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ABSTRACT

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French Fertility and Education Transition: Rational Choice vs. Cultural Diffusion

D. de la Croix and F. Perrin

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Institut de Recherches Économiques et Sociales
de l'Université catholique de Louvain



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French Fertility and Education Transition: Rational Choice vs. Cultural Diffusion

David de la Croix[1] Faustine Perrin[2]

March 3, 2016

Abstract

We analyze how much a rational-choice model can explain the temporal and spatial variation in fertility and school enrollment in France during the 19th century. The originality of our approach is in our reliance on a structural estimation technique that exploits the restrictions implied by the first-order conditions to identify the deep parameters. Another new dimension is our use of gendered education data, allowing us to have a richer theory that includes mothers, fathers, boys and girls. Results indicate that the rational-choice model explains 38 percent of the variation of fertility over time and across counties, as well as 71 percent and 83 percent of school enrollment of boys and girls, respectively. The analysis of the residuals (unexplained by the economic model) indicates that additional insights might be gained by considering cross-county differences in family structure and cultural barriers.

Keywords: Quality-quantity tradeoff, Education, Gender Gap, Demographic transition, France
JEL Classification numbers: J13, N33, O11

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Introduction

In explaining the fertility transition of the last two centuries, scientists are divided into two camps: those who believe that fertility was not subject to rational choice or control and those who believe that it was. Most economists are on the rational-choice side, giving incentives a central role,[1] while demographers tend to agree with the no-choice view (see Lee 2015) and stress the importance of social norms and imitation. This divide overlaps with another partition between socioeconomic theories of the fertility decline on the one hand and diffusionist/cultural views on the other (as named by Lee 2015). The rational-choice approach clearly belongs to the first strand, [2] while, for example, the Princeton study (Coale and Watkins 1986), which examined the timing of fertility change at the county level in Europe, concludes in favor of the diffusionist/cultural view.[3] A recent paper in the diffusionist tradition is Spolaore and Wacziarg (2014). They show that the fertility decline among European regions over 1830-1970 is closely associated with the cultural distance from France, which, because of its early move towards secular humanism, is viewed as the frontier innovator in terms of fertility limitation. Populations that were closer genealogically or linguistically to France adopted fertility control faster.[4]

Understanding which mechanism matters most is key for policy design. If, according to the diffusionist/cultural view, fertility is a question of culture and norms instead of incentives, policies based on incentives (family allowances, tax break for families, etc.) have little impact. One should acknowledge that the division between incentives vs norms is somehow artificial and that norms too may adjust to incentives. This adjustment is, however, likely to be slow – perhaps taking as long as a generation – thus requiring some patience from politicians who implement incentive policies. Understanding how norms evolve and are transmitted, and whether this transmission can be altered by policy, is also very different from studying how people respond to incentives.

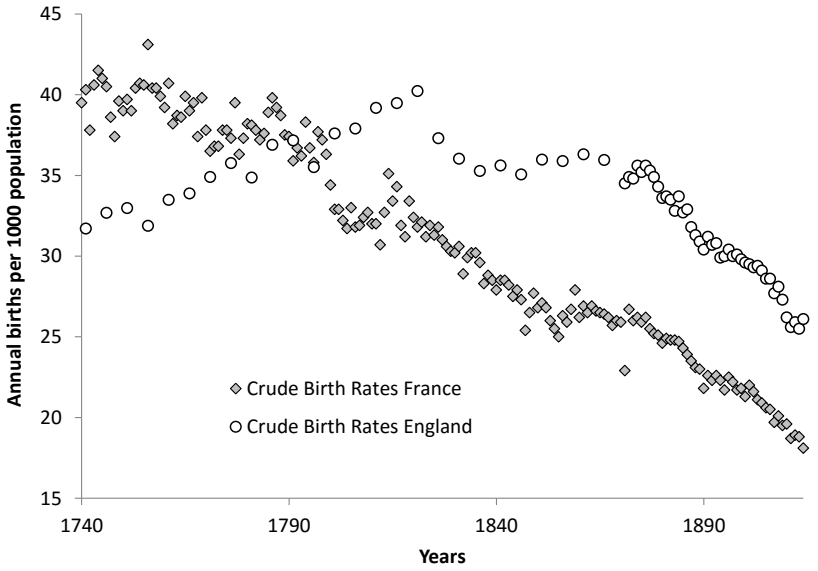
This paper contributes to the debate by evaluating (i) how much one can explain by relying

[1] However, some, such as Fernandez and Fogli (2009), stress that, in addition to economic determinants, culture plays an important role. They show that the fertility of second-generation immigrants to the US is affected by past values of the total fertility rates in the woman's country of ancestry, used as a cultural proxy. Going further, Chabé-Ferret (2016) studies the trade-off between benefits and costs of complying with a cultural norm, and shows that the crucial margin is the parity progression between the second and third birth.

[2] Responding to economic incentives (economists' terminology) belongs to the broader class of adaptation to economic change (Caldwell 1982)

[3] Under specific assumptions, it is possible to embed cultural diffusion into a rational-choice model – see Baudin (2010) for an application to fertility.

[4] Alternatively, populations having strong migration channels with Paris are likely to be influenced more by the new norms. Daudin, Franck, and Rapoport (2016) construct a matrix of migration flows between counties over the period 1861-1911. They show that fertility declined more in areas that had more emigration towards low-fertility regions, especially Paris. This does not mean, however, that socioeconomic factors are unimportant, as migration itself depends on economic incentives (wage and employment differences, transportation and housing costs).



Source: England 1740-1866, Wrigley et al. (1997, Ch. 8 and Table A9.1).
England 1871-1900, Mitchell and Mitchell (1975)
France 1740-1900: Chesnais (1992).

Figure 1: Crude birth rates in France and in England

strictly on a rational-choice model, mapping economic determinants into fertility and education choices through a structural approach; and (ii) how additional factors (cultural, geographic, institutional, etc.) might explain particular behaviors observed in certain regions/areas.

We use data from French counties (*départements*) over the 19th century. The continuity of the State allows us to use from census data covering a long time period, as well as detailed education data. Moreover, as education became compulsory relatively late (education until the age of 13 was made free and compulsory by the laws of June 16, 1881 and March 28, 1882), sending children to school can be seen as a decision of the parents during most of the 19th century.

Using French data is not neutral with respect to the nature of the process at the root of the demographic transition. Indeed, fertility started to drop in France earlier than in any other country, and, more importantly, before the materialization of any benefit from the industrial revolution. Figure 1 compares the birth rate in France with the birth rate in England over 1740-1900. In England, we find what has become the textbook pattern of the demographic transition: fertility rises during the post-Malthusian epoch and then declines sharply when entering the modern growth regime (Galor 2011). In France, fertility starts to decline well before the industrial revolution, as if "the historical fertility transition and the spread of the industrial revolution were indeed separate processes, with different early adopters" (Spolaore and Wacziarg 2014). France is the best case for the diffusionist/cultural view, as fertility transition led to the take-off of modern growth.

Explaining the variation in the demographic transition across French counties in the 19th century is challenging. According to González-Bailón and Murphy (2013), there were initially two zones of low fertility. Throughout the 19th century, these two areas spread, lending credence to the diffusionist view. This is, however, not the only way to interpret the evidence. The observed pattern could result from a process of homogenization along another dimension, be it education, mortality, or something else.

We select three representative generations of households. Within counties, we assume identical households (one household = one county).[5] The first generation was born in the decade around/after the French Revolution. We observe their enrollment rate in primary school in 1816-20, which gives a measure of their human capital. We also observe the "actions" taken by this generation: fertility (proxied by the average crude birth rate over 1821-31) and education (proxied by school enrollment in 1837). We to determine how much of the heterogeneity in actions can be explained by the observed heterogeneity across counties in child mortality and lifetime labor supply of parents within a rational-choice model. We also follow the second generation, born in 1821-31, and the third generation, born in 1846-56. These generations have a fertility rate as proxied by the crude birth rate in 1846-56 and 1872-81 and provide education to their children, around 1863 and 1886-87.

The rational-choice model that we use is an extended version of the one proposed by de la Croix and Doepke (2003). It features the typical quality/quantity tradeoff, implying that highly educated parents prefer to have a small number of children but to invest more in their "quality." It also embeds mechanisms that are typical to the economic approach: the child-rearing time is allocated optimally between the parents, and the marginal return of education is equalized across children (boys and girls). Thus, a new dimension of this research is also to use gendered education data, allowing us to have a richer theory that includes mothers, fathers, boys and girls.

Compared to the existing literature, the originality of our approach is in our reliance on a structural estimation technique that exploits the restrictions implied by the first-order conditions to identify the deep parameters. For example, compared to the recent paper by Murphy (2015) on fertility transition in France, we impose additional discipline to the exercise by considering the joint decision about fertility and education; doing so, we identify the mechanisms using both birth rate and school enrollment data. Moreover, the existing literature that studies the joint fertility and education choice in the 19th century (Becker, Cinnirella, and Woessmann 2010 for Prussia; Diebolt, Mishra, and Perrin 2015 and Bignon and García–Peñalosa 2016 for France) also uses reduced-form approaches. A theoretical model is used, at best, to derive the sign of the effects, as in Bignon and García–Peñalosa (2016), in which fertility and education are shown to react in opposite directions when a tariff on agricultural products is introduced. The

[5]Looking at how fertility and wealth inequality are related is possible in only a few locations; see Cummins (2013).

only structural approach is by Cervellati, Murtin, and Sunde (2015), who estimate a unified growth model using panel data for 63 countries over 1880-2000.

The last step in our analysis consists of relating the parts of fertility and education that the model does not explain (the "residuals" of the structural equations) and correlating them with other determinants proposed in the literature, including: family systems (Le Bras and Todd 2013; Diebolt, Menard, and Perrin 2016); cultural / social interactions (González-Bailón and Murphy 2013; Spolaore and Wacziarg 2014); religion (see Baudin (2015) for an analysis of religion and fertility using recent French data and Becker and Woessmann (2009) for the link between religion and education in 19^{th} century Prussia); and the importance of upper-tail knowledge in the preceding century (Squicciarini and Voigtländer 2015).

The results are as follows. The rational-choice model explains 38 percent of the variation of fertility over time and across counties, and 71 percent and 83 percent of school enrollment of boys and girls, respectively. On a pure cross-sectional basis, fertility is relatively poorly explained, around 30 percent of its cross-county variation captured by the model (46 percent in 1872-81). Variations in child mortality and in mothers' education are important to capture variations in fertility. Education, on the contrary, is well explained, at least for the two first generations: the model explains 83 percent of the girls' enrollment ratio and 72 percent of the boys' in the middle of the 19th century. This explanatory power declines to 39 percent and 22 percent for the last generation, but, at that time, compulsory education had became the norm. The last part of the analysis identifies additional mechanisms that are important for understanding fertility and education but that are not embedded yet in the rational-choice model. First, the cross-county variation in family structures, as elaborated by Le Bras and Todd (2013), explains why some counties in which the extended family prevailed had a stronger fertility decline, in particular for the first generation. The Oc/Oïl language barrier explains well the highest fertility of the first generation in the Oc regions. Finally, religion and upper-tail knowledge variables do not seem important.

The paper is organized as follows. Section 1 outlines the economic model. Section 2 describes the data used in the analysis. The structural estimation is presented in Section 3. Section 4 correlates what remains unexplained with a series of cultural and social variables. Section 5 concludes.

1 The Model

We develop an economic model of fertility choice with a quality-quantity tradeoff.[6] Rational households decide about the number of their children and their education . We identify the

[6]See Doepke (2015) for the history of the emergence of this notion, and Klemp and Weisdorf (2012) for an application to pre-industrial England.

parameters of the model by minimizing the distance between its prediction and the French data. The model is close to the one proposed by de la Croix and Doepke (2003) and de la Croix and Delavallade (2015), extended to allow for non-labor income, two genders and optimal degrees of involvement in child rearing by the father and the mother (inspired by Hazan, Leukhina, and Zoaby (2014)). It is a very parsimonious model that captures one supposed key feature of the demographic transition: with the time cost of rearing children being higher for more-educated parents, they prefer to have fewer children but to invest more in their quality.

Consider a hypothetical economy populated by overlapping generations of individuals who live over three periods: childhood, adulthood, and old age. They make all decisions in the adult period of their lives. Males/boys and females/girls are denoted with upper indices b and g. The adult household members are endowed with one unit of time each, which they spend either at work or in rearing children. Households' labor income is given by:

$$y_t = h_t^b(1 - a_t^b) + \omega h_t^g(1 - a_t^g), \tag{1}$$

where a_t^j is the amount of time spent on rearing children, and h_t^j is the human capital of sex j per unit of time. The wage per unit of capital is 1 for males and $\omega < 1$ for females (gender discrimination).

The household will "produce" a total number of births N_t, among which n_t will survive. Both N_t and n_t are real (continuous) variables, for simplicity. Child mortality is exogenous and denoted m_t. The number of surviving children is given by:

$$n_t = (1 - m_t)N_t. \tag{2}$$

The ratio of boys to girls is assumed to be one (in the real world, the natural male-to-female sex ratio at birth is around 105:100), and there is no sex-selective abortion, which implies:

$$n_t^g = n_t^b = \tfrac{1}{2}n_t. \tag{3}$$

The technology that allows households to produce children is given by:[7]

$$\phi n_t + \psi(N_t - n_t) = \sqrt{a_t^b\, a_t^g}. \tag{4}$$

The equation stresses that time is essential to produce children and that the mother's and father's time are mild substitutes. We do not introduce an *a priori* asymmetry between the parents. Asymmetry will arise as an equilibrium phenomenon: with the gender wage gap $\omega < 1$, it will be optimal to have the mother spending more time on child rearing. The parameter

[7] Adapted from Browning, Chiappori, and Weiss (2014) p.265, and Gobbi (2014) to the production of quantity instead of quality.

$\phi \in (0,1)$ is related to the needs of a surviving child, while $\psi \in (\phi, 0)$ captures the needs of a child who died. Both parameters imply an upper bound to the number of children. If both parents devote their entire time to produce children, and child mortality is nil, they will produce $1/\phi$ of them.

Households care about the consumption of a public good c_t, the number of children, boys and girls, n_t^b and n_t^g, and their human capital h_{t+1}^b and h_{t+1}^g, which measures their quality. Mothers and fathers have the same preferences and act cooperatively (unitary model of the household). Their joined utility function is given by:

$$\ln(c_t) + \gamma \ln(n_t^b h_{t+1}^b + n_t^g h_{t+1}^g). \tag{5}$$

The parameter $\gamma > 0$ is the weight of children in the utility function. The budget constraint for a couple with human capital (h_t^f, h_t^m) is:

$$c_t + p_t(e_t^b n_t^b + e_t^g n_t^g) = y_t + b_t. \tag{6}$$

The total educational cost per child is given by $e_t^j p_t$, where e_t^j is the number of hours of teaching bought for the children of sex j at a price p_t. The assumption that education is purchased on the market but that there is a minimum time cost required to bear children is key in explaining that highly educated parents will spend more on the quality of their children. b_t stands for exogenous non-labor income. Note that, for simplicity, we assume that children need only time and education and do not consume any private goods.

In the model, parents' influence on their children's human capital is limited to the effect through education spending. Children's human capital h_{t+1} depends on their education e_t:

$$h_{t+1}^j = (e_t^j)^{\eta_t^j + \varepsilon \ell_{t+1}^j}. \tag{7}$$

$\eta_t^j + \varepsilon \ell_{t+1}^j$ is the elasticity of human capital to education. It has a constant, gender-specific part, η_t^j and a part that depends positively on longevity ℓ_t^j. This latter component is designed to capture a possible Ben-Porath effect (de la Croix 2016), according to which the return to education is higher when the horizon is longer.[8] Parameter $\epsilon > 0$ will determine the strength of this effect. Note that this formulation does not impose the existence of a Ben-Porath effect, as ϵ can always turn out to be estimated very low.

Note that in Equation (7), we do not add a constant term to e_t^j, unlike in de la Croix and Doepke (2003). The purpose of this constant term is to allow for a corner solution in which low-skill parents forgo investment in their children and, thus, are not subject to the quality-quantity tradeoff. With such a model, fertility can display a hump-shaped relationship with

[8] Leker (2015) looks at education across French counties in the 19th century through the lens of the Ben-Porath model.

parental skill, which seems to fit the evidence well in developing countries (Vogl 2016). In the case of France's counties in the 19th century, fertility was already declining for at least 50 years, and education was positive and increasing, making this corner regime irrelevant.

In a robustness exercise, we allow for time variation in the η to reflect the idea promoted by Galor and Weil (2000), according to whom technological progress raises the return to human capital.

Given this structural model, the decision problem of the household can be summarized as:

$$\{a_t^g, a_t^b, e_t^g, e_t^b, n_t\} = \arg\max \ln(c_t) + \gamma \ln\left(\tfrac{n_t}{2}((e_t^b)^{\eta_t^b + \varepsilon \ell_{t+1}^b} + (e_g^j)^{\eta_t^g + \varepsilon \ell_{t+1}^g})\right)$$

subject to

$$\begin{aligned}\left(\phi + \psi \frac{m_t}{1-m_t}\right) n_t &= \sqrt{a_t^b\, a_t^g} \\ c_t &= h_t^b(1-a_t^b) + \omega h_t^g (1-a_t^g) + b_t - p_t(e_t^b + e_t^g)\tfrac{n_t}{2}.\end{aligned}$$

The first-order conditions are detailed in Appendix A. The main mechanisms at play, reflecting the rationality of the household, are the following:

- the share of child rearing supported by the mother is inversely related to her human capital, weighted by the gender wage gap.
- the cost of having children increases with the human capital of the parents.
- boys and girls are educated so as to equalize the return of education across genders.
- parents spend on education up to the point where the marginal gains in the quality of children equals their marginal cost in terms of forgone consumption.
- a rise in children's expected lifetime labor endowment ℓ_{t+1}^j increases education spending and decreases fertility [Ben-Porath effect].
- a rise in non-labor income increases fertility and education, as the both quantity and quality of children are normal goods [income effect].

2 French County-Level Data

In order to investigate the extent to which fertility and education changes can be explained by rational decisions, we collect French county-level data for the 19th century. Our data comprise

eight points in time from 1806 to 1886-87 and come from various sources published by the French Statistical Office (*Statistique Générale de la France*).

2.1 County Boundaries

French county-level data can be used for quantitative analysis because of the relative stability of France's administrative division since its establishment in March 1790. One should, however, be aware of some historical changes in the boundaries. The creation of counties (*départements*) resulted from a political and ideological national project undertaken by the French Constituent Assembly in 1789 to enhance the feeling of national membership. The division of the territory into counties was based on the desire to equilibrate the importance of the districts (Masson 1984 p. 680). According to Turgot (1775), the districts should be sized so that the furthest part of the district would be located, at maximum, one day on horseback from the *chef-lieu* (main city). The *Rapport du Comité de Constitution* eventually stated that each county should be divided into about 324 square lieues (leagues). A geometric division from Paris was organized so as to limit the artificial division by respecting the old boundaries, when possible, and easing communication (Rapport du Comité de Constitution, Archives Parlementaires, Tome IX, page 554). This project resulted in the creation of 83 counties (Rapport sur le Décret général relatif aux départements du Royaume, Dupont de Nemours, 1790).

The boundaries of several of these counties evolved over time, or temporarily became part of other countries/territory than France. The 1791 division of the territory increased substantially in 1810 under the First French Empire to reach 130 counties (with the territorial annexations from the Low Countries, Italy, Spain and Germany). After the fall of Napoleon I in 1815, the number of départements dropped to 86 and then increased to 89 in 1860 with the incorporation of the Alpes-Maritimes and the Duchy of Savoy (House of Savoy), resulting in Savoie and Haute-Savoie. After its defeat in the Franco-Prussian war in 1871, France conceded the Haut-Rhin, the main part of the Bas-Rhin (the whole territory except for Belfort and its surroundings) and Moselle to Germany. The remaining part of Moselle and Meurthe were merged to create the Meurthe-et-Moselle. Unlike current boundaries (established in 1968), Paris and its region (Île-de-France) were composed of only three counties: Seine (Paris, Seine-Saint-Denis, Val-de-Marne, and Hauts-de-Seine), Seine-et-Marne, and Seine-et-Oise (Val-d'Oise, Essonne, and Yvelines). To ensure that our results are not driven by changes in administrative boundaries, we do not integrate into our analysis the counties that temporarily did not belong to continental France during the study period. Hence, we exclude the following counties: Belfort, Meurthe, Moselle, Haut-Rhin, Bas-Rhin, Savoie and Haute-Savoie. In light of these exclusions, our analysis includes 81 counties.

2.2 The Variables

This paper focuses on the behavior of three generations denoted G0, G1 and G2. How the different generations overlap is illustrated in Figure 2. We consider a first generation born around the French Revolution, a second generation born in 1826, and a third generation born in 1851. Our main data sources are the Population and Education censuses.

To measure fertility behavior, we use the crude birth rate. The crude birth rate, which is defined as the number of births per thousand people. Although the crude birth rate is known as a "coarse" measure of fertility rates, the absence of county-level data by gender and age group for the early 19th century prevents us from building more "advanced" measures, such as the general fertility rate (relating the number of births to the number of females of childbearing age) or the child-woman ratio.[9] Besides, the crude birth rate is less subject to possible biases than other measures of past fertility (Sánchez-Barricarte 2001).[10]

In order to smooth for potential "temporary shocks," we average the crude birth rate over three periods (including our year of interest and the period before and after). Hence, the crude birth rate in 1826 is calculated as the average of the 1821, 1826 and 1831 crude birth rates. For 1851, we use the average of the 1846, 1851 and 1856 crude birth rates. And finally for the year 1876, we calculate the average of 1872, 1876 and 1881 rates. Therefore, we have data on births and population for the following years to account for the fertility of our three generations: 1821, 1826, 1831, 1841, 1846, 1851, 1872, 1876, and 1881. We also use the marital fertility rate in 1851 as an additional measure of fertility, to scale birth rates to obtain magnitudes in terms of number of children. Marital fertility is defined as the average number of children per marriage.

We measure education by the enrollment rate in primary schools, defined as the number of children enrolled in primary schools divided by the number of children of primary-school age (approximated by the population aged 5-15). The schools considered include public and private, secular and run by religious congregations (*congréganistes*). Data on primary education are available by gender from 1837. To account for the endowment in human capital of the first generation (G0), we first identify a relation between enrollment rates in 1837 and literacy rates in 1854-55, measured by the share of spouses able to sign their marriage contract. The goodness of fit of this relation is high (61 percent for boys, 70 percent for girls), making us confident that we can use it to build a proxy of enrollment rates around 1806 from literacy rates in 1816-20 using the same relation.[11]

To account for the educational decisions of G0, G1 and G2, we collect schooling data for boys

[9]The French Statistical Office started to publish data by age, gender, and marital status in 1851.

[10]More elaborate measures may present drawbacks when exploring the historical evolution of fertility. For instance, the Coale Ig index as used by Murphy (2015) and Franck and Galor (2015), does not incorporate the differences in definitive celibacy, age at marriage, and illegitimate births, which may exist across counties. With the Coale IG index, a late age at marriage in the population produces misleadingly high marital fertility rates.

[11]Literacy rates in 1816-20 are missing for five counties. We predict them from literacy rates in 1854-55.

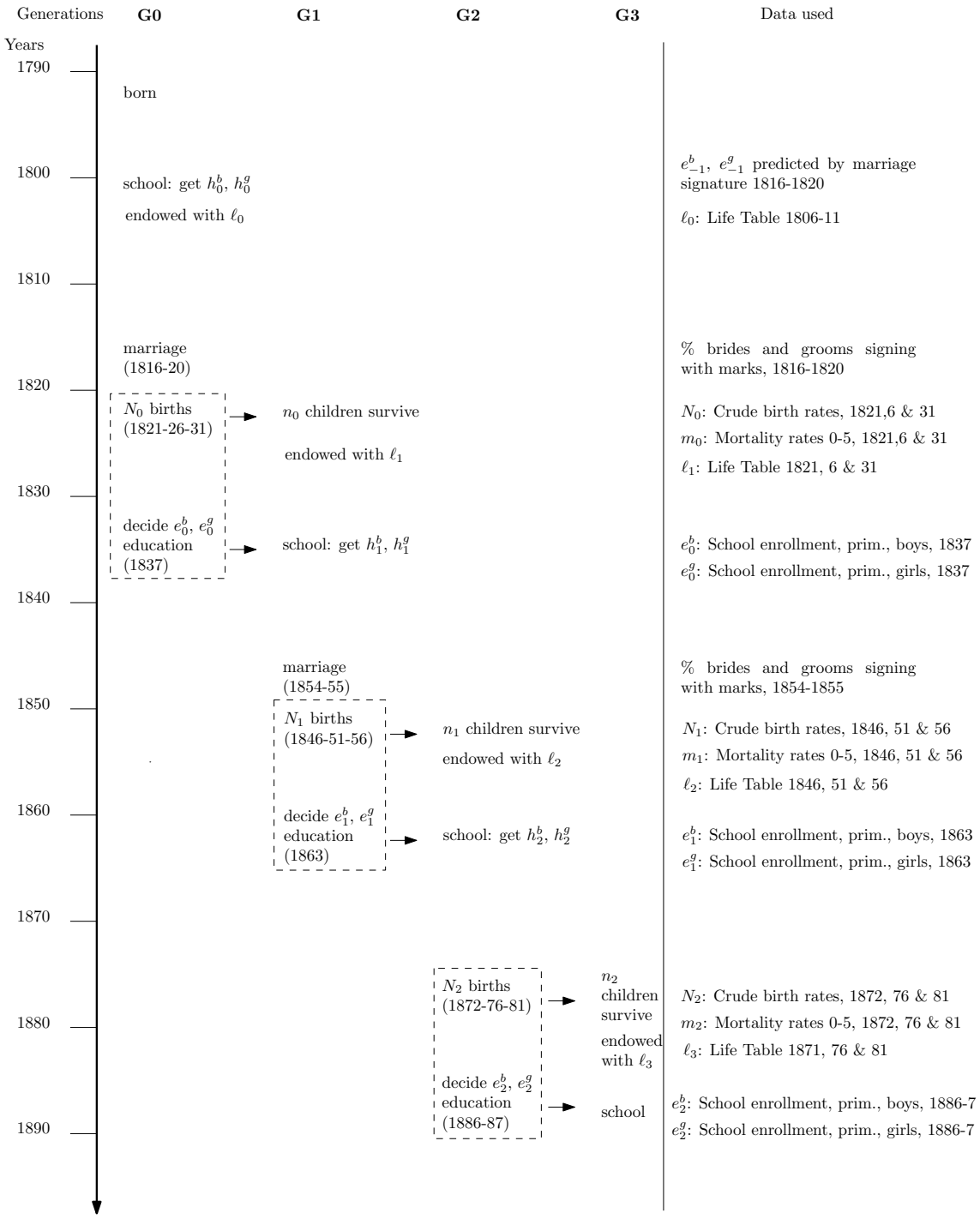


Figure 2: The generations considered

and girls from the *Statistique de l'enseignement primaire* for the years 1837, 1863 and 1886-87, respectively. The population of boys and girls aged 5-15 is constructed by using the 1861 and 1886 censuses. Population data in 1836 do not provide information by age class, which prevents us from calculating the share of boys and girls aged 5-15 in that year. We estimate the number of boys and girls aged 5-15 in 1836 by using the share of boys and girls of the same age class in 1851, thus accounting for the differences in the female-to-male ratio in 1851 versus 1836.

We integrate additional factors that could capture some of the variations in fertility. In order to account for infant mortality in 1826, 1851 and 1876, we use information from Bonneuil (1997) mortality tables. The mortality tables contain information (corrected from the original data of the *Statistique Générale de la France*) on the probability of dying at different ages by cohort between 1806 and 1906. Bonneuil's tables also allow us to calculate the expected lifetime labor supply l_G^j of our generations $G = 0, 1, 2, 3$ in the years 1806, 1826, 1851, and 1876 (unfortunately, without the gender dimension, we will assume $\ell_G^b = \ell_G^g \equiv \ell_G$). We define the lifetime labor supply as the average years that individuals could work between the ages of 15 and 65, taking into account their probability of dying within this period. Additionally, we use information on wages from the 1861-65 industrial survey (*Enquête industrielle*) and the 1852 agricultural survey (*Enquête agricole*) to calculate the gender wage gap in the middle of the 19th century. The gender wage gap is measured as the female-to-male average wage weighted by the size of the population working in industry and in agriculture.

2.3 Descriptive Statistics

Before looking at the county-level and the three generations described in Figure 2, we briefly comment on aggregate evolutions in the 19th century. Figure 3 shows the three main variables of interest. The broad picture is one of declining birth rates, with a plateau between 1845 and 1875. Primary school enrollment increased monotonically over the 19th century for both boys and girls. The gender gap was initially high but narrowed progressively, with equality (at the primary level) reached by the end of the century. The choices of our three generations are represented by sets delimited by light dotted lines.

Next, considering the variables we are going to use in the analysis, Table 1 reports the descriptive statistics. Figures 4 to 7 show the geographical distribution of crude birth rates in 1821, 1851 and 1876, and boys' and girls' enrollment rates in primary schools in 1816-20, 1837, 1863 and 1886-87. The heterogeneity across counties and over time is large.

Birth rates experienced a substantial decline between 1826 and 1876 from 31 permil to 26 permil. According to Chesnais (1992), a crude birth rate below 30 per one thousand individuals marks the entry into a regime of controlled fertility. Above this level, it is likely that only a very

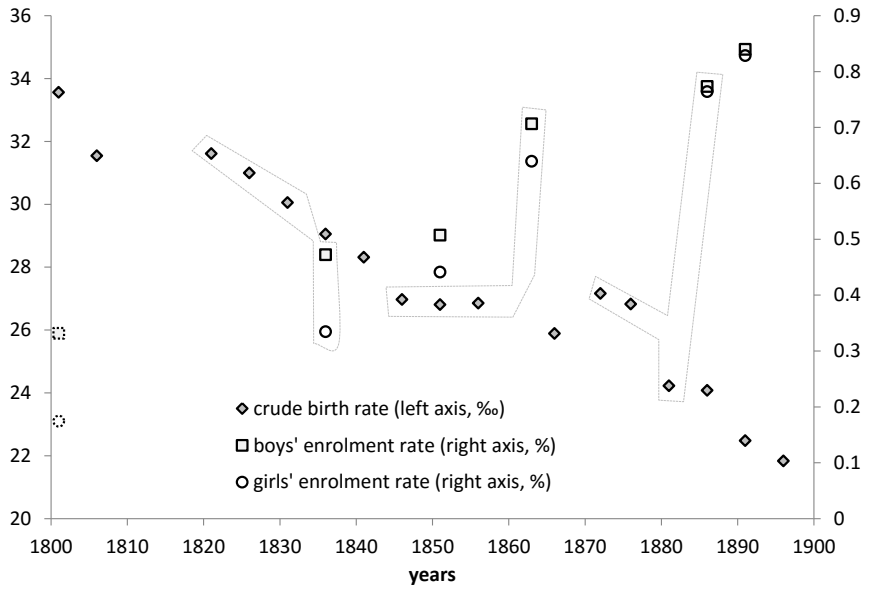


Figure 3: Aggregate Change

small share of the population uses fertility control.[12] Conversely, a crude birth rate below 20 births per one thousand individuals suggests that a large share of the population practices birth control. Counties experiencing a fertility transition should exhibit intermediate crude birth rates ranging between 20 and 30 per one thousand individuals. In 1821, 30 counties displayed a crude birth rate below 30 births per thousand. In 1851, more than three quarters of the counties were below this threshold and, amongst those, 26 were already below 25 births per thousand people (with Calvados, Eure, Orne and Lot-et-Garonne below 20). The fertility decline then continued at a slower pace. In 1876, 35 counties presented fertility rates below 25 permil (with eight of them below 20). Over the same period, the infant mortality rate decreased by 12.8 percent. The average probability of a child dying before age five declined from 30.5 percent in 1826 to 26.6 percent in 1876. The minimum and maximum infant mortality rates ranged between 16.1 percent and 54.2 percent in 1826, and 16.2 percent and 45.1 percent in 1876.

Similarly, the 19th century marked deep improvements in investment in formal primary education. In 1837, 46.2 percent of boys and 32.2 percent of girls aged 5-15 were enrolled in primary schools. In 1863, those rates reached 70 percent and 63.8 percent, respectively. Finally, in 1886-87, 77.3 percent of boys and 76.6 percent of girls were enrolled in primary schools. The massive and widespread investment in education allowed girls to catch up a large part of their delay in schooling. In fifty years, the share of boys and girls enrolled in primary schools increased substantially, by 67.3 percent for boys and 138.8 percent for girls. The mean enrollment rates

[12] A crude birth rate close to 40 is considered the level of fertility that would prevail in a population making no conscious effort to limit, regulate or control fertility (Henry 1961)

for boys and girls are obviously non-uniform across counties. Figures 3b and 3d show the geographical distribution of boys' and girls' enrollment rates. The maps reveal a clear division of the territory in two main zones. A demarcation line going from Saint-Malo to Geneva (referred to the *France des Lumières* by Charles Dupin) separates the North-East and the Center-South-West part of France. Female and male schooling was much higher in Northeastern France than in the rest of the country. The contrast is even more evident for girls' enrollment rates. In 1863, 16 counties located in the Northeastern area exhibited a schooling rate above 80 percent while 19 counties located in the Southwestern area displayed a rate below 50 percent. This clear distinction existed as early as 1837. The increase in enrollment rates between 1837 and 1886-87 occurred through the catch-up of the counties that where were the slowest to change: counties with the lowest enrollment rates in 1837 exhibit the highest growth rates. According to the diffusionist view, the rise in educational investments diffused across the French counties throughout the 19th century, from the relatively industrialized Northeastern areas of France to the dominantly agrarian Southwestern part of the country.

Table 1: Summary Statistics

		Mean	Std. Dev.	Min	Max
Crude birth rate, 1821, 26 & 31 (‰)	N_0, i	30.797	3.609	22.103	39.600
Crude birth rate, 1846, 51 & 56 (‰)	N_1, i	26.837	3.638	19.605	33.770
Crude birth rate, 1872, 76 & 81 (‰)	N_2, i	26.020	4.049	18.790	36.661
Marital fertility rate, 1851	–	3.182	0.561	2.070	4.770
Boys enrollment, 1806	$e^b_{-1,i}$	0.332	0.181	0.035	0.723
Girls enrollment, 1806	$e^g_{-1,i}$	0.174	0.148	0.016	0.568
Boys enrollment, 1837	$e^b_{0,i}$	0.462	0.198	0.145	0.951
Girls enrollment, 1837	$e^b_{0,i}$	0.322	0.202	0.060	0.886
Boys enrollment, 1863	$e^b_{1,i}$	0.700	0.178	0.376	1.096
Girls enrollment, 1863	$e^b_{1,i}$	0.638	0.184	0.294	1.015
Boys enrollment, 1886-87	$e^b_{2,i}$	0.773	0.090	0.498	1.082
Girls enrollment, 1886-87	$e^b_{2,i}$	0.766	0.090	0.524	0.978
Infant mortality, 1826	$m_{0,i}$	0.305	0.092	0.161	0.542
Infant mortality, 1851	$m_{1,i}$	0.306	0.090	0.162	0.543
Infant mortality, 1876	$m_{2,i}$	0.266	0.064	0.162	0.451
Gender wage gap, 1850s	δ_i	0.553	0.054	0.402	0.673
Lifetime labor supply 1806,11	ℓ_0	37.19	2.18	31.96	41.31
Lifetime labor supply 1821, 26 & 31	ℓ^1	37.11	2.31	31.68	41.16
Lifetime labor supply 1846, 51 & 56	ℓ_2	37.11	2.23	31.72	41.16
Lifetime labor supply 1871, 76 & 81	ℓ_2	38.10	1.71	33.57	41.17

Note: A detailed description of the variables is provided in Appendix B.

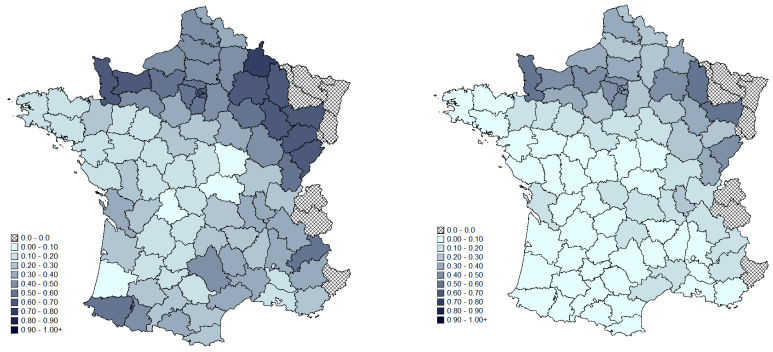


Figure 4: G0's endowment: Boys' enrollment (1806), Girls' enrollment (1806)

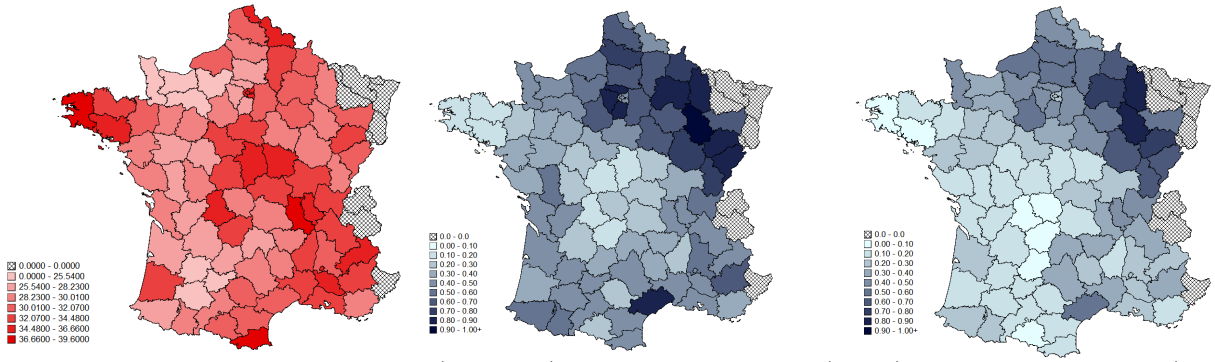


Figure 5: G0's choices: CBR (1821-31), Boys' enrollment (1837), Girls' enrollment (1837)

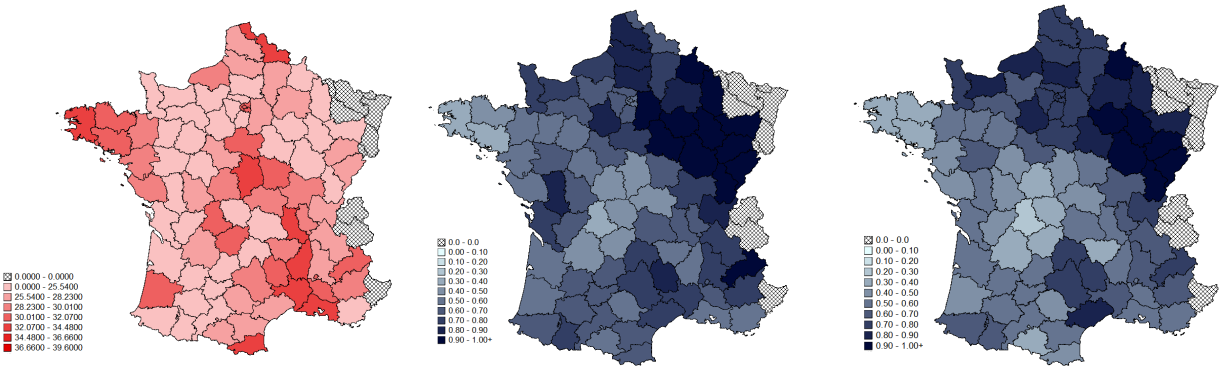


Figure 6: G1's choices: CBR (1846-56), Boys' enrollment (1863), Girls' enrollment (1863)

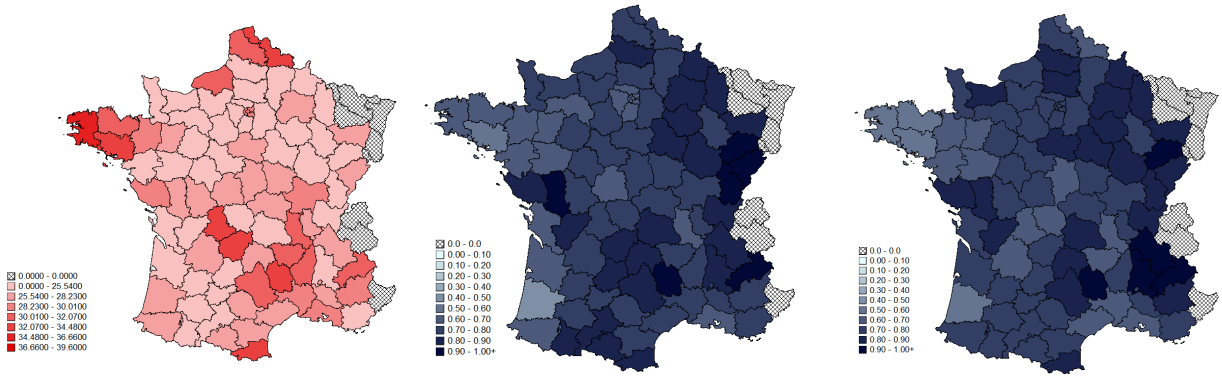


Figure 7: G2's choices: CBR (1872-81), Boys' enrollment (1886-7), Girls' enrollment (1886-7)

The lifetime labor supply variables (measuring the average years that an individual aged 15 was expected to work over his/her lifetime) was constant during the first half of the century and increased by only one year over the period 1851 to 1876. However, the variable differs greatly across counties, ranging from 31 to 41 years at the beginning of the period and decreasing in later periods.

3 Estimation and Results

The solution to the first-order conditions leads to a set of decision rules that are function of the parameters and exogenous variables. We can apply those rules for each generation $G = 0, 1, 2$ and for each county $i = 1 \dots 81$:

$$\begin{cases} n_{G,i} &= f^{\star}_{n}[\pi_G, \rho_{G,i}], \\ e^{b}_{G,i} &= f^{\star}_{eb}[\pi_G, \rho_{G,i}], \\ e^{g}_{G,i} &= f^{\star}_{eg}[\pi_G, \rho_{G,i}]. \end{cases} \tag{8}$$

The decision rules depend on the parameters of generation G, where $\pi_G = \{\phi, \psi, \gamma, \eta^b_G, \eta^g_G, b_G, \omega, \epsilon\}$, which are the same across counties, and on the exogenous variables relevant for generation G in county i, $\rho_{G,i} = \{\ell_{G,i}, \ell_{G+1,i}, h^b_{G,i}, h^g_{G,i}, m_{G,i}\}$.

The net fertility rate $n_{G,i}$ is obtained by multiplying the crude birth rate by one minus the infant mortality rate. The product is then multiplied by 110.86 (ratio of marital fertility to crude birth rate in 1851) to obtain magnitudes that can be interpreted as number of children. The enrollment rates $e^b_{G,i}$ and $e^g_{G,i}$ are taken directly from the data.

The set of parameters to identify is $\Pi = \pi_0 \cup \pi_1 \cup \pi_2$. The parameter ϕ is set *a priori* at its value from de la Croix and Doepke (2003), 0.075. The remaining parameters are estimated by minimizing the distance between predicted and observed data in percentage terms. The estimation problem is written:

$$\Pi = \arg\max_{\Pi} \sum_{i=1}^{81} \Bigg[\sum_{G=0}^{2} \Bigg[\left(1 - \frac{f^{\star}_{n}[\pi_G, \rho_{G,i}]}{\hat{n}_{G,i}}\right)^2 + \left(1 - \frac{f^{\star}_{eb}[\pi_G, \rho_{G,i}]}{\hat{e}^b_{G,i}}\right)^2 + \left(1 - \frac{f^{\star}_{eg}[\pi_G, \rho_{G,i}]}{\hat{e}^g_{G,i}}\right)^2 \Bigg] + \left(1 - \omega \frac{(\hat{e}^b_{0,i})^{\eta^b_0 + \epsilon \ell_{G+1}}}{(\hat{e}^g_{0,i})^{\eta^g_0 + \epsilon \ell_{G+1}}} \frac{1}{\hat{\delta}_i}\right)^2 \Bigg], \tag{9}$$

where hatted variables represent data. The last term is the distance between the measured gender wage gap in the 1850s and the wage gap implied by the model. It aims to find a value for parameter ω that reproduces the average gender gap $\underset{i}{E}[\delta_i]$.

The above estimation problem belongs to the family of the Simulated Method of Moments, a structural estimation technique to be applied when the theoretical moments cannot be computed explicitly and need to be simulated. The estimator Π is consistent for any weighting matrix. Estimating the distance between real and simulated data *in percentage* amounts to using a specific weighting matrix (a diagonal matrix with the inverse of the squared empirical moments on the diagonal).[13]

We first estimate a benchmark model, imposing the elasticities η to be constant over time. The estimation results are presented in Table 2.[14] The parameter ψ, which measures the time cost of children dying before age 5 is estimated very close to zero and set to zero for the final estimation. $\psi = 0$ implies that households fully replace the children who die early, and, as a consequence, birth rates are higher where infant mortality is greater. The elasticity of human capital to education is larger for girls than for boys. The cost of education p_G is the highest for the initial generation, when fewer schools were available. The non-labor income is negligible for generations 0 and 1, while it is positive for generation 2. The additional effect of longevity on the return to schooling, ϵ, is positive but not significantly different from 0.

Table 2: Parameter Estimates

Parameter	Estimation	S.E.
γ	0.407	0.029
η^b	0.338	0.091
η^g	0.482	0.095
ϵ	0.111	0.102
p_0	0.182	0.013
p_1	0.106	0.009
p_2	0.128	0.012
ω	0.739	0.012
b_0	0.012	0.012
b_1	0.000	0.001
b_2	0.098	0.021

We can measure the goodness of fit by computing coefficients of determination for fertility and enrollments. Table 3 displays the results: 37.9 percent for fertility, 70.8 percent for boys'

[13]This is not the optimal weighting matrix – i.e., the inverse of the variance-covariance matrix of the empirical moments (Duffie and Singleton 1993). When using the optimal weighting, the moments with lower standard errors have higher weight, which supposedly improves the efficiency of the estimators. In practice, though, the gain does not appear to be worth the complication.

[14]Standard errors are computed after the following the bootstrapping method: we draw 50 random new samples of counties with replacement from the original data. Each new bootstrap sample is of equal size as the original one, but the frequency of each observation changes. For each of these new datasets, we estimate the corresponding parameters. We then compute the standard errors of these 50 estimators.

Table 3: Goodness of Fit

	All sample	$G0$	$G1$	$G2$
Fertility	37.9	32.0	29.4	48.0
Boys' enrollment	70.8	55.1	71.3	19.9
Girls' enrollment	82.9	67.1	85.2	37.6

enrollment rates, and 82.9 percent for girls' enrollment rates. The corresponding graphs are provided in Figure 8, with shades of gray representing the different generations. The model matches the time trend in all series, as well as the cross-county correlation. The fit is the worst for fertility. The model has large prediction errors for some counties. For example, in Haute-Vienne, education of G0 is so low that predicted fertility is high – 1.4 children above the observed fertility.

Looking at the coefficient of determination per generation, the fit of enrollment rates deteriorates in the last period (R^2 for G2 enrollments of 19.9 percent and 37.6 percent), probably because education became compulsory for them, and there remains little for the model to explain.

Table 4: Goodness of Fit (R^2) under Different Counterfactuals

		Removing heterogeneity in...			
Equation	Benchmark	Infant mortality	Future longevity	Mothers' education	Fathers' education
	(a)	(b)	(c)	(d)	(e)
Fertility	37.9	14.6	37.6	21.1	35.9
Boys' enrollment	70.8	70.7	70.7	58.7	65.1
Girls' enrollment	82.9	82.9	83.0	65.7	80.5

To better understand which mechanisms of the model are successful, we ran several counterfactual experiments by removing each source of heterogeneity among counties separately. Table 4 presents the results. Column (a) presents the coefficients of determination in the benchmark estimation. The coefficients of determination in column (b) are obtained by setting $m_{G,i} = \underset{G,i}{E}\left[m_{G,i}\right]\ \forall i, G$ – i.e., we remove all heterogeneity across space and time in child mortality. To generate the coefficients of determination in columns (c), (d) and (e), we do the same for future longevity $\ell_{G+1,i}$, $h^g_{G,i}$, and $h^b_{G,i}$, respectively. Looking at how the coefficients of determination are affected by removing each one of the explanatory variables, we conclude that two variables are important to explain fertility: child mortality, and mothers' education. The latter is also key to explaining the school enrollments of both boys and girls, while fathers'

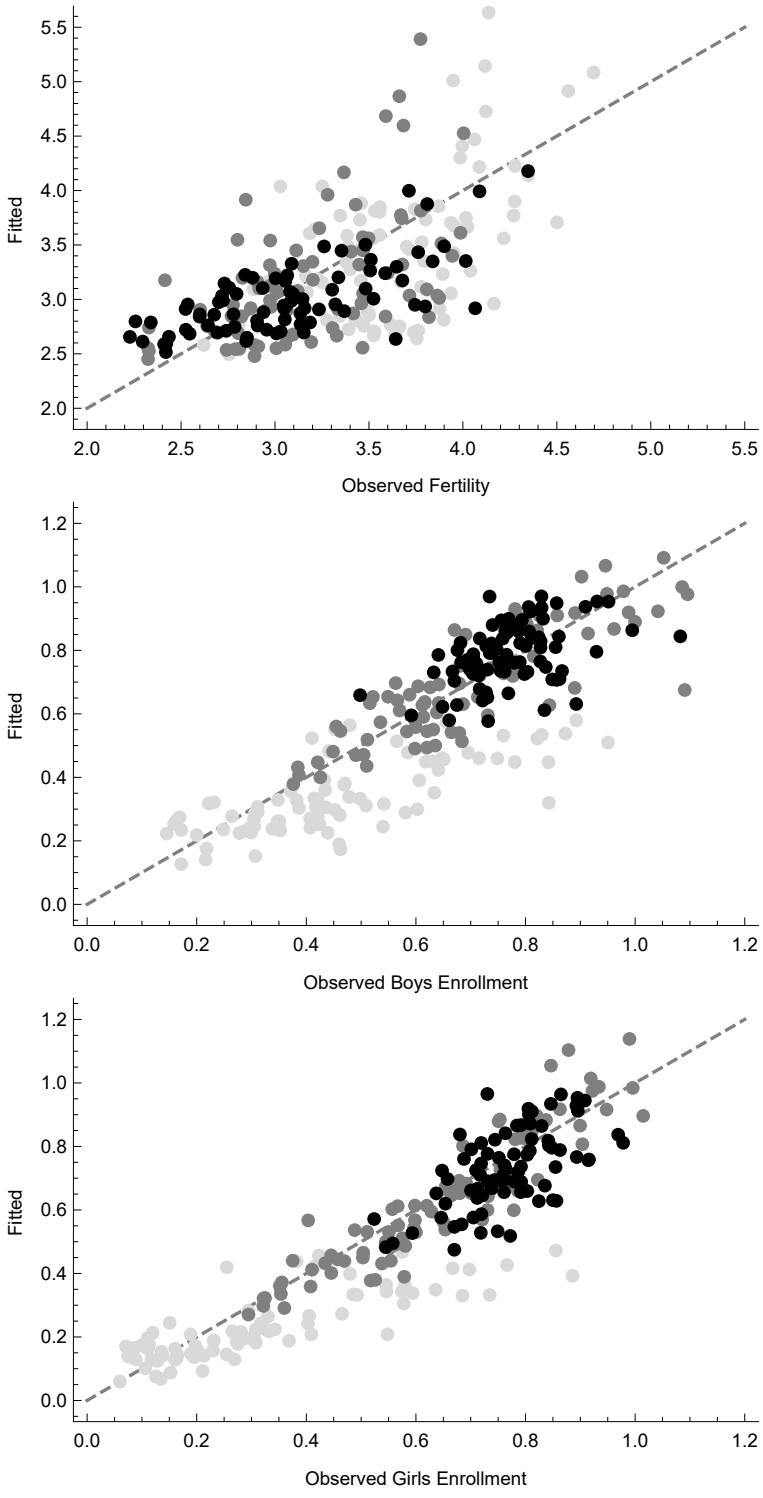


Figure 8: Goodness of Fit. G0: light gray. G1: gray. G2: black

education also contributes to explaining them. Future longevity – i.e. lifetime labor endowment of children – does not seem to play an important role.

In order to get a better idea of the size of the effects implied by the model, Table 5 shows how quickly fertility drops when one increases the mothers' education level. Fertility is computed by averaging over counties. On the whole, a rise in enrollment rates by 0.5 (which means about three years of education) implies a drop in fertility by one third of a child. The effect is stronger at lower education levels, and flattens out at higher levels. A similar convex relation between fertility and education is also found for the US in the 19th century (Jones and Tertilt 2008). For developing countries, however, results diverge. Jejeebhoy (1995) finds a positive or no relationship for seven countries, a negative relationship for 26 countries, and an inverse U-shaped (or 7-shaped) relationship for 26 other countries. More recently, Vogl (2016) finds evidence of a relationship ranging over time from positive to negative.

Our results are in line with the women's empowerment story of the demographic transition, although it does not rely here on endogenous bargaining power, but, rather, on the optimal allocation of time within the household, leading women to spend more time in the labor market. This is consistent with the rise in women's labor-market participation after 1835, documented by Marchand and Thélot (1997).

Table 5: Effect of Mothers' Education Level on Fertility

e^f	n_0	n_1	n_2
0.1	2.41	2.47	
0.2	2.20	2.22	
0.3	2.11	2.12	2.38
0.4	2.08	2.07	2.29
0.5	2.05	2.03	2.23
0.6	2.04	2.02	2.20
0.7		2.00	2.17
0.8		2.00	2.15
0.9		1.99	2.13
1.			2.12

Finally, we estimate a richer model by relaxing the constraints that the η's are constant through time. There is indeed some evidence (see the discussion in Galor and Weil (2000)) that returns to education increased during the industrialization process. Estimating such a model, however, does not provide any major gain in the fit. The coefficients of determination are equal to 31.6 percent for fertility (worse than before), 72.4 percent for boys' enrollment rates, and 84.1 percent for girls' enrollment rates. The estimated η_G^m are equal to 30.2, 19.2, and 14.2 for the three generations, showing a decreasing pattern (this does not fit with Galor and Weil (2000),

but are in line with the drop in the skill premium observed by Clark (2005) for building workers' wages in England).

4 Explaining the Unexplained

In this section, we correlate the part of fertility and school enrollment that was not explained by the rational-choice model with other determinants mentioned as important in the literature. This analysis can be used for two purposes: first, to assess the importance of these factors in explaining family decisions; and second, to indicate in which direction the economic theory should be developed. The "unexplained" is represented by the nine residuals:

$$\begin{aligned}\varepsilon_G^n &= \hat{n}_{G,i} - f_n^\star[\hat{\pi}_G, \rho_{G,i}] \\ \varepsilon_G^{e^b} &= \hat{e}_{G,i}^b - f_{eb}^\star[\hat{\pi}_G, \rho_{G,i}] \\ \varepsilon_G^{e^g} &= \hat{e}_{G,i}^g - f_{eg}^\star[\hat{\pi}_G, \rho_{G,i}]\end{aligned}$$

for $G = 0, 1, 2$, and where $\hat{\pi}_G$ are the estimated parameters. Using simple OLS regressions, we will correlate the ε's with the explanatory variables described below.

4.1 The Role of Family Structure

Davis and Blake (1956) emphasize the role of family and kinship organization (involving rules of residence and inheritance) in affecting fertility patterns. There exists a geographical diversity of family systems and traditional rules of inheritance across French counties. Todd (1985) identifies different family types based on the relationships between parents and children, and between siblings. Using Todd's classification, Perrin (2013) and Diebolt, Menard, and Perrin (2016) show that past family rules are important for understanding county-level demographic and educational trends.

In the stem-family system, the spouse of the firstborn male child moves into the house of her husband's parents when getting married; one child only (usually the eldest) inherits the assets and property of the family. Other children have to leave the family home when getting married or may stay if they remain single. This type of family prevailed in the Southern half of France – Aquitaine, Midi-Pyrénées, Massif Central, Rhône-Alpes, and Alsace. Because of this particular inheritance system, households may not have been encouraged to have fewer children. In more egalitarian areas, such as Seine-Inférieure, characterized by the nuclear family, the principle of equal division was applied to children on movable and immovable properties. The distribution of inheritance was equal among male children. A gender distinction was made; for instance, land was always given to boys, while girls inherited furniture, or wood, such as in Jura. According

to Le Play (1884), the Egalitarian Napoleonic Code (Code civil) that mandated the equality of children in inheritance, would have played negatively on fertility. The compulsory division of heritages would have induced a voluntary birth restriction in areas of large landownership in order to obtain a unique heir and avoid an excessive division of land. Finally, in the extended family system, the different generations lived together and exploited land jointly. If the father was alive, the boys would bring their spouses into the family. Only upon the death of the patriarch was the land divided among his sons equally. This system seems to have been more favorable to procreation, compared to the nuclear family system, as having more children provided the family with more workers (child labor argument) and benefited the old more (old age support argument).

To measure the importance of family structure in the aspects of fertility and education that remain unexplained by the economic model in Section 1, we construct three dummy variables indicating the type of structure for each county (as classified in Le Bras and Todd (2013)): the stem family (includes stem and imperfect stem); the extended family (includes extended and intermediate); and the nuclear family (includes nuclear with temporary co-residence, imperfect nuclear, hyper nuclear, nuclear egalitarian, and nuclear patrilocal egalitarian). These dummy variables will be used, together with religious and cultural variables, to "explain" the residuals.

4.2 The role of Religion

Two aspects of religion influenced fertility and education behavior: the type of religion – here, essentially Catholicism vs Protestantism – and the intensity of practice. Along Weberian lines, Becker and Woessmann (2009) and Boppart et al. (2013) show that Protestantism led to better education than Catholicism in 19th-century Prussian counties and in Swiss districts. From a cost side, Berman, Iannaccone, and Ragusa (2012) show that fertility across European countries was related to the population density of nuns, who were likely to provide services to families, alleviating child-rearing costs.

The type of religion can be conveniently measured by the percentage of Catholics and Protestants in each county. To capture geographical disparities of religious practices across France, we use the share of priests who agreed to adhere to the Civil Constitution of Clergy in 1791 (share of "prêtres jureurs"). It provides a fairly good idea of regional specificities in terms of religious practices. In more-religious areas, we can expect the faithful of the parish to have pressured their priest not to pledge allegiance to the Constitution.

4.3 The role of Dialects

The diffusion of norms and their effect on fertility or education, are tightly related to language. The measures allowing the spread of revolutionary ideas, such as the diffusion of the French language through education (schools), were implemented after the French Revolution. For the Jacobins, French had to be the only language spoken across the whole country as the "idiom of freedom" (Abbé Grégoire, Speech to the National Convention, June 4, 1794). Talleyrand, in his report on the organization of schools (1791), deplored the survival of dialects and expounded on to the necessity of common and free primary schools, where French would be taught. According to the traditional classification, Oïl (and Franco-provençal) dialects were close to the French language (mutually intelligible). On the contrary, Oc languages were closer to the Catalan language. The use of the French language in public schools could explain the faster spread of education among French counties speaking Oïl languages (Perrin 2013).

The spread of the fertility revolution might also have been affected by cultural distance, of which language is an important aspect. As explained in the introduction, Spolaore and Wacziarg (2014) find that the fertility decline in European regions over 1830-1970 is closely associated with the cultural distance from France which is viewed as the frontier innovator in terms of fertility control. In an earlier paper, Coale and Watkins (1986) argue that linguistic boundaries could have acted as as a barrier for the fertility decline, while, on the contrary, a common language would have contributed to the diffusion of innovation/norms in favor of (contributing to) fertility control. We can incorporate this aspect into our analysis by including language dummies: Oïl, Oc, and others.

Parisians were, apparently, forerunners of the fertility decline, and Paris might be considered a place of origin of the low fertility norm. Combining data from several sources, Brée (2016) reports fertility rates in Paris slightly below eight children per woman in 1700, around six in 1750, four in 1800, and three in 1850. To model the idea that the norm might have diffused slowly over time from Paris, we introduce in the regression the distance from Paris, both by road and "as the crow flies."

4.4 The role of Elites

A recent paper by Squicciarini and Voigtländer (2015) argues that people belonging to the upper part of the knowledge distribution played an important role in the industrial revolution. In particular, they use the density of subscribers to the famous *Encyclopédie* in mid-18th century France to predict development (industrial activity, soldiers' height - hence nutrition, disposable income) at the county level during the 19th century. The density of subscribers to the *Encyclopédie* is, therefore, a good candidate to explain our residuals.

We include in the regression the total number of subscriptions in each county divided by the size of the population in cities listed in Bairoch, Batou, and Chèvre (1988). 7,081 subscriptions were sold in France; out of these, Squicciarini and Voigtländer (2015) can match 6,944 to towns listed in Bairoch, Batou, and Chèvre (1988). The remaining 137 occurred in 12 cities not covered in Bairoch and, thus, do not show up in their dataset. When a county does not have a city listed in Bairoch, Batou, and Chèvre (1988), Squicciarini and Voigtländer (2015) consider that the number of subscriptions is not available (N.A.), while we set it to zero instead, as upper- tail knowledge was probably very low in such rural counties.

As an additional measure of upper-ail knowledge, we also include in the regression the number of universities, libraries and museums per million inhabitants (number of high education establishments), as well as their surface in hundreds of square meters per thousand inhabitants (surface of high education establishments).

Table 6: "Explaining" the residuals

	Dependent variable:								
	ε_0^n	$\varepsilon_0^{e^b}$	$\varepsilon_0^{e^g}$	ε_1^n	$\varepsilon_1^{e^b}$	$\varepsilon_1^{e^g}$	ε_2^n	$\varepsilon_2^{e^b}$	$\varepsilon_2^{e^g}$
Family types (vs nuclear):									
Extended family	0.542***	0.089*	0.114***	0.427***	−0.059*	−0.022	−0.166	−0.123***	−0.121***
	(0.137)	(0.045)	(0.039)	(0.160)	(0.032)	(0.029)	(0.122)	(0.027)	(0.026)
Stem family	0.181	0.022	0.032	0.156	−0.086**	−0.046	−0.024	−0.043	−0.046*
	(0.145)	(0.048)	(0.041)	(0.170)	(0.033)	(0.031)	(0.129)	(0.028)	(0.027)
Religion:									
Share Catholics	0.176*	0.067**	0.061**	0.017	0.009	−0.037*	0.101	−0.016	−0.043**
	(0.098)	(0.032)	(0.028)	(0.115)	(0.023)	(0.021)	(0.087)	(0.019)	(0.018)
Share Protestants	0.171*	0.067**	0.063**	−0.014	0.005	−0.040*	0.088	−0.017	−0.044**
	(0.101)	(0.033)	(0.029)	(0.118)	(0.023)	(0.021)	(0.090)	(0.020)	(0.019)
Secularization	−0.011	−0.020	0.002	0.040	0.002	0.003	0.100**	0.016*	−0.004
	(0.046)	(0.015)	(0.013)	(0.053)	(0.011)	(0.010)	(0.041)	(0.009)	(0.008)
Geographical & Cultural distance :									
Distance to Paris	0.004	0.001	0.002**	0.004	−0.0001	−0.0002	0.002	−0.001**	−0.001**
	(0.003)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Distance by road	−0.003	−0.001	−0.001*	−0.003	−0.00004	0.0002	−0.002	0.001*	0.001**
	(0.002)	(0.001)	(0.001)	(0.003)	(0.001)	(0.0005)	(0.002)	(0.0004)	(0.0004)
Oïl languages	−0.358***	−0.082*	−0.071*	−0.198	−0.041	−0.005	0.123	0.007	0.036
	(0.133)	(0.043)	(0.038)	(0.155)	(0.031)	(0.028)	(0.118)	(0.026)	(0.025)
Oc languages	−0.124	0.002	−0.036	−0.023	0.054	0.004	0.156	−0.021	0.005
	(0.156)	(0.051)	(0.044)	(0.182)	(0.036)	(0.033)	(0.138)	(0.030)	(0.029)
Upper tail knowledge :									
Subscr. *Encyclopédie*	−0.014	−0.009	−0.011**	0.006	−0.0005	0.001	0.011	0.003	0.005*
	(0.016)	(0.005)	(0.005)	(0.019)	(0.004)	(0.003)	(0.014)	(0.003)	(0.003)
Nb. infrastructure	0.013*	−0.002	−0.003	0.007	−0.003**	−0.001	0.001	0.0003	0.0001
	(0.007)	(0.002)	(0.002)	(0.008)	(0.002)	(0.001)	(0.006)	(0.001)	(0.001)
Surf. infrastructure	−0.003**	0.0003	0.0003	−0.004**	0.0004	−0.00004	−0.001	0.0002	0.0001
	(0.001)	(0.0005)	(0.0004)	(0.002)	(0.0003)	(0.0003)	(0.001)	(0.0003)	(0.0003)
Constant	−18.018*	−6.589**	−6.162**	−1.862	−0.737	3.685*	−10.595	1.625	4.353**
	(9.802)	(3.214)	(2.773)	(11.438)	(2.256)	(2.072)	(8.708)	(1.916)	(1.822)
Observations	81	81	81	81	81	81	81	81	81
R^2	0.592	0.268	0.393	0.325	0.300	0.165	0.164	0.502	0.549
Adjusted R^2	0.520	0.139	0.286	0.206	0.176	0.018	0.016	0.415	0.469

Note: The reference category is the nuclear family *p<0.1; **p<0.05; ***p<0.01

4.5 Results

We estimate nine equations i9n which the dependent variables are the residuals of the structural estimation, and the explanatory variables are those described in the previous subsections. Table 6 gives the results. The size of the coefficient can be interpreted as the magnitude of the fertility residuals and the enrollment residuals.

Column 1 shows a strong positive and significant association of the extended family type with fertility of the first generation (G0). This effect is on the order of half a child. It persists to some extent in the second generation (G1). The same family type is also correlated negatively with the education of both boys and girls, but only in the third period.

As far as religion is concerned, the percentage of Catholic and Protestant is positively associated with children, in terms of both quantity and quality, during the first period. During the last period, on the contrary, the effect on education is reversed. But those effects are small.

Among the various geographical and cultural variables, one effect appears very clearly. The first generation in counties speaking the Oïl language has a lower fertility rate. The effect is sizeable: minus a third of a child. This result gives strong support to the idea that language borders can significantly delay the diffusion of fertility norms.

Finally, distance from Paris and variables related to the upper-tail knowledge do not seem to be correlated with our residuals.

One can see that family structure and language matter when looking at residuals ε_0^n and ε_2^n. Figure 9 highlights counties for which the model over- (horizontal lines) and under- (vertical lines) estimates the fertility behavior of generation 0 and generation 2 by more than half a child. For the first generation, the model overestimates the fertility of counties located mainly in the Oïl-speaking part of France, but for the counties in which the extended family type prevails. Over time, the number of counties for which fertility is strongly over/underestimated declines, as shown in the right panel. Generation 2's fertility in Oïl-speaking counties becomes better explained by the model, except in the very north (counties that where conquered by France in the middle of the 17th century).

On the whole, it seems that extending the model to account for different family structures seems promising. Usually, models in family economics focus on the decision process within the nuclear family.[15] Modeling cultural barriers to the adoption of fertility norms seems promising,

[15]No attempt has been made to formalize the wealth of family types of the past and their impact either on growth or on the fertility and education decisions. Two recent exceptions are proposed by Salcedo, Schoellman, and Tertilt (2012) and Pensieroso and Sommacal (2014), who relate the size of the family (either as a collection of roommates sharing a public good in Salcedo, Schoellman, and Tertilt (2012) or as co-resident fathers and sons in Pensieroso and Sommacal (2014)) to economic conditions. A relation between family types (nuclear vs. extended) and growth is proposed by de la Croix, Doepke, and Mokyr (2016); according to them, apprenticeship systems based on the extended family are more complementary to growth than systems based on the nuclear family, but the latter have more incentives to adopt better systems, such as those regulated by guilds or markets.

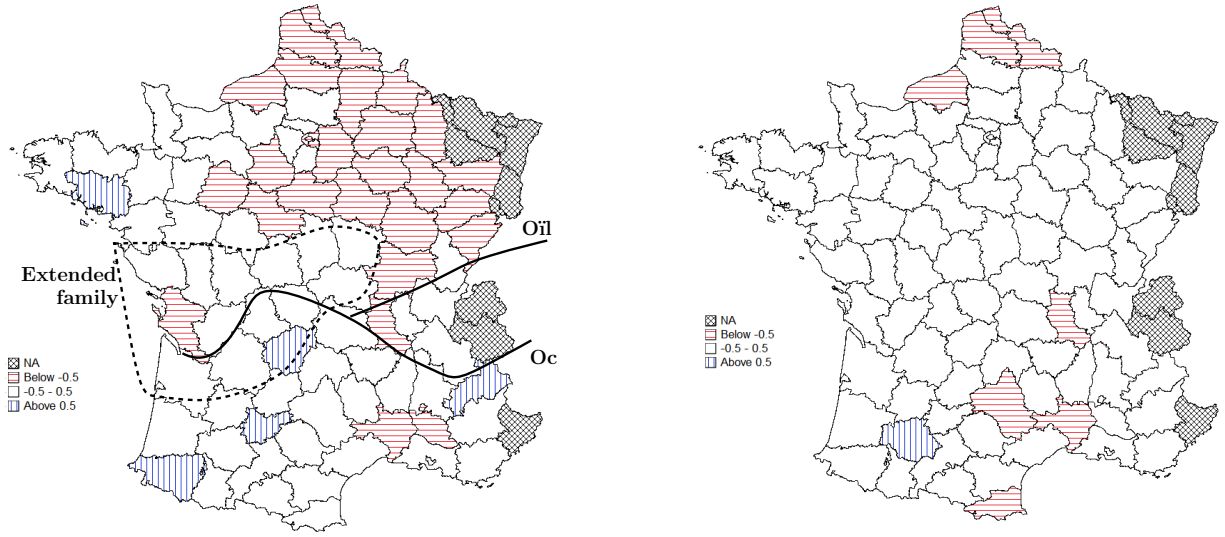


Figure 9: Residuals ε_0^n and ε_2^n

too, and complementary to explanations based on socio-economic characteristics.

4.6 Omitted Variable Bias

One might finally wonder whether neglecting the two cultural aspects highlighted above leads to a bias in the estimation of the structural parameters of the rational-choice model. Partisans of the diffusionist view of the fertility decline may claim that neglecting cultural factors not only leads to a lower explanatory power but also to biased conclusions. In the econometric literature on the "omitted variable bias" (Clarke 2005), the bias appears when the estimation compensates for the missing variable by over- or underestimating the effect of one of the other included independent variables. For this to occur (in a linear regression set-up), the missing variable needs to have a strong effect on the dependent variable and to be correlated with at least one of the included variables.

To address this question in our non-linear context, consider the problem

$$\begin{aligned}\Pi = \underset{\Pi,Z}{\arg\max} \sum_{i=1}^{81} \Bigg[\sum_{G=0}^{2} \Bigg[\left(1 - \frac{f_n^\star[\pi_G, \rho_{G,i}] + \zeta_{n,G}\mathrm{Oil}_i + \xi_{n,G}\mathrm{Ext}_i}{\hat{n}_{G,i}}\right)^2 \\ + \left(1 - \frac{f_{eb}^\star[\pi_G, \rho_{G,i}] + \zeta_{eb,G}\mathrm{Oil}_i + \xi_{eb,G}\mathrm{Ext}_i}{\hat{e}_{G,i}^b}\right)^2 \\ + \left(1 - \frac{f_{eg}^\star[\pi_G, \rho_{G,i}] + \zeta_{eg,G}\mathrm{Oil}_i + \xi_{eg,G}\mathrm{Ext}_i}{\hat{e}_{G,i}^g}\right)^2 \Bigg] + \left(1 - \omega \frac{(\hat{e}_{0,i}^b)^{\eta_0^b + \epsilon\ell_{G+1}}}{(\hat{e}_{0,i}^g)^{\eta_0^g + \epsilon\ell_{G+1}}} \frac{1}{\hat{\delta}_i}\right)^2 \Bigg], \quad (10)\end{aligned}$$

instead of (9). In problem (10), we have "augmented" the structural determinants of fertility and education $f^\star(\cdot)$ by linear terms including the two retained cultural variables, Oil_i and Ext_i

(for extended family), which are county specific. For each generation G there is a new set of parameters, $z_G = \{\zeta_{n,G}, \zeta_{eb,G}, \zeta_{eg,G}, \xi_{n,G}, \xi_{eb,G}, \xi_{eg,G}\}$ with the coefficients of these linear terms. In total, there are 18 new parameters to estimate, grouped in the set $Z = z_0 \bigcup z_1 \bigcup z_2$. The test consists in solving problem (10), and comparing the estimated Π with the Π which resulted from the simpler problem (9). If one or more of the new estimates falls outside the confidence interval of the parameters estimated with (9), one can suspect an omitted variable bias. A formal test would require to compute the standard errors of the parameters estimated with (10), but the dimension of problem (10) (29 parameters instead of 11) makes its estimation very long and prevents us from doing so.

Table 7: Parameter Estimates

Parameter	95% conf. interval from (9)	estimate from (10)
γ	$[0.349, 0.465]$	0.356
η^b	$[0.160, 0.516]$	0.212
η^g	$[0.296, 0.669]$	0.342
ϵ	$[-0.088, 0.311]$	0.237
p_0	$[0.157, 0.208]$	0.166
p_1	$[0.089, 0.124]$	0.095
p_2	$[0.104, 0.151]$	0.110
ω	$[0.716, 0.762]$	0.726
b_0	$[-0.012, 0.036]$	0.036
b_1	$[-0.001, 0.001]$	0.000
b_2	$[0.056, 0.140]$	0.127

The results are presented in Table 7. All the parameters estimated from (10) fall within the 95% confidence interval of the more parcimonious model. Hence, there is no strong case for an omitted variable bias.

To summarize, taking into account cultural variables would improve the fit of the model, but omitting them does not lead to bias the estimates.

5 Conclusion

Even in the case of France, which is considered the pioneer in low fertility norms, socioeconomic conditions affect fertility. Indeed, a rational-choice model featuring optimal parental behavior in terms of fertility, education, and child rearing has some power in explaining the variation of fertility and education across time and space. Hence, incentives matter. We have stressed that child mortality and mothers' education are important factors shaping incentives to have children.

However, the part of the reality that the economic model does not explain is not orthogonal to several observable characteristics. Among the various factors we have used in the analysis, it appears that family structure and linguistic borders are particularly important. This argues in favor of extending family economics models to consider the effect of the different family structures (extended, stem, nuclear) on fertility and education choices. Moreover, a promising avenue for future research would be to weight, in a unified framework, the relative importance of cultural norms vs. economic incentives in explaining fertility transitions.

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A First-order Conditions of the Household Maximization Problem

The maximization problem to be solved is:

$$\{a_t^g, a_t^b, e_t^g, e_t^b, n_t\} = \arg\max \ln(c_t) + \gamma \ln\left(\tfrac{n_t}{2}((e_t^b)^{\eta_t^b + \varepsilon \ell_{t+1}^b} + (e_g^j)^{\eta_t^g + \varepsilon \ell_{t+1}^g})\right)$$

subject to

$$\begin{aligned}\left(\phi + \psi \frac{m_t}{1-m_t}\right) n_t &= \sqrt{a_t^b\, a_t^g} \\ c_t &= h_t^b(1-a_t^b) + \omega h_t^g (1-a_t^g) + b_t - p_t(e_t^b + e_t^g)\tfrac{n_t}{2}.\end{aligned}$$

It can be decomposed into two steps. First, for some given number of children, parents allocate their time efficiently – i.e., they minimize the cost of child-rearing:

$$\min_{a_t^g, a_t^b} (\omega h_t^g a_t^g + h_t^b a_t^b)\, n_t \quad \text{subject to} \quad (4)$$

Focusing, from now on, on the interior solution where both a_t^f and a_t^m are lower than one, this cost minimization problem leads to the following optimal rules :

$$a_t^g = \sqrt{\frac{h_t^b}{\omega h_t^g}}\, \left(\phi + \psi \frac{m_t}{1-m_t}\right) n_t, \qquad a_t^b = \sqrt{\frac{\omega h_t^g}{h_t^b}}\, \left(\phi + \psi \frac{m_t}{1-m_t}\right) n_t. \qquad (11)$$

We see that the share of child rearing supported by the mother is inversely related to her human capital, weighted by the gender wage gap:

$$\frac{a_t^g}{a_t^g + a_t^b} = \frac{h_t^b}{h_t^b + \omega h_t^g}.$$

Given the optimal a_t^g and a_t^b from (11), we can rewrite the household labor income as:

$$y_t = \omega h_t^g (1-a_t^g) + h_t^b (1-a_t^b) = h_t^b + \omega h_t^g - 2\left(\phi + \psi \frac{m_t}{1-m_t}\right) \sqrt{\omega h_t^g h_t^b}\, n_t.$$

The second step of the maximization problem allows us to characterize the quality-quantity tradeoff faced by individuals. The problem can be rewritten as:

$$\{e_t^g, e_t^b, n_t\} = \arg\max \ln(c_t) + \gamma \ln\left(\tfrac{n_t}{2}((e_t^b)^{\eta_t^b + \epsilon \ell_{t+1}} + (e_g^j)^{\eta_t^g + \epsilon \ell_{t+1}})\right)$$

subject to

$$c_t = \underbrace{h_t^b + \omega h_t^g - 2\left(\phi + \psi\frac{m_t}{1-m_t}\right)\sqrt{\omega h_t^g h_t^b}\, n_t}_{y_t} + b_t - p_t(e_t^b + e_t^g)\tfrac{n_t}{2}.$$

The first-order necessary condition describing the optimal choice of n_t is:

$$\underbrace{\frac{\gamma}{n_t}}_{[A]} = \underbrace{\frac{1}{c_t}\left(\frac{e_t^b + e_t^g}{2}\right)p_t}_{[B]} + \underbrace{\frac{1}{c_t}2\sqrt{h_t^b h_t^g}\left(\phi + \frac{m_t}{1-m_t}\psi\right)}_{[C]} \tag{12}$$

It equalizes the marginal utility gain of children $[A]$ with the marginal cost, which is composed of education cost $[B]$ and income loss because of time spent on child rearing $[C]$. The presence of the term $\sqrt{h_t^b h_t^g}$ in $[C]$ reflects that the income loss is larger for highly educated parents.

The first-order necessary condition describing the optimal choice of e_t^s for $s = g, b$ is:

$$\frac{p_t}{c_t}\frac{n_t}{2} = \frac{\gamma(\eta_t^b + \epsilon\ell_{t+1})(e_t^b)^{\eta_t^b + \epsilon\ell_{t+1} - 1}}{h_{t+1}^b + \omega h_{t+1}^g} = \frac{\gamma(\eta_t^g + \epsilon\ell_{t+1})(e_t^g)^{\eta_t^g + \epsilon\ell_{t+1} - 1}\omega}{h_{t+1}^b + \omega h_{t+1}^g} \tag{13}$$

The left-hand side is the marginal cost of education. The right-hand side is the return of education for boys and girls, respectively. All terms are expressed in terms of marginal utility – hence the terms $\frac{1}{c_t}$ (marginal utility of consumption) and $\frac{\gamma}{h_{t+1}^b + \omega h_{t+1}^g}$ (marginal utility of children). The education returns are, thus, equalized across boys and girls, and equalized to the cost of education in terms of forgone consumption.

A higher $\epsilon\ell_{t+1}$ implies a higher return to education, $\eta_t^b + \epsilon\ell_{t+1}$ for boys, and $\eta_t^g + \epsilon\ell_{t+1}$ for girls. One can show that this implies a higher share of income spent on educating children, and a lower share spent on the number of children. Hence, the model predicts that, *ceteris paribus*, in counties with higher expected adult longevity, enrollments are higher and fertility lower.

Note, finally, that an increase in non-labor income b_t makes the budget constraint looser, which allows for increased consumption c_t, decreased marginal utility of consumption $1/c_t$, and increased demand for quantity and quality of children through their respective first-order-conditions (12) and (13).

B Data Sources

The data used in this paper are extracted mainly from books published by the *Statistique Générale de la France* (SGF) on Population, Demographic and Education censuses, between 1806 and 1925. All data are available for 81 départements. Source: INSEE; *Institut National de la Statistique et des Études Économiques*.

Education Data

The education data contain information on the number of boys and girls enrolled in public and private primary schools (which include secular and *congréganistes* schools); *Statistique de l'enseignement primaire* (years 1837, 1863, and 1886-87). We match the attendance in primary schools to the population of school-aged children (5-15 years); *Recensement and Mouvement de la population* (1836, 1851, 1861, and 1891).

(i) Boys' enrollment rates in 1816-20, 1837, 1863 and 1886-87. Number of boys enrolled in public and private primary schools over the total number of boys aged 5-15.

(ii) Girls' enrollment rates in 1816-20, 1837, 1863 and 1886-87. Number of girls enrolled in public and private primary schools over the total number of girls aged 5-15.

The enrollment rates in 1816-20 are estimated by matching the distribution of literacy rates (measured by the ability of spouses to sign their marriage contract) in 1816-20 to the level of enrollment rates in 1837.

To account for the number of boys and girls aged 5-15 in 1837, which is not available from the census, we use the share of boys and girls aged 5-15 in 1851, accounting for the evolution in the female-to-male ratio between 1836 and 1851.

Demographic Data

In order to create fertility variables, the crude birth rate and the marital fertility rate, we use data on vital statistics and population censuses; *Recensements*, *Mouvement de la population*, and Bonneuil (1997).

(i) Crude birth rate in 1826, 1851 and 1876. Number of births per 1000 inhabitants. The data are smoothed from potential short-run variations (temporary shocks) by using the average among three periods (including the period before and after our year of interest). Hence, for the crude birth rate in 1826, we calculate the average of the crude birth rates in 1821, 1826 and 1831; for 1851, we use the average of 1846, 1851 and 1856 rates; and, finally, for 1876, we calculate the average of the 1872, 1876 and 1881 rates.

(ii) Marital fertility rate in 1851. Average number of children per marriage.

(iii) Infant mortality in 1806, 1826, 1851 and 1876. Infant mortality is proxied by the quotient de mortalité at age 0 – i.e., the probability of dying before age 5. Similar to what we do for the

crude birth rates, we smooth for possible volatility by using the average infant mortality across three periods (only two for the infant mortality rate in 1806 because of lacking data on earlier periods): 1806 and 1811 for the generation 0; 1821, 1826 and 1831 for the generation 1; 1846, 1851 and 1856 for the generation 2; and 1872, 1876, 1881 for the generation 3.

Socio-Economic Data

(i) Gender wage gap in 1850s. The index measures the extent to which women achieved equality with men with regard with wages in industry and agriculture. The variable is calculated as the female-to-male average wage weighted by the size of the population working in industry and in agriculture, respectively; *Enquête industrielle* 1861 and *Enquête agricole* 1852.

(ii) Lifetime labor supply 15-65 for cohorts in 1806, 1826, 1851, and 1876. The lifetime labor supply is calculated using the rate of survival at age 15 to 65 (every five years) from Bonneuil's mortality tables. This variable measures the average years worked by individuals who would start working at age 15 and stop at age 65, accounting for the probability of dying during the period.

Cultural Data

(i) Family structure. Todd (1985) provides the characteristics of family types based on the relationships between parents and children, and between siblings. We use the classification in nine types presented in Le Bras and Todd (2013) to build three dummy variables. Stem and imperfect stem families are combined to create the stem category; community and intermediate families constitute the extended family type; nuclear with temporary co-residence, imperfect nuclear, hyper nuclear, nuclear egalitarian, and nuclear patrilocal egalitarian are grouped to create the nuclear family category.

(ii) Religion. We use the share of Catholics and Protestants in 1861 to measure the intensity of religious practice across counties. The share of Catholics (resp. Protestants) is the number of Catholics (resp. Protestants) per 100 inhabitants; *Recensement*. As an additional variable accounting for religious practice, we use data from Tackett (1986) on clergy members who took the oath of loyalty to the Civil Constitution.

(iii) Dialects. The variable dialect is created based on the knowledge of the geographical distribution of language types and dialects across France. The French dialects are the following: Oïl, Oc, Franco-provenal, Picard, Normand, Breton, Flamand, Germanique, Corse, Catalan, and Basque. We group them into three categories: Oïl languages; Oc languages; and all other languages grouped together to form the third category.

(iv) Elites. The distribution of Elites is proxied by the total number of subscriptions to the *Encyclopédie*, collected by Darnton (1979) and further used by Squicciarini and Voigtländer (2015). As additional measures of upper-tail knowledge, we use the number of universities, libraries and museums per million inhabitants in 1836, and the surface of universities, libraries

and museums in square meters per thousand inhabitants; *Statistique Générale de la France: Recensement 1836, Territoire et Population 1836*

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