent information around the civil register for the first time.

The family reconstitution method, also known as "Henry's method", was proposed by Fleury and Henry (1956). Thanks to the excellent quality of parish records, the method involves tracing the history of a couple by assembling a 'family record' tracking relevant demographic events. There is one family record for each wedding found in the parish records, which is completed with information on date of birth, marriage and death of the couple and their children (even though all of this information is not necessarily available for all couples). Two key pieces of information matter in particular: the wedding date and the ending date of observation. The wedding date is used to establish a start date for the family history, to make sure that the couple did not have any children before the first one found in the parish registers. As for the ending date of observation, it enables to be sure that the couple did not quit the city and have children in another place. A family record can be closed with the death certificate of one of the spouses, or in a census that proves that he/she is still in the city. Consequently, different types of records exist (Table 1) depending on whether the wedding date is known (M (marriage) records) or not (E (étranger = foreigner) records), and if there is an end of observation (F (fermé = closed) records) or not (O (ouvert = open) records). The analysis of fertility is conducted on the basis of information from the MF sheets relating to couples that married in the city and whose end date of observation and age of the woman are known.

In total, 200,000 documents (such as birth, marriage, and death certificates) for the period 1640–1792 were sampled by taking all the names starting with the letter

[3] It was overtaken by Lyon and Marseilles around 1700, see data in Bairoch et al. (1988).

[4] The aggregate results are detailed in the book by Bardet (1983), but the original individual data are not made available by the author.

Table 1 Family records in Henry's method

Types of family records	Wedding date is known	End of observation is known
MF	Yes	Yes
MO	Yes	No
EF	No	Yes
EO	No	No

"B", which led to an analysis of one eighth of the total number of documents. Bardet (1983) reconstituted 5889 families observed from their wedding to the death of one of the spouses, 4000 incomplete families, and many isolated individuals.

Bardet divides his sample into five broad social classes: I (gentry), II (merchants, lawyers, and bourgeois), III (shopkeepers and employees), IV (craftsmen), and V (workers). In Table 2, we report the completed fertility of women married to men in the five social groups. The drop in fertility is substantial, from more than seven children per family in 1640–1669 down to about 4 on average, and 2.7 for the highest social class in 1760–1792. The drop affects all social classes, but the change for the gentry and shopkeepers is more radical than it is for the lower groups. This is reflected in the fertility differential between the highest class and the lowest one which first decreases and then increases in absolute value.

These results tend to show that people in Rouen were forerunners, compared to the French villages studied by Cummins (2012). His sample includes people born between 1720 and 1820, hence covering our last period. His sample descriptive statistics indicate that "Where fertility is high and unchanging, the wealthfertility relationship is positive. The richest tercile here has a family size over 21% larger than the poorest. Where fertility is declining, the wealthfertility relationship is reversed. The differential between the richest and the poorest tercile's family size is now minus 30%."

Bardet studies how this drop happened in detail. He shows that, as often in the fertility transition in Europe (Van Bavel 2004), may be with the exception of England (Cinnirella et al. 2017), it is more a question of stopping having children than of spacing between births.

Over the period considered, the mean age during the last pregnancy drops from 37.1 to 33.5 for the gentry and merchants, from 40.3 to 36.6 for craftsmen, and from 39 to 37.4 for workers (the age at marriage is about 25 for women, constant or slightly increasing over the period). Stopping is generalized and more pronounced in the groups that reduced their fertility the most. Bardet also includes a table (p. 300) presenting the percentage of childless women, by year of marriage and social class. We reproduce it in Table 3. The childlessness rate is computed based on women who married before the age of 30, and for whom we have a complete record of life events. Beyond a baseline of natural sterility of about 3–4%,[5] childlessness

[5] Natural fertility does not tend to vary much across populations (see Werner (1986) and Coleman (1996)). However, sterility can be affected by venereal diseases or health problems due to abortion (Szreter 1996) Consequently, a share of sterility due to venereal diseases could come from prostitutes and could be higher in cities with numerous soldiers or sailors.

Table 2 Completed fertility by year of marriage and social class (first marriages only)

Marriage	Social classes					Δc (%)
	Gentry	Merchants	Shopkeepers	Craftsmen	Workers	
1640–1669	7.05	7.85	7.34			
1670–1699	4.66	6.73	6.53	7.19	7.21	−35
1700–1729	4.53	5.11	5.51	6.29	6.09	−26
1730–1759	3.87	5.31	4.81	5.48	5.67	−32
1760–1792	2.71	4.27	3.28	4.84	4.84	−44
Δ 1670–1792	−42%	−37%	−50%	−33%	−33%	

Couples whose husband belonged to the gentry and who married during the period 1640–1669 had 7.05 children on average, etc. The last line computes the difference between the fourth line (1760–1792) and the first line (1670–1699)

Sources: Bardet (1983) p. 280, own calculations

Table 3 Childlessness rate by year of marriage and social class

Marriage	Social classes				Difference
	Gentry	Shopkeepers	Craftsmen	Workers	Gentry-workers
1670–1699	4	4	5	3	1
1700–1729	8	9	7	6	2
1730–1759	11	11	8	6	5
1760–1792	12	13	10	8	4
Δ 1670–1792	+8	+9	+5	+5	

First line should be read as: 4% of the women belonging to the gentry who married before age 30 during the period 1670–1699 remained childless, etc. The last column gives the difference between the childlessness rate of gentry and that of the workers. The last line computes the difference between the fourth line (1760–1792) and the first line (1670–1699)

Sources: Bardet (1983) p. 300, own calculations

increases over time, for all social classes, but more so for the gentry, and shopkeepers who are inclined to imitate the former.[6]

As analyzed by Baudin et al. (2015) in the US context and Baudin et al. (2017) for developing countries, there are several causes for childlessness: natural sterility, poverty-driven childlessness, and voluntary (or opportunity driven) childlessness. Bardet interprets the rise in childlessness observed in Rouen as an extreme form of contraception, i.e., as voluntary, or rather as a consequence of a voluntary birth control that can have led to childlessness. This interpretation is consistent with the idea of Baudin et al. (2015): When childlessness is voluntary, it tends to be negatively correlated with the fertility of mothers, while when it is poverty driven, it is positively correlated with the fertility of mothers, because very poor people either have a large number of children, or none.

[6] A very high childlessness rate is found among the English upper class (Gobbi and Goñi (2016) and de la Croix and Schneider (2017) for the same period, but without the same time trend.

Some authors have found that, in the early twentieth century, childlessness was greatest in the times and places where fertility control was most evident (Morgan 1991; Poston and Trent 1982; Spencer 1983; Brée et al. 2017). This supports the idea that childlessness is an extreme case of fertility control.

Moreover, Gobbi (2013) shows that the dynamics of fertility and voluntary childlessness do not necessarily imply a negative correlation between the two. For Rouen, comparing line Δ 1670–1792 in Tables 2 and 3, it is clear that the social classes that reduced fertility the most are also those for which the rate of childlessness increased the most.

Why did the citizens of Rouen decide to reduce their fertility? Any credible and global explanation should be consistent with the facts presented above:

1. Completed fertility decreased for all social classes;
2. Differential fertility (gentry vs. workers) increased;
3. Childlessness is negatively correlated with completed fertility both over time and across social classes.

3 Possible explanations

Let us now review the possible explanations for this transition. For each possible explanation, we look at direct evidence. Then, we deal with the implications for fertility and childlessness of each explanation that has not been refuted by direct evidence. For organizational purposes, we divide the possible explanations into three somewhat arbitrary classes: bio-demographic, sociocultural, and socioeconomic.

3.1 Bio-demographic explanations

3.1.1 Decrease in child mortality

In the classical theory of demographic transition, the decline in fertility is presented as a consequence of the decrease in infant mortality (Thompson 1929).[7] Could the drop in birth rates observed be related to a reduction in child mortality during the eighteenth century in Rouen?

Child mortality is difficult to measure since many babies were sent out of town to be fed by mercenary wet nurses and therefore disappear from statistics in the event of their death. Bardet estimates that 71% of babies from the gentry had their care outsourced in this way, while the proportion goes down to 41% for workers (estimation for 1740–1789, p. 300). If one ignores this issue, the apparent mortality

[7] While that decrease in child mortality does reduce the number of births, it does not necessarily reduce the number of surviving children, depending on how uncertainty about child survival affects household preferences. This is discussed further in Doepke (2005), Baudin (2012).

rate[8] during the first year of life does not show any major trend over the period studied. In Rouen as a whole, it went from 161 per thousand between 1670 and 1699 to 150 per thousand between 1760 and 1789. There is a strong social gradient to child mortality. The small gains in apparent mortality mentioned above seem to affect workers more than the gentry. For workers, apparent mortality dropped from 249 per thousand between 1670 and 1699 to 203 per thousand between 1760 and 1789. It went from 87 per thousand between 1670 and 1699 to 98 per thousand between 1760 and 1789 for the gentry. Hence, if there was a drop in mortality, it should have benefitted the poor more. Yet even if there was a drop in child mortality that is not visible in the data because of the practice of resorting to remote wet nurses, and even if this drop was the reason behind the decline in fertility, it cannot explain why the gentry experienced even further reduced fertility, except if the uncorrected data hides a decrease in mortality for the rich.

Beyond the above argument, which is based on the social gradient of fertility and mortality, there is another argument based on the size of the effect: From Table 2, the drop in fertility over the period is of the order of two to three children. Resorting to mortality to explain this drop would require an implausibly large decline in infant mortality, of the order of what has happened over the last two centuries (see Bar and Leukhina (2010) for analyzing how much one can explain the fertility transition with the increase in child survival in England).

3.1.2 Wet nursing

One of Bardet and Dupâquier (1986)'s arguments to explain the low fertility is wet nursing. In Rouen, women often had their children cared for by wet nurses and, as such, did not breastfeed. This may have caused hyperfecundity among the women (indeed, women who do not breastfeed can become pregnant sooner after a previous birth, and therefore more often than those who do). According to Bardet, this could have prompted Rouen's women to use and know more about birth control than others. It could then have contributed to childlessness according to the hypothesis that not having children was a choice. As the intensity of the practice of wet nursing was about constant over the period, this explanation can only account for the level of fertility, but not for its change over time.

3.1.3 Increase in age at marriage

In principle, an increase in the mean age at marriage could be responsible for both a drop in fertility and an increase in childlessness (see Mattessich (1979), Morgan (1991), Hagestad and Call (2007), Rowland (2007)). The latter arises because fecundity declines with age (in particular after 35). The traditional view is that couples delay marriage until they have the financial means to live as they want Hajnal (1965). Late marriages can also bring better knowledge of contraception De Jong and Sell (1977). There is, however, no evidence of such a trend in Rouen.

[8] The number of deaths of children under one year old observed in the city divided by the number of births.

The mean age at (first) marriage fluctuated around 25 years for women, with no trend.[9]

3.1.4 Change in migration

Migration can be temporary or permanent. In the Henry's method, the calculations on fertility are made only with complete families who are the families who remained in Rouen until the death of either the husband or the wife. For this reason, permanent migrations do not affect directly the measure of fertility. Selection effects are however difficult to assess. For in-migration, Bardet compares the fertility of migrants in Rouen to that of natives (i.e., born in Rouen). Even if one out of every two husbands was born outside the city, the fertility of his marriage was no different than that of a native born (tab 117). The people who came from the countryside seemed to adopt the urban behavior very quickly; however, we should keep in mind that fertility was higher in the city than in the countryside in the seventeenth century, and so the decline in the eighteenth century really only led to an achievement of the same fertility level as the one observed in the countryside. Given the similarity between migrants' and natives' fertility, changes in migration rates, if any, did not affect the average fertility rate.

Another possible effect of permanent migration is related to the emigration of Huguenots following the revocation of the Edict of Nantes in 1685. Before the revocation, the share of baptisms of Protestant children culminated at 6.9% in 1620–1639. Two-thirds of these families chose to emigrate, either in anticipation or quickly after the revocation (p. 219). At the level of the city, this represents a small portion of the population, which cannot generate significant composition effects. Moreover, during the seventeenth century, the fertility of Catholic and Protestant married women was quite similar (7.32 vs. 7.14).

Temporary migration can affect fertility measures if the family leaves for a few years and comes back later to Rouen. We know that temporary migrations of married persons before the industrial revolution were mostly male. Moreover, it was very rare for a family to come back to the same place a few years after. For these reasons, we do not think that temporary migrations could have an sizeable impact on completed fertility.

3.1.5 New method of contraception

According to Collier (2007), in "1666, the year of the Great Fire of London, the English Birth Rate Commission officially documented the condom's popular use throughout the country by explaining that the significant decrease in births at the time was due to the use of "condoms." This is the first time that this spelling, or anything close to it, was used in an official government document." In the same book, it is also noted that promiscuous aristocrats used the condom invented under Charles II (1630–1685) as a means of preventing the spread of sexually transmitted

[9] From page 255 of Bardet (1983), the mean age at first marriage for women with a known birth certificate is: 1670–1699: 24.4, 1700–1729: 26.2, 1730–1759: 24.9, and 1760–1789: 26.1.

diseases. Its cost, however, prevented the masses from using it as a contraceptive device (Le Bras 1986; McLaren 1990), and the fertility decline was related more to marriage postponement, abstinence, and coitus interruptus (Seccombe 1992; Szreter 1996). Some authors have also argued that breastfeeding was used as a way to increase the time between births (Carlsson 1966). This is also one of the hypothesis of Bardet for Rouen.

In 1671, Madame de Sevigné, as noted by Vénard and Ariès (1954), also mentioned "restringents," which is a medical term referring to something that tightens the belly; she clearly used this word in a way suggestive of contraception. Still, for the lower classes, the large drop in fertility observed in Rouen appeared with no change in the method of contraception.

3.2 Sociocultural explanations

In explaining changes in fertility over of the last two centuries, scientists are divided between those who believe that fertility was not subject to (economic) choice or control and those who believe it was (Lee 2015). This divide overlaps with another partition between socioeconomic theories of the fertility decline on the one hand and diffusion/adaptation views on the other (Carlsson 1966). In spite of this, researchers today almost all agree that both the adjustment to socioeconomic modernization and the mortality decline (adaptation), as well as cultural effects and the diffusion process, slowed down or speeded up by cultural factors (diffusion), are all important to explain the fertility transition.

It is interesting to note that among the first observers interested in childlessness, the demographers of the interwar period had already drawn associations between low fertility and childlessness processes that now tend to be associated with the second demographic transition, namely secularization, individualism, rising consumption, and the emancipation of women, which can be summarized as modernization (Van Bavel 2010). For example, Landry (1934) situates his discussion of the demographic revolution in the context of increased welfare, driven by innovation in technology and industry, with many inventions of household goods that encouraged people to increase their consumption.

3.2.1 Secularization

There is a vast literature linking the decline in fertility and the process of secularization. In a comparative study of the Belgian, Danish, German, Italian, Dutch, and Swiss provinces, Lesthaeghe and Wilson (1986) show that the moral acceptance of birth control that developed as a result of secularization was a necessary condition for fertility decline. Moreover, there is a large body of evidence suggesting that, compared to other groups, Catholics have managed to maintain relatively high levels of fertility (Sander 1992; McQuillan 2004; Praz 2006). Other contributions have shown that Protestants were forerunners in fertility decline as compared to Catholics (Perrenoud 1974; McQuillan 2006). Using twentieth century data, Adsera (2006) shows that, in a secular society, belonging to a religion predicts

both a higher fertility norm and higher actual fertility. Baudin (2015) reports similar findings based on French data.

Concerning the French decline in fertility, Bardet (1998) argues that the collapse of ecclesiastical institutions was the most significant transformation of this period. Moreover, it is in the departments where Christianization was most deeply rooted that the declining birth rate was highest (Bardet and Van de Walle 2000). Yet this theory has been criticized, in particular by Binion (2000) who rejects the religious cause because "the English of the time (not among others) were just as libertine as French, while their American contemporaries knew rather a religious revival."

Bardet provides several indications that secularization was on the rise during the eighteenth century. We have no evidence of different levels of secularization across social classes in Rouen, but we do know that in Paris, where religious practice was already very low in the eighteenth century (Chaunu et al. 1998), secularization in the nineteenth century was higher among workers than among the richest segment of the population (Jacquemet 1984; Laroulandie 1997; Boudon 2001; Brée 2017). If there is such strong evidence of a higher degree of secularization among workers, then the secularization argument should be rejected based on fertility differentials, since the upper classes were those which underwent the greatest reduction in fertility. However, since the evidence does not pertain to Rouen in the eighteenth century, there is room for further discussion, which we will turn to in the modeling part.

3.2.2 Increase in materialism

By an increase in materialism, we mean an increasing availability, variety, affordability, and quality of consumer goods, implying a rising demand for them. According to De Vries (2008), such a change is a key characteristic of Northern Europe from the period from mid-seventeenth century to about 1830. De Vries (2008) documents that many households began to consume a wider variety and amount of consumer goods, accompanied by an intensification of household labor and engagement with different aspects of the market. From a theoretical point of view, we also know that if children and consumption goods are gross substitutes, growing product variety induces a reduction in the demand for children (Guzmán and Weisdorf 2010).

Even if an increase in materialism may explain why households desired fewer children, could it also explain why some of them even stopped wanting children altogether? Did certain kinds of new (luxury) goods become accessible or desirable, and was being child-free a requirement to procure them? Van de Walle and Etienne, and Francine Van de Walle (1972) identify two major arguments that were advanced by authors of the 18th and nineenth centuries to explain why women did not want children. The first of these arguments was that women did not want to experience the physical changes of pregnancy, and the second was that women wanted to preserve their freedom and avoid the burden of a pregnant belly. Implicit in these two arguments is the desire to avoid losing one's place in society—not to be kept away from salons and high society. This would then only have concerned the elite. This priority given by couples to their careers and a luxurious lifestyle is also

one of the arguments put forward by researchers in the interwar period who tried to account for the very high levels of childlessness (Van Bavel and Kok 2010).

We looked for evidence of some luxury activities which became progressively accessible to women in Rouen. Here is an interesting example. From 1486 to 1789, the association "de l'Immaculée Conception" (Immaculate Conception) in Rouen organized a writing contest and gave literary prizes to selected works. The association took the name "Académie" in 1614. Initially with a very strong religious character, the prize became progressively a real literary award. The presence of women in the laureates in the second half of the period is stunning. Jacqueline Pascal (sister of Blaise Pascal) got a prize in 1640, followed by Mademoiselle d'Argences in 1653 (Dottelonde-Rivoallan 2001). The trend accelerates with no less than six prizes given to women in the eighteenth century.[10] Obviously, these persons belong to the nobility. We do not know, however, if they were childless (the latter wrote a poem on breastfeeding). The eighteenth century also witnessed the success of several female writers linked to Rouen.[11]

More generally, during the seventeenth century, Rouen has experienced a significant intellectual growth (Herval 1949, p. 146). The city is known for its printers, and many writers came to settle there. Scientific societies were created (notably the one that later became the Academy of Sciences). Bardet notices (p. 251) that more and more books were registered in the *post-mortem* inventories (books were mentioned in 40% of them in 1700 and in 63% of them in 1789). During The Age of Enlightenment, more and more mansions were constructed in Rouen as the successful traders adopted the housing type of the nobles (Bardet 1983, p. 92; Herval 1949, p. 208). Rouen was at the climax of its luxurious life at the end of the eighteenth century (Bardet 1983, p. 92). We will thus keep this mechanism as a possible explanation in our model.

3.2.3 Increase in divorce

Divorce implies a material cost imposed on former couples and may lead to a lower number of children per women. Divorce was, however, illegal in France before the French Revolution. It is interesting to note that, as soon as it was allowed by the new constitution in 1792, 1046 couples made use of this option in Rouen and separated, which gives a divorce rate of 3% (Phillips 1976).[12] This is an indication of the early 'modern' character of its inhabitants. In the city, a divorced woman could work and was better able to survive than she would have been in the countryside where she would have had no roof over her head and no job, Bardet notes. Yet even in cities,

[10] Marie-Anne Lepage, born in Rouen, married to Fiquet du Bocage, in 1768; Madame de l'Etoile (born in Rouen) in 1770 and 1771; Madame de Courcy in 1774; and Julie d'Assier de la Chassagne comtesse de Laurencin in 1774 and 1777.

[11] Jeanne Bisson de la Courdraye, Anne de la Roche Guilhem, Jeanne Marie le Prince de Beaumont, Marie Caroline Delabarre, and Louise Cavelier. The first four can be found in the *Index Biobliographicus Notorum Hominum*, the last one in Briquet (1804).

[12] Divorce, however, became illegal again in 1816, and people wanting to divorce had to wait until 1884 when a new divorce law was passed. See de la Croix and Mariani (2015) for a political economy theory of the adoption of divorce laws in Western Europe.

women had a hard time living alone due to the low wages and were sometimes forced into prostitution to survive, especially during periods of unemployment and upon the arrival of a new child (Fuch 1992). The ability to divorce, however, came too late to have any explanatory power in terms of the continuous drop in fertility and the increase in childlessness between 1670 and 1790.

For the sake of completeness, let us mention that couples could be separated by death. Since mortality usually increased with urbanization, higher mortality might have reduced the average fertility period and led to lower completed fertility. This argument does, however, not apply to Rouen, as the size of the city did not increase significantly over the period, and there is no evidence of an increase in adult mortality.

3.3 Socioeconomic explanations

Economists have always defended the view that fertility responds to incentives and, hence, that economic conditions matter to economic decision-making. On the side of demographers, Caldwell (1976, 1982) reintroduced the role of economic factors into demography, without abandoning cultural factors. He advocated taking into account couples' decision-making process, which he analyzed in terms of costs and benefits. Children's education required a significant investment and had an economic and emotional cost: Intergenerational wealth flows then changed directions to benefit children (Caldwell 1976) in the transition from a productive family model to a capitalist mode of production.

3.3.1 Change in income

Income has always been considered as a key determinant of fertility. According to the "Malthusian" view, first elaborated by Bruckner (1768), fertility can be expected to rise and fall as income increases and decreases.

The view that fertility increases in relation to income is supported by some empirical studies of pre-industrial times, but was contradicted by the large decline in birth rates after some countries industrialized at the end of the nineenth century and the beginning of the twentieth century. The failure of Malthus's simple model of fertility led economists to consider decisions pertaining to family size as being outside the scope of their research. However, as noted by Becker (1993), the trouble with the Malthusian approach is not its use of economics per se, but rather its use of an economics that is inappropriate for modern life. It neglects the fact that the time spent on childcare becomes more expensive when countries are more productive. Indeed, time becomes more valuable as goods become more abundant. The higher value of time increases the cost of children, thereby reducing the demand for large families.

What do we know about trends in income in Rouen before the Industrial Revolution? In a Malthusian context, the size of cities is often taken as a measure of wealth. Table 4 shows two estimates of the city size from 1500 to 1800. The first one is by Bardet (1983), the second one by Bairoch et al. (1988). According to both measures, the population fluctuated between 60,000 and 80,000, with no trend.

Table 4 Measures of income in Rouen

Source	1500	1600	1650	1700	1750	1800–1820
Rouen population (Bardet)		60,233	81,931	63,940	67,425	80,000
Rouen population (Bairoch et al.)	40,000	70,000		50,000	66,000	80,000
GDP per capita, France	727	841		910		1135
Workers' real wage, Paris	0.12	0.05	0.05	0.06		

Population is measured in number of inhabitants. GDP per capita is in real dollars (base 1990). Workers' real wage is measured in a fixed quantity of barley (one "setier")

Sources: Bardet (1983) for the first line, Bairoch et al. (1988) for the second line, Maddison (2010) for the third line, and Baulant (1971) fig.4 for the last line

Table 4 also shows estimates of French GDP per capita by Maddison (2010). There is a slightly positive trend, with an annual growth rate in real income of 0.14% over the period 1500–1820. The average income estimated by Maddison may, however, hide a diversity of situations. The next line in Table 4 shows the real wage (in terms of barley) of workers in the building industry in Paris computed by Baulant (1971). This shows a rather sharp loss of purchasing power at the beginning of the period, followed by a stabilization.

Unless Rouen experienced a very specific trend in income during this period which did not translate into city growth, available evidence supports the view that income was stagnant between 1500 and 1800.

3.3.2 Increase in the return to education

Again, Becker (1993) says of the Malthusian model: "It also fails to consider that the greater importance of education and training in industrialized economies encourages parents to invest more in the skills of their children, which also raises the cost of large families. The growing value of time and the increased emphasis on schooling and other human capital explain the decline in fertility as countries develop, and many other features of birth rates in modern economies."

This is the view that was pushed by Galor (2012) (building on his previous work) as the fundamental reason for the decline in fertility: Industrialization brought about increased demand for skilled workers and "the rise in the future demand for the children's human capital [led] to a pure substitution effect, which [induced] parents to substitute quality for quantity of children."[13]

These views echo a perspective developed by historians (Ariès 1960; Flandrin 1973) according to which there was a shift in the nineenth century in parental views away from the 'useful child' to the 'precious child'—precious because of the cost of the education then needed to climb the social ladder (Praz 2005). One could also link the return to education to the new role that children acquired in that century. Ariès (1980) argues that the fertility transition was due to a revolution in sensitivity:

[13] See Doepke (2015) for a survey on the emergence of the concept of the quality-quantity trade-off, and Klemp and Weisdorf (2016) and Galor and Klemp (2017) for evidence of the mechanism on historic parish reconstitution data from England and Quebec.

Table 5 Percentage of good quality signatures-marriage registers

	Men	Women	Women/men	Men–women
1670	57	34	0.60	23
1680	63	36	0.57	27
1690	61	39	0.64	22
1700	58	41	0.71	17
1710	65	45	0.69	20
1720	63	47	0.75	16
1730	64	48	0.75	16
1740	66	49	0.74	17
1750	65	48	0.74	17
1760	67	50	0.75	17
1770	69	53	0.77	16
1780	70	54	0.77	16
1790	67	53	0.79	14

In I760, 67% of men and 50% of women signed with their name the marriage register at their wedding

Sources: Bardet (1983) Table 104 in vol. II, own calculations

Couples simply started caring more about the welfare of their children and their living conditions. Thus, parents invested emotionally as well as financially in the welfare of their children.

We do not know whether such a change could have occurred so early in Rouen. In principle, the Industrial Revolution had not yet reached France. However, this explanation should not be discarded too easily, especially since the rising literacy rates over the period (Table 5) could indicate a higher investment in the education of children. This is particularly remarkable as the opportunity costs of sending children to school, related to forgone income from child work, were quite considerable (Klemp and Weisdorf 2016)

An increase in the return to education might have also been generated by non-industrial factors, such as the professionalization of the army, the rise of a technocratic administration. With the military revolution,[14] for example, being a nobleman was no longer sufficient in and of itself to become an officer; passing examinations became the rule. The change in children's "status" is also a fairly unobserved variable. Hence, in the absence of hard evidence against this mechanism, in the next section, we will analyze its theoretical consequences for fertility and childlessness and compare them to the data.

3.3.3 Women's empowerment

Women's power can be measured along several dimensions, and each dimension has its own effect on fertility (see de la Croix and Vander Donckt (2010)). Essential dimensions in today's economies are: political empowerment, educational attainment, economic participation and opportunity, and health and survival.

[14] Until the seventeenth century, noblemen assumed positions of command (regardless of their competence). Over the period 1600–1700, armies grew considerably in size, requiring more competent officers. For instance, in 1675, Louis XIV made power dependent on merit and seniority (rather than on social class or birth).

Table 6 Percentage of brides able to sign compared to grooms

	Gentry	Shopkeepers	Craftsmen	Workers
1670–99	0.94	0.79	0.61	0.55
1700–29	0.95	0.86	0.77	0.48
1730–59	0.96	0.82	0.77	0.55
1760–92	0.97	0.91	0.83	0.61
Δ 1670–1792	+0.03	+0.12	+0.22	+0.06

Each number represents the ratio of % brides able to sign/% groom able to sign. The last line provides the difference between the fourth line (1760–1792) and the first line (1670–1699)

Sources: own calculations based on p. 244 of Bardet (1983)

With regard to political empowerment, it seems fair to say that the observable political power of women was nil, at least when measured with the indices we use today, such as the number of seats in parliament, or in the municipal council in the case of a city.

For educational attainment, marriage registers can be used to evaluate the basic level of literacy through the quality of someone's signature. Bardet shows this information in Table 104, from which we can compute a gender gap. Table 5 conveys a clear message: The educational gap between (married) men and women shrunk over the period.

This decrease in the educational gender gap seems to have affected all social classes. Table 6 shows the evolution of the gender gap by social class. All ratios are higher at the end of the period. The improvement is generalized.

With regard to the gender gap in economic participation and opportunity, we use the database of famous people built by de la Croix and Licandro (2015). This database includes famous people that appear in the encyclopedias and dictionaries upon which the *Index Bio-bibliographicus Notorum Hominum* is built. We extracted all those related to Rouen, either through birth, or through occupation or death. We looked at them one by one to identify the women. The results are presented in Table 7. Prior to the eighteenth century, only a few women were found. Then, the share of women among famous people increases to 10–12%. Although some of the new occupations held by women do not necessarily correspond to our idea of highly

Table 7 Famous people in Rouen

Death date	Women	Men	% Women
<1400	3	157	2
1400–1600	4	594	1
1600–1649	1	215	0
1650–1699	4	280	1
1700–1749	15	257	6
1750–1799	46	345	12
1800–1849	85	578	13
1850–1899	62	544	10

Count of people related to Rouen in the *Index Biobliographicus Notorum Hominum*

skilled jobs (like playing the role of a soubrette in theater, for example), it is fair to conclude that the gender gap in economic participation and opportunity started to shrink in the eighteenth century.

The health and survival gender gap depends partly on maternal mortality. Maternal mortality was about 10 for 1000 births, with a slight social gradient (8.8 for the gentry and 12.8 for workers). There is a small improvement in survival after 1750, from 11 over the period 1700–1749 to 9.3 over the period 1750–1800 (Bardet, p. 366). On the whole, the proportion of married women who died during delivery declines over time, but rather because of the drop in the birth rate than improvements in medicine. It is 3.9% for the period 1760–1792.

On the whole, there is converging evidence that the gender gap in Rouen started to shrink along the educational, occupational, and health dimensions during the eighteenth century. This may have affected fertility in a variety of ways. For example, Caldwell (1981) attributes, among other things, the decline of French fertility to schooling for both sexes which may have produced greater equality between partners in a couple, thereby increasing the efficacy of coitus interruptus. However, this explanation is based on the assumption that women inherently desire fewer children than men. Yet this assumption is not necessary for women's empowerment to have an effect on fertility. Alternatively, the reduction in the education gender gap makes women's time more valuable, thereby increasing the opportunity cost of having children. This is the way we model women's empowerment in the analytical framework.

3.4 Intermediate conclusion

Several explanations appear irrelevant because of the absence of change during the period under consideration: contraception, wet nursing, age at marriage, income, and divorce. Other explanations have been rejected because they are not consistent with the fact that changes were more pronounced among the higher social groups; they include: mortality and secularization. As such, three explanations without any direct evidence for or against them remain: increase in materialism, women's empowerment, and increase in return to education. Secularization will also be further discussed in the context of the model.

4 Analytical framework

Our strategy is now to use economic theory to highlight the logical implications for households' choices of these three changes and show that we can discriminate between them by looking at childlessness and investment in education. Here, we will assume that households are interested in three goods, beyond those related to subsistence consumption, which is not modeled: a superior consumption good, the number of children (fertility), and the quality of children (as evidenced by their education). Preferences are such that it may be optimal for them to decide not to have children at all. We will also assume that households differ in their preference for children, allowing for the existence of an equilibrium in terms of the proportion

of the population that decides to be childless. The model abstracts from other causes of childlessness.

The purpose of the model is to derive the effect of exogenous changes on the three endogenous variables: fertility, childlessness, and education. It also derives implications for the social gradient in these variables. The increase in materialism will be modeled by a decrease in the price of the superior good. This implies that this good becomes more accessible to households. With regard to women's empowerment, different ways of modeling are possible. We concentrate on economic empowerment, including a reduction in the gender education gap. This kind of change implies an increase in the opportunity cost associated with having children. Finally, the increase in the return to education will be modeled by a change in the household's preferences, giving more weight to the quality of children.

Our theoretical approach is quite novel. Since Becker (1960)'s economic analysis of fertility, economists have disregarded the possibility of childlessness as a choice. However, they have stressed that education and fertility decisions are interrelated. On the contrary, the two existing economic models of voluntary childlessness (Gobbi 2013; Baudin et al. 2015) do not incorporate choices pertaining to education.

Let us now present this formally. Consider a unitary household i of social class j. Preferences are defined over a basket $\{x_{ij}, n_{ij}, h_{ij}\}$, which represents its own consumption, the number of children, and the quality of children (health and education). They are described by the following non-homothetic utility function:

$$u(x_{ij}, n_{ij}, h_{ij}) = \ln(\bar{x} + x_{ij}) + \gamma_{ij} \frac{n_{ij}}{1-\beta} \frac{h_{ij}^{\beta}}{\beta}.$$

γ_i is the preference for children, distributed in the population according to a density function independent of social class. Hence, households of the same social class vary by their preference for children γ. The parameter $\beta \in (0, 1)$ measures the returns to quality in the utility. The constant parameter $\bar{x} > 0$ reflects the idea that x_{ij} is a superior good which is not required for survival.[15]

Compared to the literature, we abstract from the basic consumption good (adding it to the utility function in a log-linear way would not change any of our result). The introduction of a superior good is comparable to what is done by Voigtländer and Voth (2013) and d'Albis et al. (2017). In Voigtländer and Voth (2013), there is an agricultural good and a manufacturing good. The manufacturing good is a superior good as the share of manufacturing expenditures grows with per capita income. d'Albis et al. (2017) have a two-period model where households enjoy consuming a superior good and having children. They are interested in how the timing of fertility is affected by productivity growth. Notice also that Wu et al. (2013) develop a Malthusian model with two consumption goods, bread and circus, but preferences are homothetic.

[15] Superior goods make up a larger proportion of spending as income rises. Here, because of the constant term $\bar{x}$, x_{ij} is not consumed at all for low level of incomes, while becomes consumed once income is above a certain threshold. Notice, however, from "Appendix A" that the income-elasticity of its demand is not strictly larger than one for any level of income.

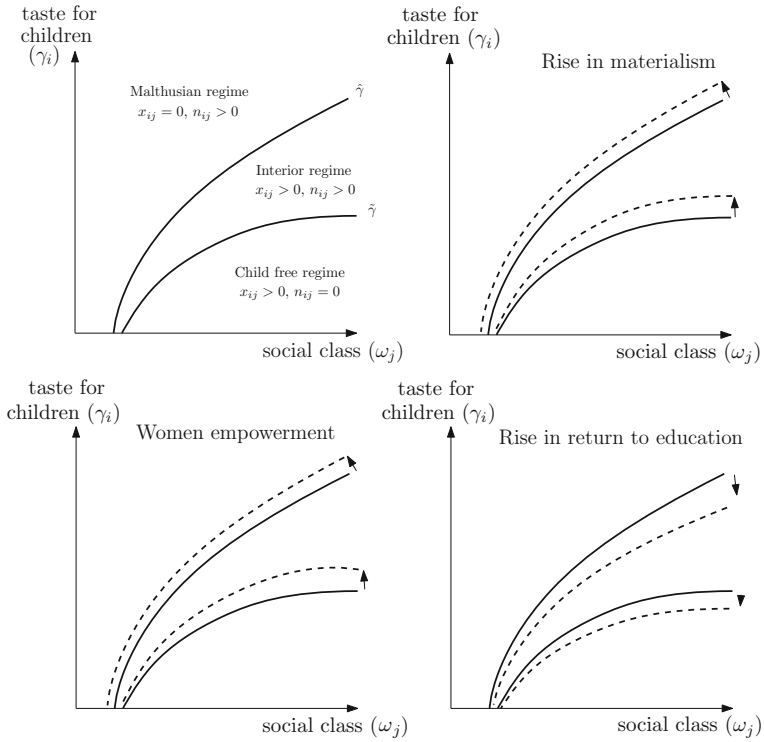

Fig. 2 Different regimes as a function of γ_i and social class j and comparative static results. *Note*: The *top left panel* represents the three regimes. In the three other panels, the *solid line* represents the initial situation and the *dashed line* represents the situation after a rise in materialism/women empowerment/rise in return to education

The individual's budget constraint is

$$p_x x_{ij} + p_n(\omega_j) n_{ij} + n_{ij} h_{ij} = \omega_j,$$

where p_x is the price of the final good, ω_j is the income, and $p_n(\omega_j)$ is the cost of children. This cost includes the spending on goods needed to rear a child and the time cost. The time cost is an opportunity cost, when rearing a child takes time away from the professional activity. Assuming that the amount of time needed to rear a child is the same for all households, the total time cost is proportional to the lost income ω_j, and is hence higher for the upper social classes. The household also buys some education and health good, h_{ij}, the same amount for each child (for simplicity); the spending on quality is thus $n_{ij} h_{ij}$. h_{ij} and is taken as the numeraire.

To better understand the role of parameter β, it is useful to define the total education spending as $s_{ij} = n_{ij} h_{ij}$. Substituting h_{ij} by s_{ij}/n_{ij} in the utility function and the budget constraint, the problem of the household becomes:

$$\max \ln(\bar{x} + x_{ij}) + \gamma_{ij} \frac{n_{ij}^{1-\beta}}{1-\beta} \frac{s_{ij}^{\beta}}{\beta} \quad \text{s.t.} \quad p_x x_{ij} + p_n(\omega_j) n_{ij} + s_{ij} = \omega_j, \quad x_{i,j}, n_{ij} \geq 0.$$

Here, it appears clearly that the last term of the utility is a geometric average of quantity n_{ij} and total spending s_{ij} whose weights are $1 - \beta$ and β, respectively.

The model is solved in detail in "Appendix A". A first result is that, depending on its preferences and on exogenous variables, the household can be in three different situations. In the Malthusian regime, the household does not consume superior goods and all resources are directed toward spending on children. In the interior regime, the household spends on both superior goods and children. In the child-free regime, the household decides not to have children at all.

The top left panel of Fig. 2 shows which regime households belong to depending on their preference for children and their social class. The graph is made under the assumption that the cost of children p_n is increasing with ω_j. The figure shows that the low social classes are more likely to fall into the Malthusian regime. The middle class will sort depending on their preference for children. Those with the highest γ_i will be in the Malthusian regime. The intermediate γ_i households are in the interior regime, and only those with a very low γ_i remain childless. In the upper social class, the proportion of the latter increases further.

When the price of the superior good p_x decreases, the consumption of superior goods by those who have already bought some increases. Fewer resources are spent on children by those in the interior regime, and fertility declines.[16] Those in the Malthusian regime are not affected by the change, as they do not consume any superior goods. Moreover, the regime borders change, as indicated in the top right graph, and more low γ_i households will become childless as the area covered by the child-free regime widens. Hence, on the whole, when p_x goes down, fertility drops and childlessness rises. These effects are stronger for the upper classes that consume superior goods.

Women's empowerment in the form of an increased opportunity cost of having children has the same effects as the increase in materialism along some dimensions. Fertility decreases for those in the interior regime. The regime borders change in a similar way (bottom left panel). Childlessness increases, in particular for the upper social class. The difference is that fertility also drops for those in the Malthusian regime. Hence, there should not be an increase in the fertility gap between the rich and the poor. Moreover, spending on the quality of children increases for all households with children—this is the quality–quantity trade-off stressed in the literature (Doepke 2015).

When the return to education increases (β), parents put more weight on the quality of their children. Households in the interior regime reduce their fertility levels in order to be able to spend more on quality. Fertility in the Malthusian regime is reduced too. The regime borders change as indicated in the bottom right panel. There are more people in the Malthusian regime, and fewer people in the child-free regime (this is the result stressed in Aaronson et al. (2014)). It is likely that fertility on the whole is reduced (unless there are many households in the Malthusian regime). The intuitive explanation for the drop in childlessness is as follows: When the return to education increases, it makes sense to reduce the number of children to invest more in their quality, but not to the point of having no

[16] In general, this is true as long as substitution effects dominate income effects.

children at all, in which case education is purposeless. This stresses a fundamental difference between being childless and having few children. Moreover, having better prospects for one's children may also lead some otherwise childless people to procreate.

A counter argument to the above reasoning can be raised when one considers childlessness as the outcome of a too effective contraception. In that case, even if couples did not want to remain childless, reducing the number of their children (especially by delaying marriage) can have led to childlessness.[17] This remains an hypothesis, however, as the rise in childlessness is observed for those who marry before 30 (Table 3), and the effectiveness of contraception methods used in the seventeenth and eighteenth centuries was quite variable.

Before summarizing the results, let us discuss the possible effect of secularization. There is no straightforward way of modeling religion and religiosity in a canonical economic model. Several approaches have been proposed, and the interpretation depends on the one chosen. A first approach is to assume religion affects the resource constraint of households. Berman et al. (2012) show that fertility across European countries is related to the population density of nuns, who are likely to provide services to families, alleviating child-rearing costs. If this is the case, secularization would imply increasing the cost of children, hence leading to the same consequences as women's empowerment. A second approach is to assume that religion affects preferences directly. Cavalcanti et al. (2007) explicitly model an afterlife period (heaven or hell) in an overlapping generation setup and show that beliefs about how to maximize one's chances of going to heaven affect capital accumulation. Assuming that Catholicism preaches in favor of a sober life as the pathway to heaven, secularization would be similar to the rise in materialism described above. Finally, de la Croix and Delavallade (2017) view religion as affecting the preference for children along its two dimensions, quality and quantity. This would correspond to parameters γ_i and β in our setup. For East Asia, they find that Catholics have higher γ_i and lower β than people with no religious affiliation. Here, secularization resembles a rising weight on the quality of children, like the rise in the return to education. Secularization could thus be seen as reinforcing our three hypothetical scenarios.

Table 8 summarizes the impact of the three possible mechanisms on total fertility, education, childlessness rate and differential fertility. On the whole, one can claim that the 'increase in return to education' explanation cannot be dominant to drive fertility trends observed in Rouen before the nineteenth century, as, if it were dominant, we would have observed a drop in childlessness.[18] As explained by Aaronson et al. (2014), "Intuitively, it is necessary to have at least one child in order to invest in the quality of children. Consequently, fertility along the extensive margin increases as the opportunity to invest in child quality expands." The

[17] Such a postponement-driven childlessness has an involuntary component in the sense that the couple would have preferred to still be fertile, but has a voluntary component too, as, by postponing, the couple accepted to lower its probability to be able to procreate.

[18] It is interesting to note that in de la Croix (2012), p. 48–65, the early drop in fertility in Rouen is related to the rise in the return to schooling. Yet, at the time, de la Croix did not look at childlessness, which would have discredited this mechanism.

Table 8 Theoretical implications of shocks

Hypothesis	Modeling	Effect on fertility n	Effect on education	Effect on % childless	Effect on $n_{\text{workers}}/n_{\text{gentry}}$
Increase in materialism	Superior good cheaper $p_x \downarrow$	$\searrow$	0	$\nearrow$	$\nearrow$
Women's empowerment	Opportunity cost of children p_n higher	$\searrow$	$\nearrow$	$\nearrow$	$\sim$
Increase in return to education	Households value education more $\beta \uparrow$	$\searrow$	$\nearrow$	$\searrow$	$\sim$
Data		$\searrow$	$\nearrow$	$\nearrow$	$\searrow$ then $\nearrow$

The first line should be read as follows. When superior goods become cheaper (more accessible), fertility declines, there is no effect on education, childlessness increases, and differential fertility $n_{\text{workers}}/n_{\text{gentry}}$ increases

'increase in materialism' hypothesis fits well with the demographic data, but should imply no change in education. Although we do not observe the investment in education directly, we observe better outcomes in terms of the ability to sign, which may cast doubt on this hypothesis (although something else could be at play in terms of education). Finally, the 'women's empowerment' hypothesis fits well with the demographic and educational outcomes (as already noticed by Perrin (2013) for France). It should, however, not lead to substantial changes in differential fertility across groups (unless one assumes that such empowerment only applied to the upper classes), when, in reality, fertility differentials were on the rise at the end of the period considered.

5 Conclusion

To better understand the forces underlying fertility decisions, we look at the forerunners of fertility decline, and in particular those who remained childless. Childlessness is worthwhile to be considered as such, as theories concerning a decrease in the number of children people have do not always apply to not having children at all. In particular, we have shown that the increase in the return to education cannot provide an explanation for the observed increase in childlessness. Indeed, when the return to education increases, it makes sense to reduce the number of children to invest more in their quality, but not to the point of having no children at all, in which case education is purposeless.

The increase in childlessness could be a consequence of an increase in materialism, according to which the elite participates in new luxury activities and upper class women do not wish to be excluded from social life due to pregnancy or children. As this mechanism only affects the upper classes, it is consistent with the widening fertility differential and childlessness differential across social classes. In a similar vein, the evolution of women's empowerment, and more generally, the evolution of the role and place of women in society, could lead to similar effects, provided this empowerment benefits the upper classes more. To conclude, analyzing

the reasons for childlessness can help to interpret trends in fertility. To do so, one needs to combine sound knowledge of the data and their context, together with simple economic theory to highlight the consequences of potential mechanisms.

We cannot be sure that the example of Rouen allows us to draw general conclusions about France or other European countries (external validity). However, it is certain that looking at social gradients in childlessness helps to unravel the trade-offs at work in historical populations.

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Appendix A: Solving the model

Using $s_{ij} = n_{ij}h_{ij}$, the utility can be rewritten:

$$\ln(\bar{x} + x_{ij}) + \gamma_i \frac{n_{ij}^{1-\beta}}{1-\beta} \frac{s_{ij}^{\beta}}{\beta} \tag{1}$$

The household maximizes utility subject to her budget constraint,

$$p_x x_{ij} + p_n(\omega_j) n_{ij} + s_{ij} = \omega_j \tag{2}$$

and the non-negativity constraints:

$$x_{i,j}, n_{ij} \geq 0.$$

Three regimes are possible: the interior regime with $x_{ij},\ n_{ij} > 0$, a Malthusian regime with no luxuries and $x_{ij} = 0,\ n_{ij} > 0$, and a child-free regime $x_{ij} > 0,\ n_{ij} = 0$.

Interior Regime We start with the interior regime with both x_{ij} and n_{ij} positive. In that case, the first-order conditions can be solved as:

$$s_{ij} = \beta(p_x \bar{x} + \omega - \varrho_i) \tag{3}$$

$$n_{ij} = (1-\beta)\ \frac{p_x \bar{x} + \omega - \varrho_i}{p_n}, \tag{4}$$

$$x_{ij} = \frac{\varrho_i}{p_x} - \bar{x}, \tag{5}$$

$$h = \frac{\beta p_n}{1-\beta}, \tag{6}$$

where

$$\varrho_i = \frac{(1-\beta)^{\beta} \beta^{1-\beta} p_n^{1-\beta}}{\gamma_i} \tag{7}$$

is a monotonic transformation of the relative cost of quantity p_n over quality.

The demand for superior goods x_i is decreasing in its price p_x and increasing in the cost of children quantity p_n. The demand for quality h_i only depends on its cost relative to quantity and is thus a positive function of the price p_n. It does not depend on the price of luxuries p_x.

Fertility, i.e., the demand for quantity of children n_i, depends positively on income ω_j for given p_n. If the cost of children is a time cost, p_n is proportional to income, say $p_n = \phi\omega_j$. In that case, fertility varies negatively with income. Moreover,

Proposition 1 *Fertility in the interior regime decreases in its own price p_n, increases with the price of the superior good p_x, and decreases with the return to education β if and only if*

$$\omega > \left(3 - \frac{1}{\beta}\right) - p_x\bar{x} + (1-\beta)\varrho_i \ln\frac{\beta p_n}{1-\beta}$$

The indirect utility is this regime is:

$$V_{ij} = \frac{p_x\bar{x} + \omega_j}{\varrho_i} + \ln\varrho_i - \ln p_x - 1. \tag{8}$$

Child-free regime Now consider the regime where the household is childless and consumes superior goods. In that case, $x_i = \omega_j/p$, $n_i = 0$ and $h_i = 0$. The indirect utility is:

$$W_j = \ln\left(\frac{\omega_j}{p_x} + \bar{x}\right). \tag{9}$$

Malthusian regime Finally, consider the regime where the household does not consume superior goods: $x_i = 0$. In that case, the first-order conditions can be written as:

$$s_j = \beta\omega_j, \tag{10}$$

$$n_j = (1-\beta)\frac{\omega_j}{p_n}, \tag{11}$$

$$h = \frac{\beta p_n}{1-\beta}. \tag{12}$$

And the indirect utility function is:

$$Z_{ij} = \ln\bar{x} + \frac{\omega_j}{\varrho_i} \tag{13}$$

In this regime, we have:

Proposition 2 *Fertility in the Malthusian regime is unaffected by the price of the superior goods* p_x *and decreases with its own price* p_n *and with the return to education* β.

From the comparisons of the indirect utilities, we can infer bounds on γ_i delimiting the different regimes.

Proposition 3 *There exists*

$$\tilde{\gamma}_j = \frac{(1-\beta)^{\beta}(\beta\, p_n)^{1-\beta}}{(p_x\, \bar{x} + \omega_j)}, \qquad \text{and} \qquad \hat{\gamma} = \frac{(1-\beta)^{\beta}(\beta\, p_n)^{1-\beta}}{p_x\, \bar{x}},$$

with $\tilde{\gamma}_j < \hat{\gamma}$, *such that:*

1. *if* $\gamma_i < \tilde{\gamma}_j$, $x_{ij} > 0$ *and* $n_{ij} = 0$ *(child-free regime),*
2. *if* $\tilde{\gamma}_j \leq \gamma_i \leq \hat{\gamma}$, $x_{ij} > 0$ *and* $n_{ij} > 0$ *(interior regime),*
3. *if* $\hat{\gamma} < \gamma_i$, $x_{ij} = 0$ *and* $n_{ij} > 0$ *(Malthusian regime).*

Proof From Eq. (5), γ_i needs to be larger than $\tilde{\gamma}$ for x_i to be positive. Moreover, the difference $V_{ij} - W_j$ is given by:

$$V_{ij} - W_j = \ln\left(\frac{\varrho_i}{p_x\bar{x} + \omega_j}\right) + \frac{p_x\bar{x} + \omega_j}{\varrho_i} - 1$$

The derivative of this difference with respect to γ_i is

$$\frac{\partial(V_{ij} - W_j)}{\partial\gamma_i} = \frac{p_x\bar{x} + \omega_j - \varrho_i}{\gamma_i\varrho_i}$$

At the point $\gamma_i = \tilde{\gamma}$, the indirect utilities are equal: $V_{ij} = W_j$. When γ_i increases above $\tilde{\gamma}$, V_{ij} increases and W_j stays constant; hence, the interior regime dominates the corner regime $x_i = 0$ for all $\gamma_i > \tilde{\gamma}$.

From Eq. (4), γ_i needs to be larger than $\hat{\gamma}$ for n_i to be positive. Moreover, the difference $V_{ij} - Z_{ij}$ is given by:

$$V_{ij} - Z_{ij} = \ln(\varrho_i p_x\bar{x}) + \frac{p_x\bar{x}}{\varrho_i} - 1$$

The derivative of this difference with respect to γ_i is

$$\frac{\partial(V_{ij} - Z_{ij})}{\partial\gamma_i} = \frac{p_x\bar{x}}{(1-\beta)^{\beta}(\beta p_n)^{1-\beta}} - \frac{1}{\gamma_i}$$

At the point $\gamma_i = \hat{\gamma}$, the indirect utilities are equal: $V_{ij} = Z_{ij}$. When γ_i decreases below $\tilde{\gamma}$, $V_{ij} - Z_{ij}$ increases, hence the interior regime dominates the corner regime $n_i = 0$ for all $\gamma_i < \hat{\gamma}$. □

Figure 2 plots the two thresholds $\hat{\gamma}$ and $\tilde{\gamma}$ as a function of γ_i and ω_j.

The childlessness rate χ in the economy is given by:

$$\chi = F(\tilde{\gamma}),$$

where $F(\cdot)$ is the cumulative distribution function of γ_i. Hence, when there exogenous changes in parameters, childlessness varies in the same direction as $\tilde{\gamma}$.

Proposition 4 *The childlessness rate* $F(\tilde{\gamma})$ increases with the price p_n *and decreases with the price of luxuries* p_x. *It decreases with the return to education* β *if and only if:*

$$1 - 2\beta - (1-\beta)\beta \ln\left(\frac{\beta p_n}{1-\beta}\right) < 0$$

i.e., when p_n *is not too large.*

Proof Let us compute

$$\frac{\partial \tilde{\gamma}}{\partial \beta} = \frac{p_n^{1-\beta}\left(1 - 2\beta - (1-\beta)\beta \ln\left(\frac{\beta p_n}{1-\beta}\right)\right)}{(1-\beta)^{1-\beta}\beta^{\beta}(p_x\bar{x} + \omega_j)}.$$

The proposition follows. □

Appendix B: Robustness to the introduction of a basic consumption good

We introduce a consumption good c_{ij} and show how the main equations are altered.

Utility is now:

$$\ln(\bar{x} + x_{ij}) + \gamma_i \frac{n_{ij}^{1-\beta}}{1-\beta} \frac{s_{ij}^{\beta}}{\beta} + \ln c_{ij} \tag{1}$$

The budget constraint is

$$p_x x_{ij} + p_n(\omega_j) n_{ij} + s_{ij} + c_{ij} = \omega_j \tag{2}$$

Interior regime
The solution is:

$$s_{ij} = \beta(p_x\bar{x} + \omega - 2\varrho_i) \tag{3}$$

$$n_{ij} = (1-\beta)\,\frac{p_x\bar{x} + \omega - 2\varrho_i}{p_n}, \tag{4}$$

$$x_{ij} = \frac{\varrho_i}{p_x} - \bar{x}, \tag{5}$$

$$h = \frac{\beta p_n}{1-\beta} \tag{6}$$

$$, c_{ij} = \varrho_i \tag{7}$$

where

$$\varrho_i = \frac{(1-\beta)^{\beta}\beta^{1-\beta}p_n^{1-\beta}}{\gamma_i} \tag{8}$$

The indirect utility is this regime is:

$$V_{ij} = \frac{p_x\bar{x} + \omega_j}{\varrho_i} + 2\ln\varrho_i - \ln p_x - 2. \tag{9}$$

Child-free regime
The indirect utility is:

$$W_j = 2\ln\left(\frac{\omega_j}{p_x} + \bar{x}\right) - \ln(4p_x). \tag{10}$$

Malthusian regime
The first-order conditions can be written as:

$$s_{ij} = \beta(\omega_j - \varrho_i), \tag{11}$$

$$n_{ij} = (1-\beta)\frac{\omega_j - \varrho_i}{p_n}, h = \frac{\beta p_n}{1-\beta}, \tag{12}$$

$$c_i = \varrho_i \tag{13}$$

And the indirect utility function is:

$$Z_{ij} = \ln\bar{x} + \frac{\omega_j}{\varrho_i} + \ln\varrho_i - 1 \tag{14}$$

It remains true that there exists

$$\tilde{\gamma}_j = \frac{2(1-\beta)^{\beta}(\beta\, p_n)^{1-\beta}}{(p_x\,\bar{x} + \omega_j)}, \qquad \text{and} \qquad \hat{\gamma} = \frac{(1-\beta)^{\beta}(\beta\, p_n)^{1-\beta}}{p_x\,\bar{x}},$$

with $\tilde{\gamma}_j < \hat{\gamma}$, such that:

1. if $\gamma_i < \tilde{\gamma}_j$, $x_{ij} > 0$ and $n_{ij} = 0$ (child-free regime),
2. if $\tilde{\gamma}_j \leq \gamma_i \leq \hat{\gamma}$, $x_{ij} > 0$ and $n_{ij} > 0$ (interior regime),
3. if $\hat{\gamma} < \gamma_i$, $x_{ij} = 0$ and $n_{ij} > 0$ (Malthusian regime).

And it remains true that the childlessness rate $F(\tilde{\gamma})$ increases with the price p_n and decreases with the price of luxuries p_x. It decreases with the return to education β if and only if:

$$1 - 2\beta - (1-\beta)\beta\ln\left(\frac{\beta p_n}{1-\beta}\right) < 0$$

i.e., when p_n is not too large.

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