How far can economic incentives explain the French fertility and education transition?

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ABSTRACT

We analyze how much a core 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 the structural estimation of a system of 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 having implications for the gender wage and education gaps. Results indicate that the parsimonious 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 interacting incentives with cross-county differences in family structure and cultural barriers.

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1. Introduction

In explaining the fertility transition of the last two centuries, scientists are divided into two camps: those who believe that socioeconomic determinants were key, and those who stress culture and norms as of primary importance. The Beckerian approach to fertility choices clearly belongs to the first strand, as well as the "adaptation to economic change" approach (demographers' terminology, see Caldwell, 1982). For Becker (1993), "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 features of birth rates in modern economies." On the contrary, 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. 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.[1]

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[1] Alternatively, populations having strong migration channels with Paris are likely to be influenced more by the new norms. Daudin et al. (2019) 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
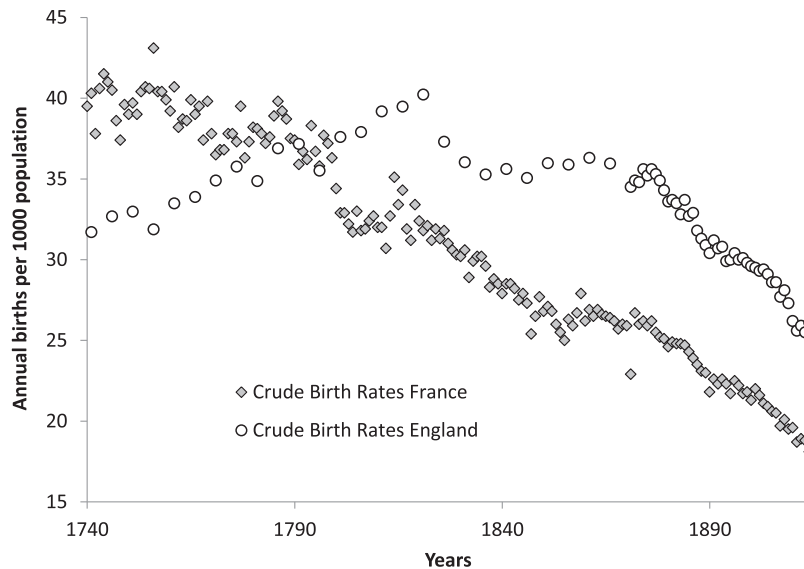
Source: England 1740-1866, Wrigley et al. (1997, Ch. 8 and Table A9.1).
England 1871-1900, Mitchell (1975)
France 1740-1900: Chesnais (1992).

Fig. 1. Crude birth rates in France and in England. *Source:* England 1740–1866, Wrigley et al. (1997, Ch. 8 and Table A9.1). England 1871–1900, Mitchell (1975). France 1740–1900: Chesnais (1992).

This divide partially overlap with another partition between tenants of rational choice theory and advocates of (uneval-uative) imitation (see Lee, 2015). The overlap between the two divides is however partial, depending on whether one sees culture as a social norm leading people to deviate from their otherwise "rational" choice, or, rather, as heterogeneity in pref-erences. Several authors incorporate cultural elements within rational choice theory – see Baudin (2010) for an application to fertility.[2]

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. Over time, though, 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 strictly on a baseline 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. The use of a parsimonious model implies that step (i) leads to a lower bound on the explanatory power of rational-choice models. One can expect richer models to be more powerful. Step (ii) documents the limits of the economic model but can also be useful to indicate in which direction models should be developed in the future.

We use data from French counties (*départements*) over the 19th century. The continuity of the State allows us to use 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. Fig. 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 rose during

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low-fertility regions, especially Paris. This does not mean, however, that socioeconomic factors are unimportant in their study, as migration itself depends on economic incentives (wage and employment differences, transportation and housing costs).

[2] On the empirical side, Fernandez and Fogli (2009) stress that, in addition to economic determinants, culture plays an important role for fertility behavior. 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.

the post-Malthusian epoch and then declined sharply when entering the modern growth regime (Galor, 2011). In France, fertility started 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 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. We assume that all households have the same preferences but that they are endowed with county specific human capital and mortality risks (one household = one county).[3] The first generation was born in the decade around/after the French Revolution. We reconstruct their enrollment rate in primary school based on their ability to sign their marriage act 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 to have a coherent measure through the 19th century) and education (proxied by observed school enrollment in 1837). We 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.[4] 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.

Following the approach initiated by Galor and Weil (1996) and de la Croix and Doepke (2003) we develop a "demand" model of household fertility behavior. 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."[5] It also embeds mechanisms that are typical to an incentive based 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. This cannot be done by the existing literature that studies the joint fertility and education choice in the 19th century (Becker et al. (2010) for Prussia; Fernihough (2016) for Ireland; Bignon and García-Peñalosa (2016) and Diebolt et al. (2017) for France) as it relies on 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 only structural approach is by Cervellati et al. (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); 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). This step is designed to see whether there is something to gain from combining an incentive based approach with broader determinants of fertility, but how to do it within a new modeling approach is left for future research.

The results are as follows. The 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 become the norm. Moreover, in the model as in the data, a shrinking gender education gap accompanies the fertility transition. 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

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

[4] We consider mortality as exogenous, being mainly driven by epidemiological shocks. Beyond epidemics, the second main determinant of child mortality is location, cities vs countryside. If one wants to have a model with endogenous mortality in the future, one may need to also model urban - rural dimension.

[5] The existence of such a tradeoff in the 19th century/early 20th century is a hotly debated issue in the empirical literature. See Bignon and García-Peñalosa (2016), Fernihough (2016), and Clark and Cummins (2016).

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.

2. The model

We develop an economic model of fertility and education choice with a quality-quantity tradeoff.[6] Rational households decide about the number of their children and their education. We identify the 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 (2018), 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 et al. (2014)). It is a 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. This holds for both boys and girls, depending on the gender wage gap and on the return to education.

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), which implies:

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

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 as we cannot rely on information to calibrate such an asymmetry parameter, like time use surveys. 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 $\phi \in (0, 1)$ 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:

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

This utility function displays warm-glove altruism with respect to children. Indeed the utility depends on what is given to the children in terms of human capital. The parameter $\gamma > 0$ is the weight of children in the utility function. Very similar fertility behaviors would be obtained if one had assumed that the motive to have children lied in old age support (children giving a transfer to their old parents in proportion to their labor income) or in child labor instead of altruism. Finally, notice that, with a unitary model of the household, there is no scope for women empowerment under the form of higher bargaining power (Diebolt and Perrin, 2013), money transfers within the couple (Doepke and Tertilt, 2016) or higher treat point (Doepke and Tertilt, 2009).

The budget constraint for a couple is:

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

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[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.

[7] Adapted from Browning et al. (2014, p. 265), and Gobbi (2018) to the production of quantity instead of quality.

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. 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.

The assumption that households have to buy education for a generation specific price p_t is a way to introduce supply side elements into the model. When the creation of municipal schools became subsidized by the State, education became cheaper for the parents.[8] 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.

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:

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

$\eta_t^j + \varepsilon \ell_{t+1}^j$ is the elasticity of human capital to education. It has a 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, 2017), according to which the return to education is higher when the horizon is longer.[9] 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 Eq. (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 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 the benchmark version of the model, we assume the η^j to be constant through time, while 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:

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

$$\text{subject to } \left(\phi + \psi \frac{m_t}{1 - m_t}\right)n_t = \sqrt{a_t^b \, a_t^g}$$

$$c_t = h_t^b(1 - a_t^b) + \omega h_t^g(1 - a_t^g) + b_t - p_t(e_t^b + e_t^g)\frac{n_t}{2}.$$

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 both the quantity and quality of children are normal goods [income effect].

3. French county-level data

In order to investigate the extent to which fertility and education changes can be explained by the above model, we collect French county-level data for the 19th century. A description of which counties are included in the sample is provided in Appendix B. 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*). We detail here how the data are constructed and provide some contextual information on fertility, and education.

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[8] Making p_t function of county's characteristics, and/or assuming a difference in the price of education for boys and girls are two interesting extensions.
[9] Leker (2015) looks at education across French counties in the 19th century through the lens of the Ben-Porath model.
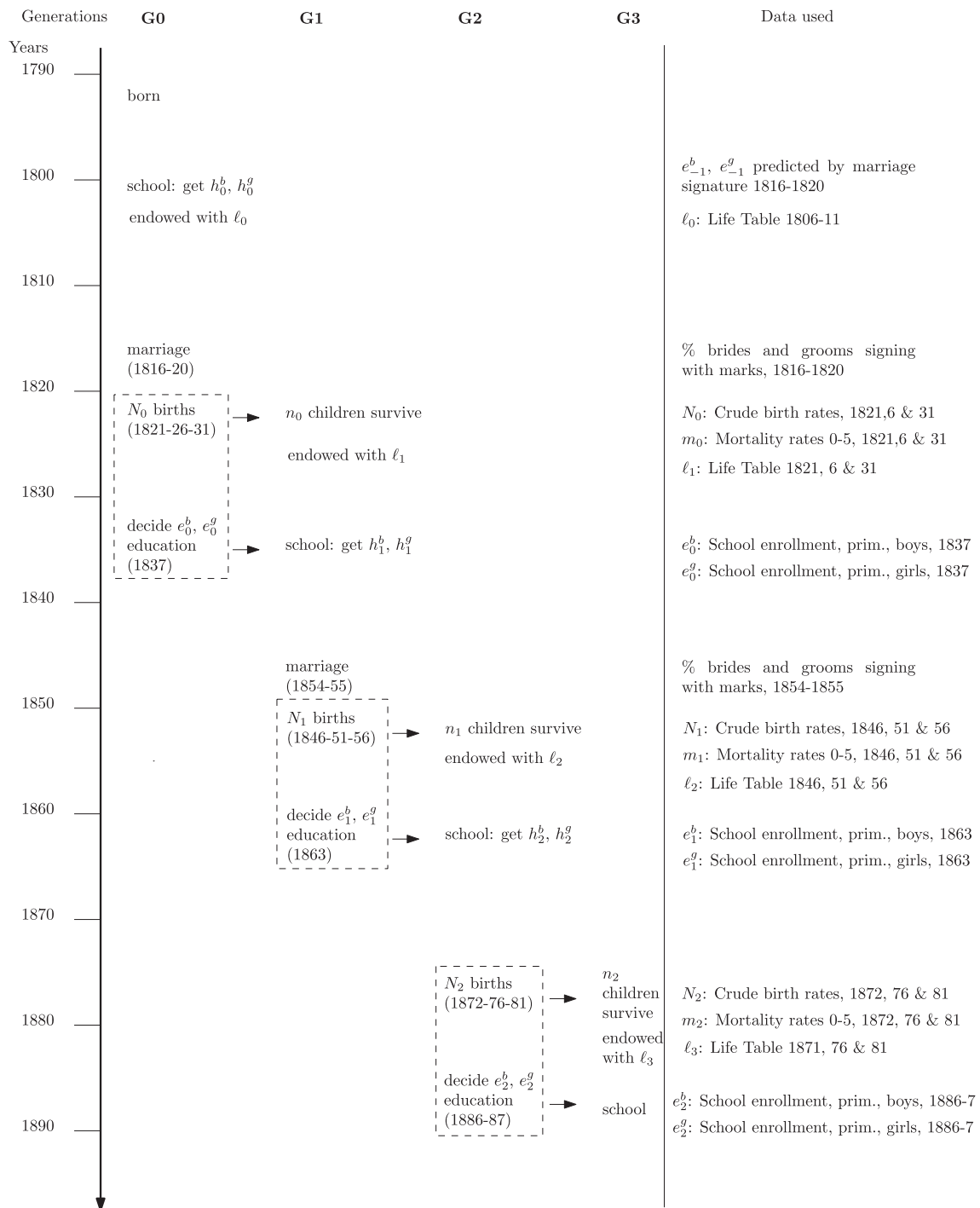
Fig. 2. The generations considered.

3.1. Three generations

This paper focuses on the behavior of three generations denoted G0, G1, and G2. How the different generations overlap is illustrated in Fig. 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.

We assume that, within a county, the children of the previous generation are the adults of the next generation. This is an approximation which is valid if permanent migrations between counties are not too important. This assumption is backed by several empirical studies. Rosental (2004) shows that about 80 percent of the population was composed of either sedentary

Table 1

Cross-country correlation between Crude Birth Rates (CBR) and other measures of fertility.

	1831	1851	1876
Correlation CBR - General fertility rate	N.a.	0.91	0.94
Correlation CBR - Child-women ratio	N.a.	0.53	0.69
Correlation CBR - Coale index of marital fertility	0.63	0.75	0.84

Note: all coefficients are computed over the 81 selected counties, except the correlation CBR - Coale index of marital fertility in 1831 which is computed over 77 counties.

individuals or short-distance migrants (less than 25 km) during the 19th century. Among the long-distance migrants, some might be seasonal migrants. For Châtelain (1967), migrations during the 19th century were temporary migrations, mainly seasonal migrations (to help with the harvests). For Bonneuil (1997), long distance migration was very unevenly distributed among the counties. Only a few counties such as Seine, Rhône, Bouches-du-Rhône, and Var, have attracted individuals intensively from more agrarian counties. Finally, international migration was small. For example, between 1861 and 1911, the share of foreign migrants among the total population of the region Rhône-Alpes increased from 0.5 percent to 2 percent (Schweitzer et al., 2009).

3.2. Fertility

Before the development of the modern methods of contraception, different strategies were used by individuals to reduce/limit their fertility. There were two main types of strategies to control births: a control via nuptiality (Malthusian control) and a control through birth limitation (early contraception). The control of births through marriage consisted in delaying the age at marriage, or remaining single (Malthus, 1807). Birth limitation consisted in acting directly on births within marriage through births spacing or stopping early births (see, for instance, Flandrin (1984), Dupâquier and Lachiver (1969), and Blanc and Wacziarg (2018) for empirical investigations of French villages during the pre-industrial period, and Murphy (2015) and Brée and de la Croix (2018) for an extensive discussion of the means and motivations of fertility control).

To measure the fertility behavior, we use the crude birth rate (number of births per thousand people). The crude birth rate are 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. 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.[10] Besides, the crude birth rate is less subject to possible biases than other measures of past fertility (Sánchez-Barricarte, 2001). More elaborate measures may present drawbacks when exploring the historical evolution of fertility. For instance, the Coale Ig index as used by Murphy (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. Table 1 shows the correlation coefficient between the Crude Birth Rate we use and other measures of fertility.

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.

3.3. Education

Before describing data, one should be aware of the major institutional changes that affected education over this period. The 19th century witnessed strong divergences on how education had to be organized. On one side, the politics of secularization of the republicans (i.e. the partisans of a secular State) aimed at placing the schools under the control of the State. While on the other side, the Catholic Church argued in favor of a schooling system providing religious education.

Prior to the French Revolution, the schools were placed under the supervision of the Church with the primary objective to provide a religious education to the pupils. During the enlightenment period, this purpose became increasingly contested. The pro-republicans argued that schooling had to be organized so as to prepare individuals to become the citizens of the State (requiring the education to be organized and controlled by the State, and no longer by the Church). The Concordat signed in 1801, between Napoléon and the Pope Pius VII, aimed at reconciling the revolutionaries and the Catholics. The key role played by the Catholic Church focused on specific area and did not extent any longer to the whole Society.

Deep-seated policy changes in primary education occurred under the July Monarchy with the Guizot Law in 1833. It established the principle that primary education should be accessible to all citizens. It also encouraged each religion (Catholic,

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

Protestant, Jewish) to have its own primary schools, contributing thereby to the development of the congreganist movement. The schooling system was characterized by the coexistence of public and private primary schools (most of them *congréganistes*, i.e. organized by religious congregations) competing with each other.

Slow progress also occurred with regards to girls' education. While during the First French Empire, Napoléon considered that girl's education should be limited to the tasks in link with housework and consequently did not need education higher than basic, the Falloux Law (March 15, 1850) required that every town populated by more than 800 inhabitants have a school for girls (conditional to the resources of the municipalities). This law revived the conflict between the Catholic Church and the anticlerical movements by bounding to the compliance of the schools to the Church (and eventually favored the congreganist schools leading to their expansion and prosperity). For the republicans, the enlightenment of the citizens relied on the expansion and spread of secular education.

Limitations and shortcomings of the Falloux law were corrected by the application of the Duruy law in 1867. The law contributed to improve the remuneration and living conditions of teachers, allowed municipalities to provide free education through the creation of an "extraordinary taxation" and the possibility to receive subventions from the State and the county. The creation of the "caisses d'écoles" aimed at increasing the school attendance and reward the most diligent pupils and subsidizing the poorest. Overall, the law increased the control of the State on private schools. The Republican policy towards the secularization of education pushed congreganist schools away from public education and constrained them to open private schools instead.

These three laws, Guizot, Falloux and Duruy, imply that the cost of education for families decreased over time. For our overview to be complete, we should finally mention the 1881 law, named by the Minister of Public Instruction Jules Ferry, established free education and was followed by the 1882 law establishing mandatory and secular education. Primary instruction became compulsory for all children aged 6–13 with no gender distinction. With the 1882 Ferry law and the 1886 Gobelet law, religious schools were not under the span of control of the State anymore.

We measure education by the enrollment rate in primary schools, defined as the number of children enrolled in all types of 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. Data on primary education are available by gender from 1837 and by the four types of school from 1850.

In computing the enrollment rates, we thus aggregate different types of schools. This amounts to assume that the different types of schools are perfect substitute. In particular, it implies that all types of schools provide the same quality of education and have the same cost. This is an approximation as we know that, depending on the period considered, teachers were of different quality, as noted by Squicciarini (2018): "With the Loi Falloux of 1851, Catholic public schools were encouraged: Catholic teachers were now exempted from the *brevet*, since a simple *lettre d'obédience* from any religious order was sufficient to qualify as teacher." Also, despite public schools started to receive more funding at the end of the nineteenth century, they were not able to crowd-out the primary school network of the Catholic Church aimed at girls (see Franck and Johnson, 2016),[11] which is another indication of non perfect substitutability. The content of the provided education might also differ between types of schools. Squicciarini notes that "girls' schools were particularly strict on issues concerning marriage and divorce and very little emphasis was put on counting." From this evidence it seems there is room for a follow up paper which would relax the perfect substitutability assumption.[12]

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.[13]

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

3.4. Additional variables

We integrate additional factors that could capture some of the variations in fertility. In order to account for child 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

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[11] Catholic schools turned out to be very resilient to change, see the extensive study in Grew and Harrigan (1991).

[12] Such a study of the possible differences between the types of schools should try to estimate different costs for the various school systems using the data available after 1850, and also the different returns in terms of human capital, with a gender dimension. This would also require to model the heterogeneity of religiosity across counties.

[13] Literacy rates in 1816–20 are missing for five counties. We predict them from literacy rates in 1854–55.
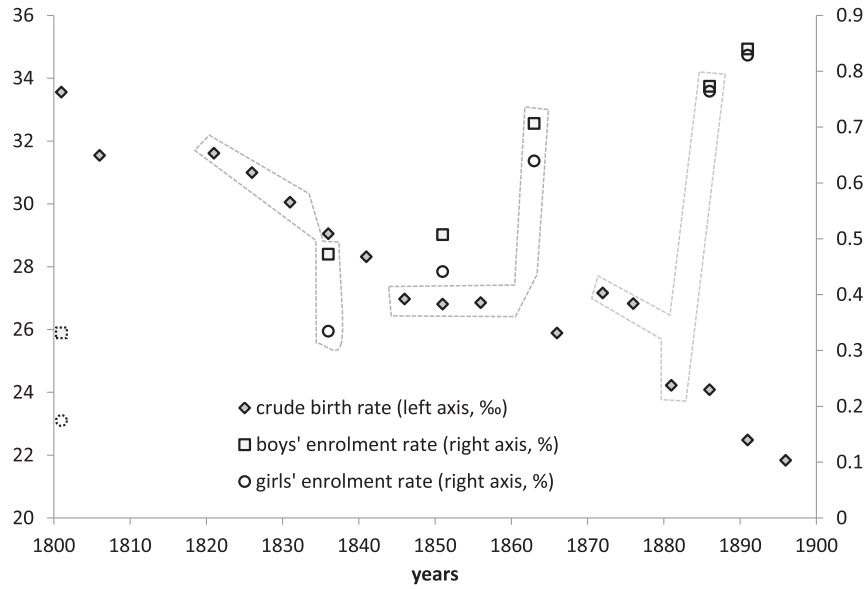
Fig. 3. Aggregate change.

Table 2
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
Child mortality, 1826	$m_{0,i}$	0.305	0.092	0.161	0.542
Child mortality, 1851	$m_{1,i}$	0.306	0.090	0.162	0.543
Child 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_3	38.10	1.71	33.57	41.17

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

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.

3.5. Descriptive statistics

Before looking at the county-level and the three generations described in Fig. 2, we briefly comment on aggregate evolutions in the 19th century. Fig. 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 2 reports the descriptive statistics. Figs. 4–7 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.
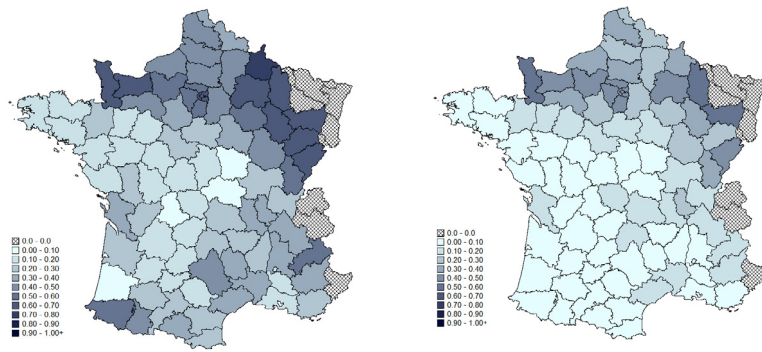
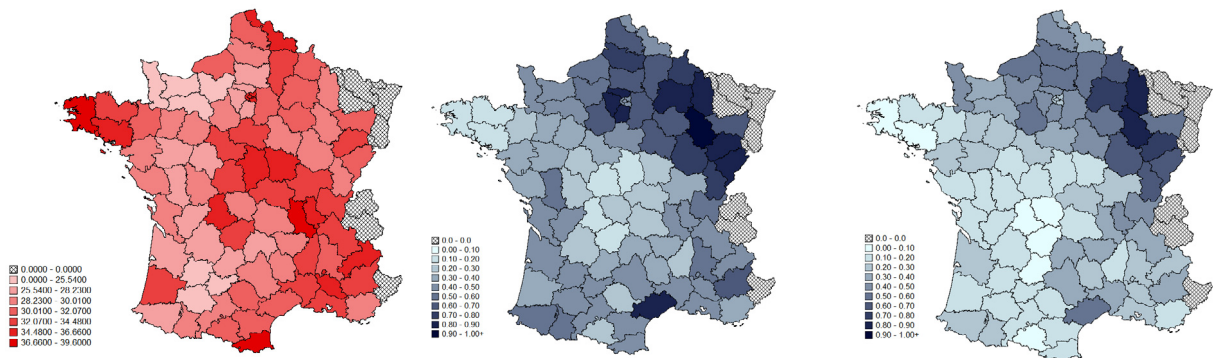**Fig. 4.** G0's endowment: Boys' enrollment (1806), Girls' enrollment (1806).

Fig. 5. G0's choices: CBR (1821–31), Boys' enrollment (1837), Girls' enrollment (1837).
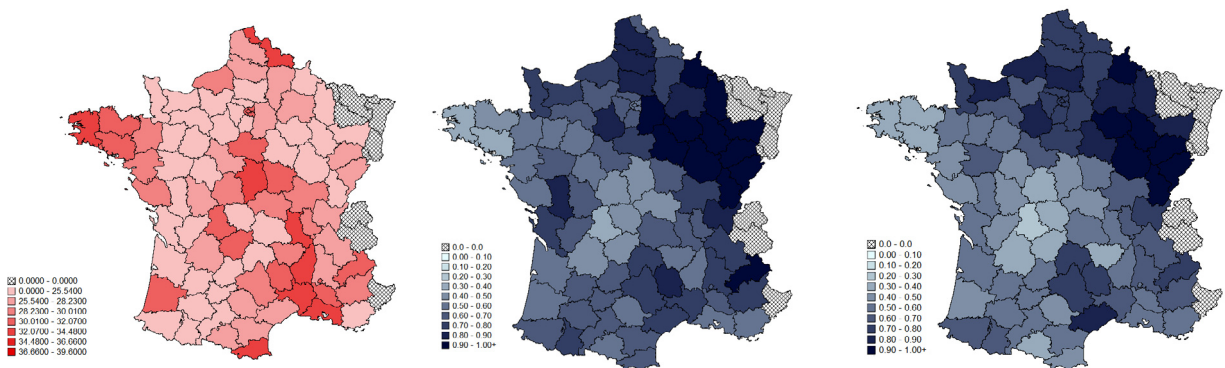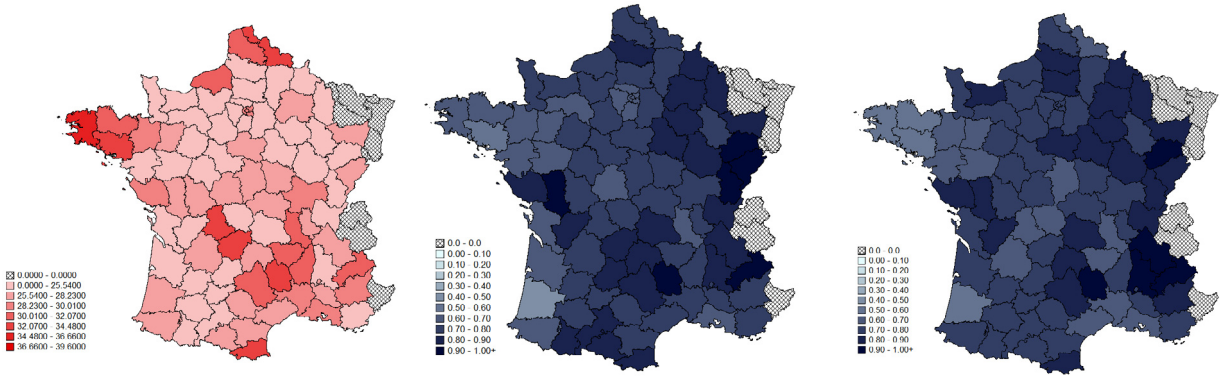

Fig. 6. G1's choices: CBR (1846–56), Boys' enrollment (1863), Girls' enrollment (1863).

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 small share of the population uses fertility control.[14] 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 child mortality rate decreased by 12.8 percent. The average probability of a child dying before age five declined from 30.5 percent

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[14] 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)

Fig. 7. G2's choices: CBR (1872–81), Boys' enrollment (1886–7), Girls' enrollment (1886–7). *Note:* Figs. 4–7 use the administrative divisions in France after 1968, when two counties around Paris were split into smaller units. We have imputed to each of these smaller units the value of the large county they were part of.

in 1826 to 26.6 percent in 1876. The minimum and maximum child 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 for boys and girls are obviously non-uniform across counties. Fig. 3b and d 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 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.

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.

4. Estimation and results

4.1. Methodology

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 $i = 1, \ldots, 81$:

$$\begin{cases} n_{G,i} = f_n^\star[\pi_G, \rho_{G,i}], \\ e_{G,i}^b = f_{eb}^\star[\pi_G, \rho_{G,i}], \\ e_{G,i}^g = f_{eg}^\star[\pi_G, \rho_{G,i}]. \end{cases} \tag{8}$$

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

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:

$$\Omega(\Pi) = \arg\min_\Pi \sum_{i=1}^{81} \Bigg[\sum_{G=0}^{2} \left[\left(1 - \frac{f_n^\star[\pi_G, \rho_{G,i}]}{\hat{n}_{G,i}} \right)^2 + \left(1 - \frac{f_{eb}^\star[\pi_G, \rho_{G,i}]}{\hat{e}_{G,i}^b} \right)^2 \right.$$

$$\left. + \left(1 - \frac{f_{eg}^\star[\pi_G, \rho_{G,i}]}{\hat{e}_{G,i}^g} \right)^2 \right] + \left(1 - \omega \frac{(\hat{e}_{0,i}^b)^{\eta_0^b + \epsilon \ell_1}}{(\hat{e}_{0,i}^g)^{\eta_0^g + \epsilon \ell_1}} \frac{1}{\hat{\delta}_i} \right)^2 \Bigg], \tag{9}$$

Table 3
Parameter estimates.

Parameter	Benchmark $\hat{\Pi}$	S.E.	Alternative (1) $\hat{\Pi}$	Alternative (2) $\hat{\Pi}$
γ	0.407	0.029	0.335	0.180
η^b	0.338	0.091		0.070
η^g	0.482	0.095		0.171
ϵ	0.111	0.102	0.203	0.261
p_0	0.182	0.013	0.181	0.080
p_1	0.106	0.009	0.082	0.043
p_2	0.128	0.012	0.078	0.051
ω	0.739	0.012	0.709	0.678
b_0	0.012	0.012	0.130	0.000
b_1	0.000	0.001	0.000	0.000
b_2	0.098	0.021	0.000	0.290
η_0^b			0.302	
η_0^g			0.443	
η_1^b			0.192	
η_1^g			0.325	
η_2^b			0.278	
η_2^g			0.142	
$\Omega(\hat{\Pi})$		38.512	33.900	44.715

Table 4
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

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.

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).[15]

Intuitively, the identification of the structural parameters goes as follows. The time varying parameters b_t and p_t are identified from the time variation of cross-county average fertility and education. ψ is identified from the effect of mortality on fertility across counties. γ is identified from the effect of parent's human capital on fertility. The two η's parameters are identified from the correlation across counties between fertility and education levels. ϵ is identified from the average effect of longevity of children on educational investment by their parents. ω is identified from the average gender gap $\underset{i}{E}[\delta_i]$.

### 4.2. Estimation of deep parameters

We first estimate a benchmark model, imposing the elasticities η to be constant over time. The estimation results are presented in the first columns of Table 3.[16] 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 child 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.

4.3. Goodness of fit

We can measure the goodness of fit by computing coefficients of determination for fertility and enrollments. Table 4 displays the results for the full sample and for each generation separately. The corresponding graphs are provided in Fig. 8,

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[15] 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.

[16] Standard errors are computed after the following 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.
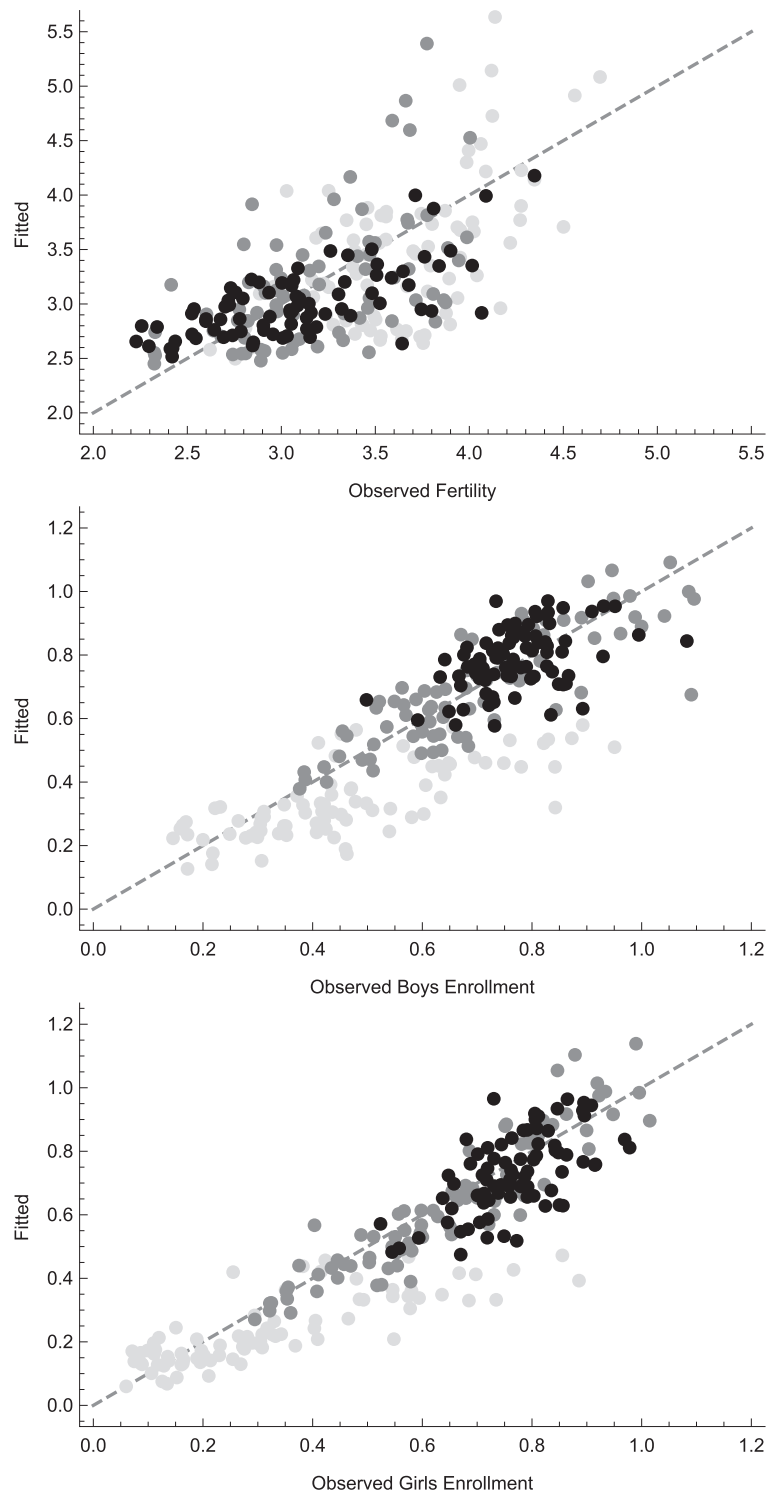
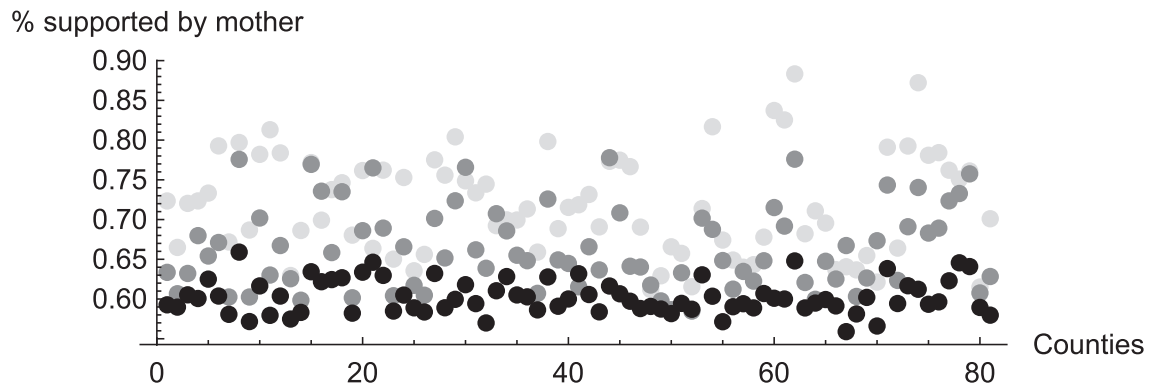**Fig. 8.** Goodness of Fit. G0: light gray. G1: gray. G2: black.

% supported by mother

Fig. 9. Time devoted to children - mothers' share. G0: light gray. G1: gray. G2: black.

Table 5
Effect of parents' education level on fertility.

e^f	n_0	n_1	n_2	e^m	n_0	n_1	n_2
0.1	2.41	2.47		0.1	2.25		
0.2	2.20	2.22		0.2	2.34	2.28	
0.3	2.11	2.12	2.38	0.3	2.42	2.36	
0.4	2.08	2.07	2.29	0.4	2.48	2.43	2.69
0.5	2.05	2.03	2.23	0.5	2.54	2.48	2.73
0.6	2.04	2.02	2.20	0.6	2.59	2.54	2.77
0.7		2.00	2.17	0.7		2.58	2.81
0.8		2.00	2.15	0.8		2.62	2.85
0.9		1.99	2.13	0.9		2.66	2.88
1.			2.12	1.			2.91

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.

4.4. Mechanisms

To understand the mechanisms of the model, one should first stress that the time cost of children is split between mothers and fathers in order to minimize the time cost (in terms of lost income). As a consequence, the share of child rearing supported by the mother is inversely related to her human capital relative to the one of her husband. As there is a gender wage gap, the mother will do more even if she has the same level of human capital. Once the parameters have been estimated, the model delivers predictions on the time allocation within the household. Although we cannot compare this allocation to data, it is interesting to look at it in order to better understand how parents' human capital impacts fertility. Fig. 9 presents the results. For generation G0, mothers take between 60 percent and 90 percent of the total time devoted to children. For subsequent generations, G1 and G2, this share converges to about 60 percent in all counties.

These 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 of later generations 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).[17]

In order to get a better idea of the size of the effects implied by the model, the left panel of 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

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[17] The share of women in the working age population increased regularly throughout the 19th century to reach 45% at the dawn of the 20th century. Throughout the 19th century, most women were working in "traditional" occupations, namely in agriculture but also to a lesser extent in domestic services, garment making and textile. For most of the 19th century, women's manufacturing work was mainly concentrated in the textile industry. Women moved slowly into more modern occupations. At the end of the 19th century, the number of women employed in industry represented a small proportion of the entire female labor force. The share of married women represented about 50% of the total working female population, 40% for single women and 10% for widows.
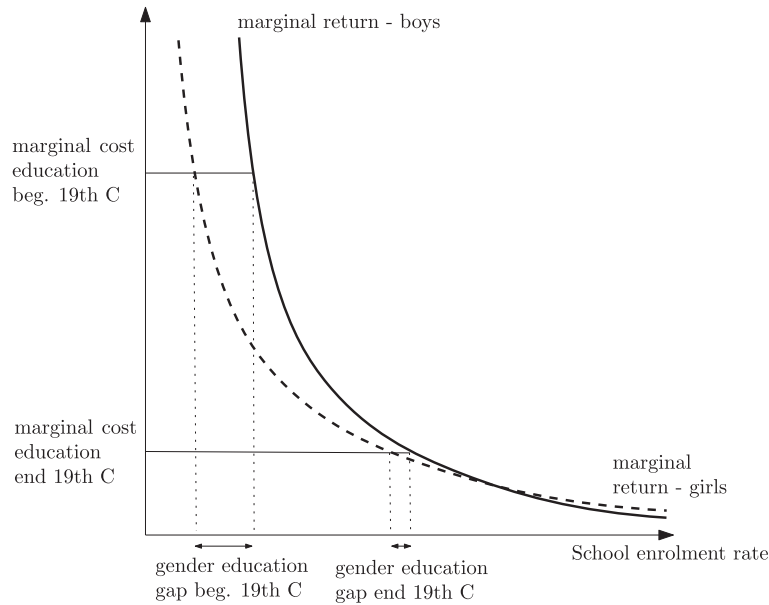
Fig. 10. Closing the gender education gap.

Table 6
Goodness of Fit (R^2) under different counterfactuals.

Equation	Benchmark	Removing heterogeneity in...			
		Child 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

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.

We can complete the picture with the effect of fathers' education on fertility. The right panel of Table 5 provides the results. Here, the effect is positive, as the income effect dominates the opportunity cost effect in the case of fathers. This stresses the importance of the gender dimension in assessing the effect of human capital on fertility. Notice also that the effect is more linear than in the case of mothers, where a rise in education implied a sharp drop in fertility only at low education levels.

Given that we have both $\omega < 1$ and $\eta^g > \eta^b$, the income gap induced by ω (be it discrimination or true productivity) is higher in counties with low enrollment rates. Indeed, when both enrollment rates equal 20 percent the gender gap is $\omega h_t^g / h_t^b = 0.739 \times 0.2^{0.482-0.338} = 0.586$. The same gap for enrollments at 80 percent equals 0.716. Hence, $\eta^g > \eta^b$ implies that the gender wage gap is more marked for persons with low levels of education. Moreover, the estimated gender difference in η allows the model to explain the closing of the education gender gap along the fertility transition (the enrollment gap e^g / e^b goes between G0 and G2 from 70 percent to 99 percent in the data and from 70 percent to 91 percent in the simulation). Fig. 10 illustrates the reasoning by showing how marginal returns of education (solid for boys, dashed for girls) equalize with marginal costs. When the marginal cost of education is high, because either fertility is high or schools are expensive or inaccessible (high p_0), the enrollment rates which equalize the marginal returns for boys and for girls display a large education gap. When the cost of education drops, following either the drop in fertility or the increase in school provision (p_2 lower), the optimal education gender gap which equalizes marginal returns across genders decreases.

Finally, to better understand which mechanisms of the model weight for the overall fit, we ran several counterfactual experiments by removing each source of heterogeneity among counties separately. Table 6 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 $m_{G,i} = \underset{G,i}{E}[m_{G,i}] \ \forall i, G$ – 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 $\ell_{G+1,i}$, $h_{G,i}^g$, and $h_{G,i}^b$, 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' education also contributes to explaining them. The importance of women's education has already been stressed in other contexts (see Becker et al., 2013 for 19th century Prussia), and is confirmed here. It also shows the importance of using gendered education data to be able to single out the effect of the mother. Finally, future longevity – i.e. lifetime labor endowment of children – does not seem to play an important role.

4.5. Alternative specifications

We finally estimate two alternative models. First, 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. The results are shown in the column "alternative (1)" of Table 3. 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 is more in line with the drop in the skill premium observed by Clark (2005) for building workers' wages in England). Although the objective function $\Omega(\hat{\Pi})$ attains a lower value, this model 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.

Another possible model, perhaps more in line with 19th century rearing practices, is to assume a linear production function for children:

$$\phi n_t = \tfrac{1}{2}(a_t^b + a_t^g) \quad \text{instead of} \quad \phi n_t = \sqrt{a_t^b \, a_t^g}.$$

Such a production function implies that the optimal allocation of time is $a_t^g = 2\phi n_t$ and $a_t^b = 0$. Indeed, as the gender wages gap makes the father's opportunity cost always higher than that of his wife, only mothers spend time with children. The parameters estimates under this assumption are shown in the column "alternative (2)" of Table 3. Here the objective function is higher (i.e. worse) for the same number of parameters. The coefficients of determination are equal to 33.6 percent for fertility, 64.3 percent for boys' enrollment rates, and 81.2 percent for girls' enrollment rates, all of them being worse than before.

5. Explaining the unexplained

In this section, we correlate the part of fertility and school enrollment that was not explained by our parsimonious 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 potentially explaining family decisions; and second, to indicate in which direction the economic theory should be developed. The "unexplained" is represented by the nine residuals:

$$\varepsilon_G^n = \hat{n}_{G,i} - f_n^\star[\hat{\pi}_G, \rho_{G,i}]$$
$$\varepsilon_G^{e^b} = \hat{e}_{G,i}^b - f_{eb}^\star[\hat{\pi}_G, \rho_{G,i}] \tag{10}$$
$$\varepsilon_G^{e^g} = \hat{e}_{G,i}^g - f_{eg}^\star[\hat{\pi}_G, \rho_{G,i}]$$

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.

5.1. 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) shows 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.

5.2. 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 et al. (2018) 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.

5.3. 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."

5.4. 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 et al. (1988). 7081 subscriptions were sold in France; out of these, Squicciarini and Voigtländer (2015) can match 6944 to towns listed in Bairoch et al. (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 et al. (1988),

Table 7
"Explaining" the residuals.

	Dependent variable: residuals of the structural equations								
	Generation 0			Generation 1			Generation 2		
	Fertility ε_0^n	Boys' ed. ε_0^{eb}	Girls' ed. ε_0^{eg}	Fertility ε_1^n	Boys' ed. ε_1^{eb}	Girls' ed. ε_1^{eg}	Fertility ε_2^n	Boys' ed. ε_2^{eb}	Girls' ed. ε_2^{eg}
Family types (vs nuclear):									
Extended family	0.573***	0.101**	0.125***	0.425***	−0.058*	−0.030	−0.149	−0.126***	−0.129***
	(0.138)	(0.046)	(0.040)	(0.158)	(0.031)	(0.029)	(0.121)	(0.027)	(0.026)
Stem family	0.215	0.035	0.045	0.153	−0.085**	−0.054*	−0.007	−0.046	−0.054*
	(0.146)	(0.048)	(0.042)	(0.167)	(0.033)	(0.031)	(0.128)	(0.028)	(0.028)
RELIGION:									
Share Catholics	0.011	0.002	0.0004	0.031**	0.003	0.002	0.017	0.0005	−0.001
	(0.013)	(0.004)	(0.004)	(0.015)	(0.003)	(0.003)	(0.011)	(0.002)	(0.002)
Secularization	−0.013	−0.021	0.001	0.040	0.002	0.004	0.099**	0.016*	−0.004
	(0.046)	(0.015)	(0.013)	(0.053)	(0.010)	(0.010)	(0.041)	(0.009)	(0.009)
Geographical & cultural distance :									
Distance to Paris	0.005	0.001	0.002**	0.004	−0.0001	−0.0003	0.003	−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	−0.352**	−0.080*	−0.069*	−0.199	−0.041	−0.007	0.126	0.007	0.034
	(0.134)	(0.044)	(0.039)	(0.154)	(0.030)	(0.029)	(0.118)	(0.026)	(0.025)
Oc languages	−0.103	0.010	−0.028	−0.024	0.054	−0.001	0.166	−0.023	0.0001
	(0.157)	(0.052)	(0.045)	(0.180)	(0.036)	(0.033)	(0.138)	(0.030)	(0.030)
Upper tail knowledge :									
Subscr. *Encyclopédie*	−0.012	−0.008	−0.010**	0.006	−0.0004	0.0004	0.013	0.002	0.004
	(0.016)	(0.005)	(0.005)	(0.018)	(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	0.0004	0.0001
	(0.007)	(0.002)	(0.002)	(0.008)	(0.002)	(0.001)	(0.006)	(0.001)	(0.001)
Surf. infrastructure	−0.003**	0.0002	0.0002	−0.004**	0.0004	0.00003	−0.001	0.0002	0.0002
	(0.001)	(0.0005)	(0.0004)	(0.002)	(0.0003)	(0.0003)	(0.001)	(0.0003)	(0.0003)
Constant	−1.625	−0.115	−0.106	−3.210**	−0.212	−0.151	−2.181*	−0.014	0.137
	(1.294)	(0.428)	(0.371)	(1.480)	(0.292)	(0.275)	(1.134)	(0.249)	(0.245)
Observations	81	81	81	81	81	81	81	81	81
R^2	0.575	0.224	0.350	0.325	0.299	0.122	0.152	0.497	0.512
Adjusted R^2	0.507	0.100	0.246	0.217	0.188	−0.018	0.017	0.417	0.435
Shapiro–Wilk p-value	0.98	0.75	0.19	0.91	0.01	0.07	0.21	0.31	0.45

Note: The reference category is the nuclear family $^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

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-tail 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).

5.5. Results

We estimate nine equations in which the dependent variables are the residuals of the structural estimation, and the explanatory variables are those described in the previous subsections. Table 7 gives the results. The size of the coefficient can be directly interpreted in terms of fertility rates and enrollment rates. The descriptive statistics of the explanatory variables are in Appendix C, Table 9.

One is directly surprised by the very low number of significant variables and the remarkably high R^2. As the number of observations is not large enough to invoke the law of large numbers, we provide in the last line the p-value of the Shapiro–Wilk test for the normality of the distribution of the residuals. The null hypothesis is that residuals are normally distributed, thus a small p-value indicates one should reject the null and conclude the residuals are not normally distributed. In all equations except the two enrollment rates ε_1^{eb} and ε_1^{eg}, the p-value is large and we cannot reject normality at conventional significant levels.[18] For fertility of all generations, and enrollment rates for the first and last generations, standard inference may apply.

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

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[18] For ε_1^{eg}, the inspection of the QQ-normal plot indicates that the rejection of normality is driven by one very negative residual.
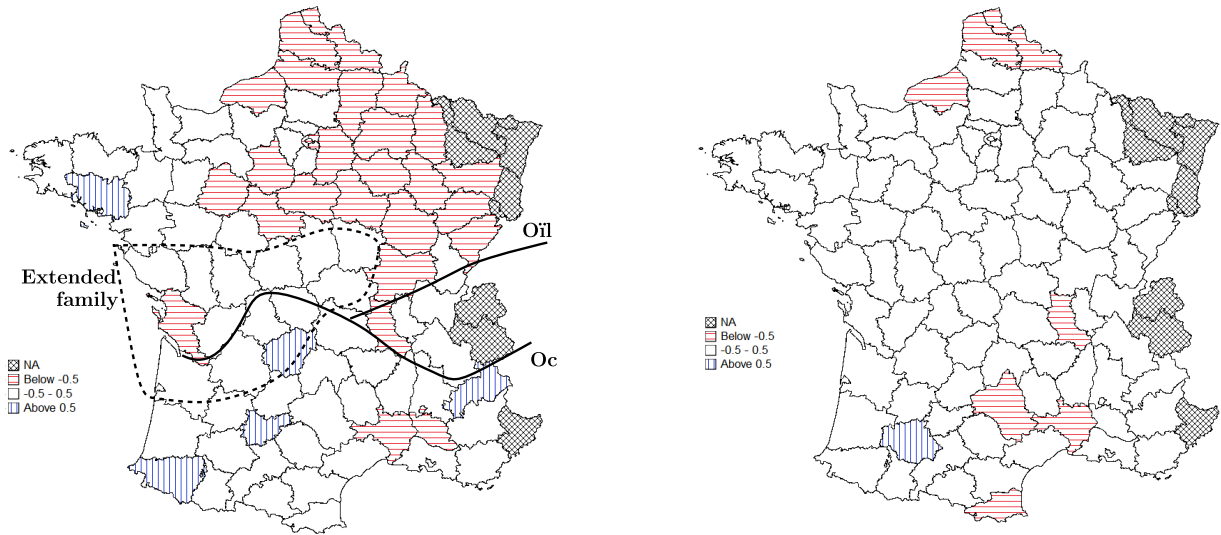
Fig. 11. Residuals ε_0^n and ε_2^n.

family type is also correlated negatively with the education of both boys and girls, but only in the third period. The vanishing effect of the extended family type on fertility can be understood under the light of changes in the inheritance laws in the 19th century. The implementation of new laws in favor of equality in inheritance, stemmed from the French Revolution (1794, 1798) and from the Napoleonic Code (1804), deeply affected the inheritance practices Steiner (2008). The 19th century witnessed deep social transformations and a reshape of the family system. The revolutionary government's policies abolished the ancient customs and practices by removing the right to freely dispose of its property and by establishing a strict system of equal inheritance between all children. Although the transformation was thorough, it took some time to fully diffuse across the French territory. Much of the 19th century had been necessary in certain areas to observe the change in practices.

Unlike family types, religious variables do not show an easily interpretable pattern. They are in general insignificant at the 5% level, except in two cases. The percentage of Catholic is positively correlated with the fertility residual in the second period. The secularization variable is positively correlated with fertility in the third period. It remains unclear whether a finer modeling of the different types of schools (as suggested in Section 3.3) might help to take these effects into account within the economic model.

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 mostly family structure and language matter when looking at residuals ε_0^n and ε_2^n. Fig. 11 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.[19] Modeling cultural barriers to the adoption of fertility norms seems promising, too, and complementary to explanations based on socio-economic characteristics.

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[19] 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 et al. (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 et al. (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 et al. (2018); 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.

Table 8
Parameter estimates.

Parameter	95% conf. interval from (9)	Estimate from (11)
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

5.6. 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 or 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:

$$\arg\min_{\Pi,Z} \sum_{i=1}^{81} \left[\sum_{G=0}^{2} \left[\left(1 - \frac{f_n^\star[\pi_G, \rho_{G,i}] + \zeta_{n,G}\text{Oil}_i + \xi_{n,G}\text{Ext}_i}{\hat{n}_{G,i}} \right)^2 + \left(1 - \frac{f_{eb}^\star[\pi_G, \rho_{G,i}] + \zeta_{eb,G}\text{Oil}_i + \xi_{eb,G}\text{Ext}_i}{\hat{e}_{G,i}^b} \right)^2 \right.\right.$$
$$\left.\left. + \left(1 - \frac{f_{eg}^\star[\pi_G, \rho_{G,i}] + \zeta_{eg,G}\text{Oil}_i + \xi_{eg,G}\text{Ext}_i}{\hat{e}_{G,i}^g} \right)^2 \right] + \left(1 - \omega \frac{(\hat{e}_{0,i}^b)^{\eta_0^b + \epsilon\ell_1}}{(\hat{e}_{0,i}^g)^{\eta_0^g + \epsilon\ell_1}} \frac{1}{\hat{\delta}_i} \right)^2 \right], \tag{11}$$

instead of (9). In problem (11), 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 $Z = z_0 \bigcup z_1 \bigcup z_2$. Our test consists in solving problem (11), 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 covariance matrix of the parameters estimated with (11) and to perform a joined test of equality, but the dimension of problem (11) (29 parameters instead of 11) makes its estimation very long and prevents us from doing so.

The results are presented in Table 8. All the parameters estimated from (11) fall within the 95 percent confidence interval of the more parsimonious 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.

6. Conclusion

Even in the case of France, which is considered the pioneer in low fertility norms, socioeconomic conditions affect fertility. Indeed, a 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.

Appendix A. First-order conditions of the household maximization problem

The maximization problem to be solved is:

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

subject to

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

$$c_t = h_t^b(1 - a_t^b) + \omega h_t^g(1 - a_t^g) + b_t - p_t(e_t^b + e_t^g)\tfrac{n_t}{2}.$$

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:

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

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 (A.1), 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:

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

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:

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

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:

$$\frac{p_t}{c_t}\frac{n_t}{2} = \frac{\gamma(\eta_t^b + \epsilon \ell_{t+1})(e_t^b)^{\eta_t^b + \epsilon \ell_{t+1} - 1}}{h_{t+1}^b + \omega h_{t+1}^g} = \frac{\gamma(\eta_t^g + \epsilon \ell_{t+1})(e_t^g)^{\eta_t^g + \epsilon \ell_{t+1} - 1}\omega}{h_{t+1}^b + \omega h_{t+1}^g} \tag{A.3}$$

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 (A.2) and (A.3).

Appendix B. 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 was based on the desire to equilibrate the importance of the counties (Masson, 1984, p. 680). According to Turgot (1775), the counties should be sized so that the furthest part of the county 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 (Ilê-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.

Appendix C. 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) Child mortality in 1806, 1826, 1851 and 1876. Child 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 child mortality across three periods (only two for the child 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-provençal, 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*

Table 9
Descriptive statistics.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Extended family	81	0.173	0.380	0	0	0	1
Stem family	81	0.272	0.448	0	0	1	1
Share Catholics	81	98.223	3.856	77.630	98.760	99.790	99.990
Secularization	81	2.654	1.086	1	2	4	4
Distance to Paris	81	354.228	183.311	0.000	203.740	495.710	687.900
Distance by road	81	426.090	225.867	0	245	591	870
Oïl languages	81	0.420	0.497	0	0	1	1
Oc languages	81	0.358	0.482	0	0	1	1
Subscr. *Encyclopédie*	81	2.168	3.054	0.000	0.000	3.152	15.167
Nb. infrastructure	81	13.954	7.378	2.739	7.526	18.152	37.725
Surf. infrastructure	81	41.093	34.397	2.925	19.469	50.955	172.909

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.euroecorev.2018.07.001.

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