Clio's Role for Economic Growth: New Findings on the Quantity-Quality Tradeoff in 19th Century France

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[Preliminary Draft]

Abstract

Recent theoretical developments of growth models, especially on unified theories of growth, suggest that the child quantity-quality trade-off has been a central element of the transition from Malthusian stagnation to sustained growth. Using an original census-based dataset, this paper explores the role of gender on the trade-off between education and fertility across 86 French counties during the nineteenth century, as an empirical extension of Diebolt-Perrin (2013). We first test the existence of the child quantity-quality trade-off in 1851. Second, we explore the long-run effect of education on fertility from a gendered approach. Two important results emerge: (i) significant and negative association between education and fertility is found, and (ii) such a relationship is non-unique over the distribution of education/fertility. While our results suggest the existence of a negative and significant effect of the female endowments in human capital on the fertility transition, the effects of negative endowment almost disappear at low level of fertility.

Keywords: Cliometrics • Education • Fertility • Demographic Transition • Unified growth theory • Nineteenth century France

JEL Classification: C22, C26, C32, C36, C81, C82, I20, J13, N01, N33.

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Introduction

During the past two centuries, the Western world witnessed dramatic economic, demographic and cultural upheavals. This period marked a turning point in historical economic and demographic trends. Western countries experienced similar patterns of economic and demographic transition, despite some variations in terms and timing and speed of changes (Galor, 2012). Before the Industrial Revolution, all societies were characterized by a very long period of stagnation in per capita income with high fertility rates. Since this fateful period, Western countries observed a complete reversal with high sustained income per capita and low fertility (Becker *et al*., 2012; Klemp, 2012). In parallel to economic and demographic transitions, we note profound changes in the structure of the population: formal education became accessible to a vast majority of the population while drastic changes occurred in gender relations.

Empirical regularities raise numerous questions about the potential interaction between demographic transition and economic development in the transition from the epoch of Malthusian stagnation to the Modern Growth Regime. In particular, what can explain the dramatic reversal of the relationship between output growth and population? What are the underlying behavioral forces behind the demographic transition? What are the endogenous interactions between education and fertility that result in the transition phase?

Despite a renewed interest in recent years, empirical evidence of the existence of a parental trade-off between the quantity and the quality of children is still scarce and controversial. The question of whether this correlation is causal remains open (Diebolt, 2015). Besides, as pointed out by Becker *et al.* (2010, 2012), most existing evidence supporting the quantity-quality trade-off is based on modern data (such as Rosenzweig and Wolpin (1980), Cáceres-Delpiano (2006), Black *et al.* (2005), Angrist *et al.* (2010) or Li, Zhang and Zhu (2008) for contemporary analysis). Historical analyses have recently been addressed by Becker *et al.* (2010, 2012), Klemp and Weisdorf (2011) and Fernihough (2011) respectively for Prussia, England and Ireland. Moreover, despite the existence of sporadic research on the existence of any causality between quantity and quality of children, neither modern nor historical antecedents exist that might answer an important question: Does the quantity-quality trade-off (if there is any) exhibit monotonicity over the distribution of the dependent variable or it is just an empirical artefact of only one point of the distribution. For apparent theoretical and policy reasons, heterogeneity in the existence of such a relationship over the entire distribution of education or fertility may have varied implications, which thus far have not been investigated in the literature. Given the veritable importance of this aspect of modelling, this paper will model the interaction between investment in education and fertility using a heterogeneous distribution approach, viz., quantile regression approach.

Ours will be an investigation from a historical perspective. In particular, using a census-based dataset of 86 French counties built from the *Statistique Générale de la France* (1851, 1861, 1867, 1881, 1911 censuses), we empirically investigate: *(i)* whether a child quantity-quality trade-off existed in France in the 19th century; and *(ii)* whether and to what proportion male and female endowment in human capital affected fertility. This paper is the first attempt to test the existence of a quantity-quality trade-off using French data.

France is an iconic case, particularly interesting to investigate. While France was the most populated European country at the dawn of the nineteenth century, it is the first country to experience the fertility transition in Europe. The French demographic transition can be clearly divided in two clear phases. Before 1851, fertility transition is a rural phenomenon, rapid in its infancy and driven by prosperous departments (Van de Walle, 1986). After 1851, the process slows down and fertility even increases slightly for almost half departments. During the last quarter century, France experiences a resurgence of its demographic transition at the same time of the beginning process in most European countries. In the 19th century France was also a precursor in the light of primary education. In 1792, Condorcet already proposed a reform for secular, compulsory and free schooling. Since 1833, the Guizot law has required municipalities with more than 500 residents to fund a primary school and a teacher. An even more fundamental progress is the repeal of the Ferry laws establishing free (1881), secular and compulsory (1882) primary school.[1]

Our empirical analysis focuses on the link between education and fertility choices. We first start by investigating the existence of the trade-off in 1851 France using simultaneous quantile regression framework – which is known to allow significant heterogeneity in the slope estimates over the distribution of the dependent variable. Possible endogeneity bias is corrected by employing an instrumental variable quantile regression approach for both education and fertility equations. Our results show evidence of a significant interaction between quantity and quality of children in 19th

[1] These laws are seen as a consequence of the 1870 war against Prussia – German soldiers being judged better educated than the French one.

century France. Second, based on the same method, we test the impact of the accumulation of maternal and paternal human capital in the middle of the 19th century on the fertility transition at the turn of the 20th century. We find that the fertility transition in France was significantly more pronounced in counties with higher female endowment in human capital. Hence, our findings of a negative relationship between female human capital and fertility are consistent with the unified cliometric growth model of Diebolt and Perrin (2013b) – in which the transition from stagnation to sustained growth is brought about by a gradual change in the female bargaining power within the household.

The rest of the paper is structured as follows. Section 1, introduce the theoretical background and place our contribution within the existing literature. Section 2 presents an annotated description of our dataset by presenting main conclusions from the descriptive statistics and distributional characteristics. Section 3 presents methodological setting where we provide both empirical construct drawn from theory and estimation method concerning quantile regression approach. Empirical results on the existence of a quantity-quality trade-off in 1851 France are discussed in Section 4. Section 5 tests the validity of the hypothesis that female empowerment played a key role in the process of demographic transition. Finally, we conclude by summarizing the main findings of the paper.

1. Theoretical Background and Related Literature

1.1 Theoretical Illustration and Testable Predictions

First advanced by Galor and Weil (1999, 2000),[2] unified theories of growth model the transition from Malthusian stagnation to modern economic growth in a single framework. Common to most unified models, the emergence of new technologies during the process of industrialization increased the need for skilled workers (i.e. the demand for human capital) and induced parents to invest more in the education of their offspring. Investing in education increases the opportunity cost of having children and implies for parents to choose between number and education of children. This process in turn triggered a shift from high fertility to greater education of children which led to the demographic transition. This is the so-called child quantity-quality trade-off.[3] Since the seminal work of Galor and Weil (1999, 2000) and Galor and Moav (2002), the role of

[2] The seminal work of Galor and Weil was quickly followed by new contributions (for an overview see Diebolt and Perrin, 2013b).
[3] Becker (1960) was the first to introduce the distinction between child quantity and child quality, followed by Becker and Lewis (1973) and Willis (1973).

human capital has been largely recognized as crucial in the movement toward developed economies. In most unified growth model, the child quantity-quality trade-off is considered as a key mechanism allowing economies to switch from a positive correlation linking income and population size, during the Malthusian stagnation, to a negative one, during the modern growth regime.

In this line of research, Diebolt and Perrin (2013b) bring to light new determinants of the long transition process. Their work incorporates novel and additional mechanisms consistent with observed stylized facts, emphasizing the importance of the role played by women in the development process. The main concern of their study is precisely to show to what extent and through which mechanisms gender equality affects decisions taken by members of the household and acts on long run economic development. Through the construction of a cliometric unified growth model, they capture the interplay between fertility, technology and income per capita in the transition from stagnation to sustained growth. The theory suggests that female empowerment has been at the origin of the demographic transition and engaged the take-off to Modern economic growth. At the dynamical level, the increase in gender equality and the rise in technological progress create higher opportunities for women to invest in skilled human capital. The negative correlation linking maternal investments in human capital and fertility (career or family – Goldin, 2006) encourages families to have fewer children but better educated ones. This process ultimately triggers to the demographic transition and plays a central role for the transition from stagnation to modern growth. The model therefore generates documented facts about epochs of stagnation, characterized by high fertility and low output, and modern growth, combining low fertility and sustained output growth.

Using the framework of Diebolt and Perrin (2013b), the quantity-quality trade-off can be characterized by the following simplified model. We consider a two-sex household that generates utility from the male consumption, c^m, the female consumption, c^f, and from the lifetime income of their children, yn – which results from supplying human capital on a competitive labor market. The parameter θ represents the female bargaining power in the household decision process[4]. A fraction θ of income is spent by the woman on consumption. The remaining fraction $(1-\theta)$ is spent by the man income on consumption. The parameter γ measures the value attached to the number of offspring relative to the labor force participation. The household preferences are represented by the following utility function:

[4] The female bargaining power is assumed to be function of the relative stock of human capital of the spouses and can be interpreted as a measure of gender equality within the household.

$$U\left(c^m, c^f, yn\right) = (1-\theta)lnc^m + \theta lnc^f + \gamma ln(yn) \qquad \text{with} \qquad \theta, \gamma \in (0,1) \tag{1}$$

Each member of the household is endowed with one unit of time. The women spend a fraction of her time r^f (with $r^f > r^m = 0$) rearing children. The price of a child is the opportunity cost associated with raising it, $rnwh^f$.Individual's quality is conditional to its endowment in human capital that depends positively on maternal endowment in human capital, $\hbar^f$, and on one's own investment in education e. The household lifetime budget constraint is therefore:

$$c^m + c^f \leq \left(1 - rn - e^f\right)wh^f + (1 - e^m)wh^m \tag{2}$$

The optimization problem yields to the following first order conditions on education,

$$e^m = \frac{1 + \underline{e}}{2} \tag{3}$$

$$e^f = \frac{\left(1 + \underline{e} - rn\right)}{2} \tag{4}$$

Everything else being equal, equation (4) depicts a trade-off between female investment in education and fertility. The optimal number of children is decreasing with the time invested by the woman in her education. Consequently, the acquisition of skilled human capital induces women to spend more time on education and to have fewer children.

The household optimal fertility is given by:

$$n^* = \frac{\left(1 - \underline{e}\right)}{r\theta} \frac{\gamma}{(2 + \gamma)} \tag{5}$$

The optimal fertility level is decreasing with the female marital bargaining power within the household. A higher level of gender equality within the household allows women to reduce their fertility and to invest more in education. Hence, women have fewer children but better educated ones. Ultimately, equations (4) and (5) show a trade-off between the number of children and their quality. The quantity-quality trade-off implies the optimal number of children to be decreasing with the time invested in each of them.

Thus, the theory generates two main testable implications:

(1) The existence of a child quantity-quality trade-off[5]
   - The optimal number of children declines if the cost of raising a child increases
   - The level of child quality increases when the cost of raising a child increases

(2) The existence of a female trade-off between educational investment and fertility[6]
   - The level of fertility is inversely proportional to the level of female investments in education
   - The female accumulation of human capital triggers a fertility transition

1.2 Related literature

Despite the key role played by the quantity-quality trade-off in the unified growth literature, empirical investigations of the links between fertility and education remain scarce. Two types of studies have emerged: the studies investigating the effect of fertility on education and the studies investigating the effect of education on fertility. Most of these studies are based on modern data. This is the case of the work done by Rosenzweig and Wolpin (1980), Cáceres-Delpiano (2006), Black *et al.* (2005), Li *et al.* (2008) or Angrist *et al.* (2010) for more contemporaneous studies. Analyses based on past data have however been recently addressed. Hence, Becker *et al.* (2010, 2012) have investigated the relation using Prussian data while Klemp and Weisdorf (2011) studied the English case and Fernihough (2011) the Irish one.

Some authors have chosen to investigate the effect of fertility on education. The first study investigating the fertility effect on education is Rosenzweig and Wolpin (1980). Using an IV strategy with modern data, they found evidence supporting the existence of a quantity-quality trade-off among Indian households. Hanushek (1992) finds a distinct trade-off between quantity and quality of children, using individual level data within 1971 and 1975 in Iowa. Considering the allocation of time to children, he finds that achievement falls systematically with increased family size. Using multiple births Black *et al.* (2005) and Angrist *et al.* (2010) corroborate this effect from fertility to education.

[5] An increase in the relative price of the quantity of children decreases the number of children and increases the investment in each child.
[6] According to the theory, this trade-off (based on women anticipations) is at the origin of the child quantity-quality trade-off.

Several studies have investigated this relationship using Chinese data and have found contradictory results. Estimating the effect of family size on school attainment using multiple births and variation in China's one-child policy, Qian (2009) find a positive effect of the increase in family size on the child enrollment rate. Conversely, Rosenzweig and Zhang (2009) show that having extra-child decreases significantly endowment in human capital of all children in the family. Based on individual level data from 15 Anglican parishes within the period 1700-1830, Klemp and Weisdorf (2011) examine the existence of the child quantity-quality trade-off for historical England. Using time interval from marriage to first birth (number of siblings who survive to age five) as a measure of exogenous variation in family size, they find a negative causal effect of family size on individual literacy. Using a sample of individual level data from 1911 Census of Ireland, Fernihough (2011) investigates the impact of sibship size on school enrollment in Belfast and Dublin. He finds strong evidence of a negative impact of extra sibling on school enrollment. He also finds that the quantity-quality mechanism is stronger in more industrialized areas.

Other authors have however chosen to analyze the opposite direction of causation, from education to fertility. Galloway, Hammel and Lee (1994) show a negative effect of educational variables on the marital fertility rate for Prussia. Similarly, Dribe (2009) find that variations in the levels of education are relevant for explaining fertility decline in Sweden for the period 1880-1930. From micro data in 1970s Indonesia, Breierova and Duflo (2004) estimate the effect of education on fertility and child mortality. On the one hand, they show that parental education has a strong causal effect on the reduction of child mortality. They also find that female education seems to matter more on female age at marriage and on early fertility rather than does male education. Similarly, Osili and Long (2008) estimate the exogenous effect of female education on fertility (by age 25) in 1970s Nigeria. They conclude that the establishment of an educational program increased female schooling and decreased fertility. Bleakley and Lange (2009) show the consistency of the quantity-quality trade-off and unified growth theory in the case of Southern USA. They argue that the eradication of hookworm disease reduced the cost of child quality increased education and decreased fertility. Murphy (2015) examines the potential factors driving the fertility decline within France during the fertility transition. Using panel fixed-effects, he finds that more education (measured by the literacy rates) is negatively correlated with fertility[7].

[7] These results are not confirmed when the author uses the pooled OLS analysis.

Only Becker *et al.* (2010) investigate both direction of causality. Based on aggregated regional data for 19th century Prussia, they find evidence of a causal relation between education and fertility, consistent with the quantity-quality trade-off. More recently, Becker *et al.* (2013) show that increases in women's education played a role in reducing fertility in 19th century Prussia, already before the demographic transition.

2. A French County-Level Database on Education and Fertility

2.1 Source and Measurement

In this paper, we address the quantity-quality trade-offs in historical perspective using French county-level data. We consider both the short-run and the long-run nexus between education and fertility. First, we investigate the two directions of causality between child quantity and child quality in 1851 in France. Second, we study the long-run impact of the accumulation of human capital on the demographic transition during the 19th century. Our incentive is to check whether parental investment in education has an effect on the ability of their children to succeed in education (process driving to the accumulation of human capital). To do so, we use county-level data collected from diverse publications of the *Service de la Statistique Générale de la France*. Our dataset covers information about aggregated individual-level behavior for 86 French counties (*départements*).[8] The French Statistical Office publishes data from 1800 but it is from 1851 only that published data rank population by age, gender, marital status and other essential information to study the evolution of fertility behavior and habits regarding education.

The major part of the dataset is constructed from General Censuses, Statistics of Primary Education, Population Movement and Industrial Statistics conducted in 1851 (1850 for Education, 1861 for Industrial Statistics). The rest of the data stems from diverse sources. A part of fertility data is available from the Princeton European Fertility Project (Coale and Watkins, 1986). Data on life expectancy at birth come from Bonneuil (1997). A combined use of the various Censuses allows us to construct a dataset with detailed information on fertility, mortality, literacy rates, and enrollment rates in primary schools for both boys and girls, employment in industry and agriculture by gender, level of urbanization and stage of industrialization. In addition, we use data

[8] 1851 France consists of current metropolitan French *départements* except Alpes-Maritimes, Savoie and Haute-Savoie.

from French Censuses for the years 1821, 1835, 1861, 1881 and 1911 to get more demographic and socio-economic information necessary to carry out our analysis.[9]

In the *short-run* analysis, we use the crude birth rate as a measure of fertility behavior, defined as the number of birth per thousand people. To measure education, we use enrollment rates in public primary school in 1850, constructed as the number of girls (boys) attending school divided by the total number of girls (boys) aged 6-14. The main specifications applied in our analysis are expected to capture: *(i)* the variations in fertility with educational level and in education with fertility level; and *(ii)* the supply and demand factors represented by a set of control variables. The supply and demand factors aim at capturing both economic and cultural factors likely to have impacted educational and fertility behaviors. The demand for children, for instance, depends on the opportunity cost of having children. Based on the prediction of theoretical models, we expect income to affect fertility. As a proxy for the income level, we use the urbanization level, the population density, as well as the employment opportunities, measured by the share of women (men) employed in manufacturing and in agriculture. As a control for the supply of children, we use the life expectancy at birth. The life expectancy at birth allows controlling for the decline in infant mortality and may be a proxy for the lengthening of both the individual longevity and the reproductive period. We also control for religion in order to account for cultural differences that may have affected individuals' behaviors in regards with fertility (birth control) and education (Lutheran ideas). As a measure a religious practices, we use the share of Protestants within the population.

For the *long-run* analysis, we use literacy rates to capture the amount of human capital accumulated. One limitation (already raised by Becker *et al.*, 2010) of using enrollment rate in education relates to the fact that attendance at the census date might not be the same as year-round attendance what prevent from capturing the amount of human capital accumulated. We use similar control variables to the one used in the short-run analysis. Hence, we control for the level of urbanization, employment opportunities, and religious practices. As additional controls, we use the crude birth rate in 1851 in order to address potential issues raised by intergenerational correlation of fertility. In order to account for differential fertility development that might have occurred before the fertility transition, investigated over the period 1881-1911, we control for the initial level of fertility in 1881, measured by the crude birth rate.

[9] To our knowledge, these data have not yet been used for micro-econometric analysis.

2.2 Data characteristics

a) *Descriptive statistics*

Table 1 reports descriptive statistics of the variable used in our analysis. In general, the statistics evince heterogeneity in our variables across counties and over time. In 1850, 54.5% of boys aged 6-14 were enrolled in public primary school, while the enrollment rate in public primary school for girls was 36%. Enrollment rates go from about 19% to 106% for boys and from 0.3% to 99% for girls.[10] In 1881, 70.84% of boys and 57.16% of girls were enrolled in public primary schools. In thirty years, both shares increased substantially. The minimum and maximum boys' and girls' enrollment rates in 1881 are 41.14% and 106.44%, and 19.88% and 97.67%, respectively. These variations can be explained by several factors: the diffusion of the official French language, the difference in attitudes toward education between Catholics and Protestants (Becker and Woessmann, 2009), the wave of spreading ideas coming from Prussia and the insufficiency of educational resources deployed in rural areas in terms of teachers and financial spending.

Data on fertility also show an important heterogeneity across counties. The minimum and maximum crude birth rates in 1851 are 18.72‰ and 34.27‰, respectively. These differences suggest that some counties have experienced a demographic transition before others. According to Chesnais (1992), a crude birth rate below 30 per one thousand individuals marks the entry into a regime of controlled fertility. Longitudinal data on fertility shows the existence of two clear phases in the French demographic transition during the 19th century. The premises of a fertility decline in France appear at the turn to the 19th century. Before the mid-century, it consisted mainly in a rural phenomenon led by more prosperous districts. After a couple of decades of stagnation (from 1851), the fertility transition resumes in the 1870s (after the Franco-Prussian war) and diffuses to the rest of France. In 1881, the minimum and maximum crude birth rates are 17.28‰ and 34.57‰, respectively.

[10] Enrollment rates above 100% are due to the possibility that children below 6 years old and above 14 years old might have been enrolled in public primary schools. In 1851, 44.4% of boys aged 5-15 were enrolled in public primary school, while the enrollment rate in public primary school for girls was 30%. Yet, there is a strong heterogeneity in education across counties. It goes from a minimum of about 15.5% to a maximum of 86.1% for boys and from 0.3% to 81% for girls.

Table 1 – Summary statistics				
	Mean	Std. Dev.	Min	Max
Crude birth rate	26.95	3.597	18.717	34.275
School enrollment rate	0.454	0.229	0.13 3	1.029
Boys enrollment rate	0.544	0.211	0.188	1.059
Girls enrollment rate	0.356	0.259	0.003	0.997
Share in industry	0.029	0.047	0	0.370
Share in agriculture	0.426	0.106	0.031	0.655
Female in industry	0.036	0.070	0	0.552
Female in agriculture	0.615	0.179	0.037	1.054
Male in industry	0.057	0.081	0	0.636
Male in agriculture	0.737	0.171	0.046	1.135
Urbanization	0.059	0.083	0.007	0.736
Population density (km²)	1.011	3.166	0.219	29.907
Life expectancy at age 0	38.792	6.115	25.8	50.8
Marital fertility rate	0.497	0.109	0.298	0.747
Share Protestants (1861)	2.258	5.332	0.003	31.298
Male workers (1861)	0.048	0.037	0.006	0.160
Female workers (1861)	0.027	0.056	0.001	0.497
Share married women	0.389	0.048	0.303	0.479
Crude birth rate (1881)	24.22	3.798	17.28	34.57
Crude birth rate (1881-1911)	-0.245	0.092	-0.405	-0.002
Marital fertility rate (1881)	0.473	0.130	0.266	0.819
Marital fertility rate (1881-1911)	-0.290	0.091	-0.476	0
Boys enrollment (1851-67)	0.600	0.342	-0.076	1.624
Girls enrollment (1851-67)	1.067	1.962	0.017	17.485
Male literacy (1856-66)	0.113	0.092	-0.093	0.358
Female literacy (1856-66)	0.271	0.213	-0.085	0.956

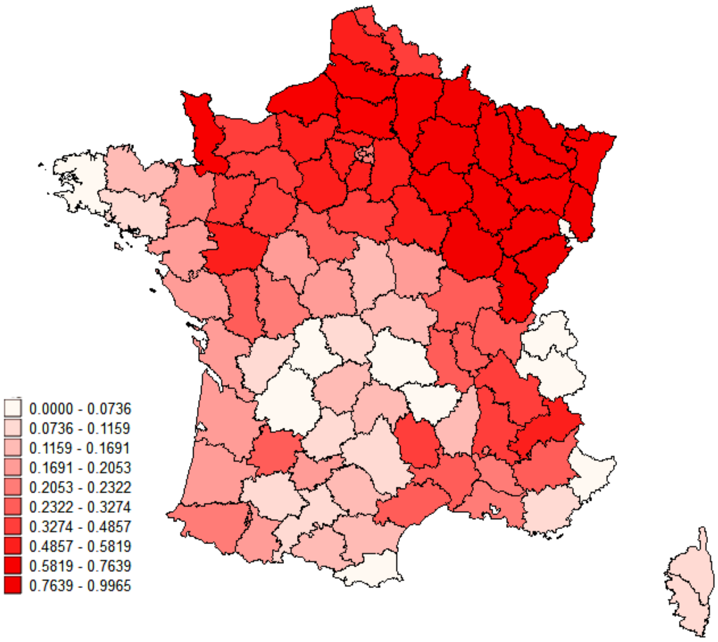
Note: Detailed description of variables is provided in appendix

b) Distribution

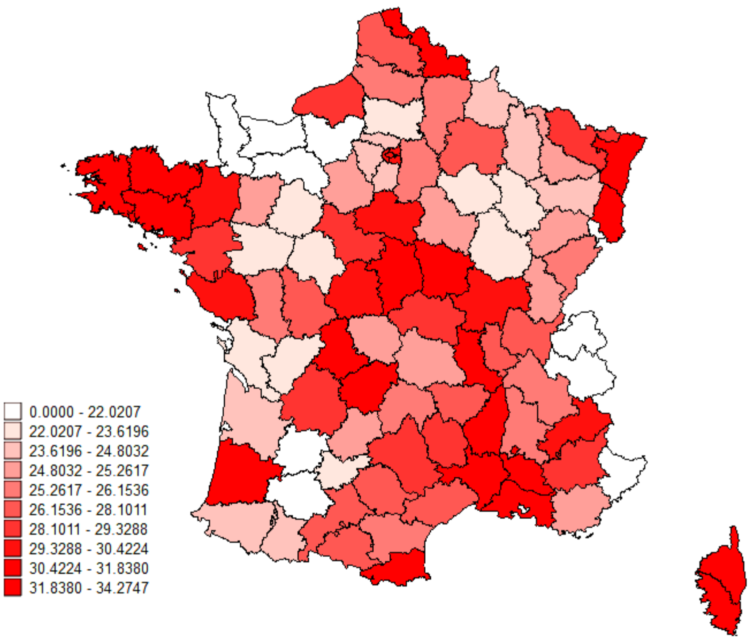
We present here distributional characteristics of fertility and education to motivate the development of required estimation tool for testing hypotheses on quality-quality trade-off. First, we provide evidence of geographic distribution of enrollment rates (proxy for education) and crude birth rates (proxy for fertility). Second, we present density plots of these variables to detect possible multimodality or cluster dynamics in the data. The geographical distribution of enrollment rates in 1850 is shown in Figure 1a. Figure 1b displays the geographical distribution of crude birth rates in 1851. Similarly to Prussia (see Becker *et al.*, 2010), the most industrialized area (the Northeast part in France) shows higher enrollment rates. The remainder of France which is more agricultural displays higher levels of fertility.

Figure 1: Geographical Distribution of Education and Fertility

(1a) Girls Enrollment Rate, 1850



(1b) Crude Birth Rate, 1851



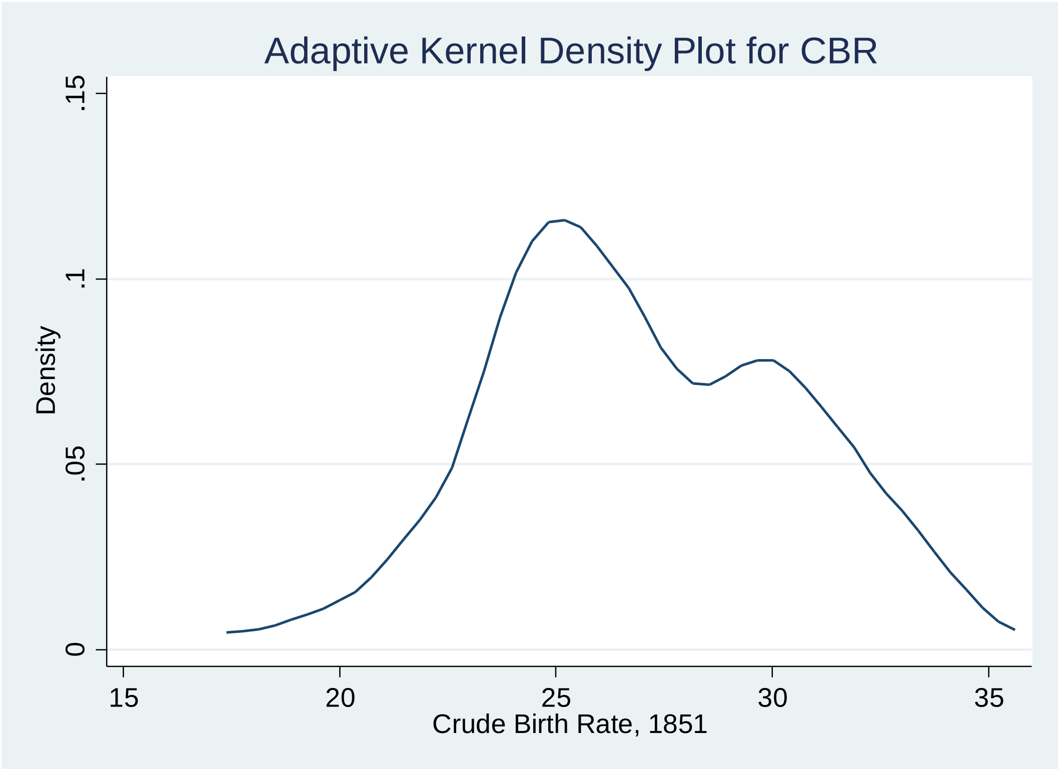
Sources: Using data from Statistique Générale de la France – Enseignement Primaire 1850; Census 1851

Our next focus is on detecting if the (statistical) distribution of these variables presents any evidence of multimodality. This is important for several reasons; one of them being that such evidence would guide us in choosing the correct estimation method – for instance, whether to focus on the 'mean-based' conventional OLS method or to adopt 'quantile-based' full distributional method. Another leading reason is that any evidence against unimodality of distribution of these variables would indicate possible presence of multiple equilibria/clusters, leading to variable inferences at various points of the distribution the dependent variable. Alternately speaking, it might be possible for instance, that the response of fertility to low educational attainment level is significantly different (both quantitatively and direction of causality-wise) from the one at high educational attainment levels. From theoretical perspective, this makes sense as one would expect the existence of quality-quantity theory primarily at higher educational achievement levels leading to gender equality in education and female empowerment. The choice of fewer children then becomes essentially a reflection of investigation of the relationship at higher quantile of the distribution of the variable. The non-uniqueness of fertility-education trade-off relationship at various quantile of the distribution (instead of just focusing on the mean of the distribution, i.e., OLS) is more informative and would enable us to test the validity and consistency of the theory at various points of the distribution.

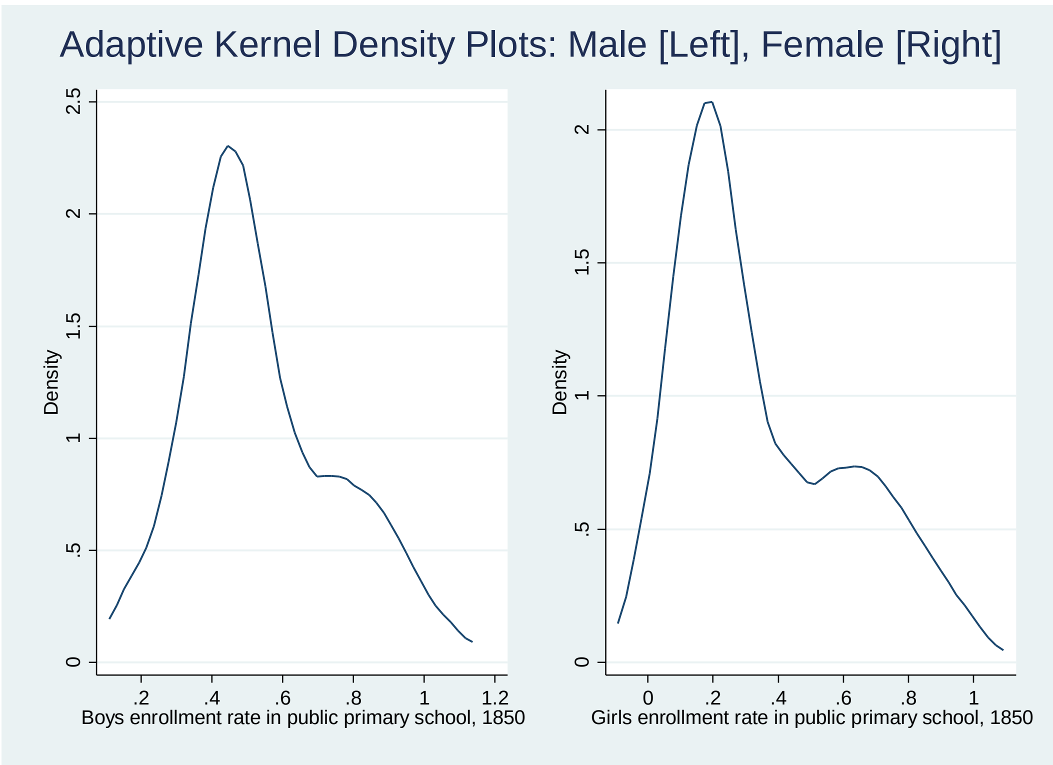
Following this idea, we have presented Adaptive Kernel density plots of crude birth rate (Figure 2a) and enrollment (Figure 2b). It needs mentioning at this point that adaptive Kernel density extends the possibilities offered by Kernel density estimation in two ways: first, it allows the use of varying, rather fixed bandwidth. Second, it provides estimation of pointwise variability bands. Following this density estimation, these two figures present evidence of significant bimodality – which is further confirmed by Hartigan and Hartigan's (1985) Dip test. In case of fertility, the crude birth rate mean is 26.976 with a standard deviation of 3.610. However, Figure 2a present two significant modes (one around 30 years and another at 25 years). These modes, as confirmed by Diptest are significant at 5% level. Likewise, education (enrollment rates) for both men and women also depict significant bimodality (weaker for men – Diptest accepted at 10% level) whereas it is stronger for women (accepted at 5% level). These results and the reasons cited above motivate us to go beyond conventional OLS based estimation method, as the estimated coefficients may be either under- or over-estimated and may not present the complete picture of the response of education to changes in fertility (and the converse). Alternative estimation method, such as quantile regression technique, has been found to be very useful in this regard. We present them in the next section.

Figure 2: Distributional Characteristics of Fertility and Education

(2a) Distribution for crude birth rate



(2b) Distribution for enrollment rate



3. Methodological setting

In this section we develop and present the methodological construct that would adequately account for sensitivity of education-fertility relationship to distributional heterogeneity. Towards this end, we first describe the empirical framework and use the same to develop necessary methodological tool.

3.1 Empirical construct

a) Short-run

We investigate the short-run relationship between investment in human capital and fertility. Following the work done by Becker *et al.* (2010), we differentiate between the two directions of causality: from education to fertility and from fertility to education. We estimate the following empirical models separately (Wooldridge, 2002):

$$fertility_i^j = \alpha_1 + \beta_1 education_i + \boldsymbol{X}_{i1}\, \delta_1 + e_{i1} \tag{6}$$

$$education_i^k = \alpha_2 + \beta_2\, fertility_i + \boldsymbol{X}_{i2}\delta_2 + e_{i2} \tag{7}$$

where $fertility_i$ and $education_i$ refer to the crude birth rate and the enrollment rate in public primary schools for each county i. The coefficients β_1 and β_2 are our parameters of interest. $\boldsymbol{X}_1$ and $\boldsymbol{X}_2$ are the vectors of control variables.

b) Long-run

We use equation (8) to test the hypothesis that increasing investment in education might have played a significant role in the fertility transition:

$$\Delta fertility_{i,1881-1911} = \alpha_i + \beta\, \Delta\, education_{i,1856-66} + \boldsymbol{X}_i\; \delta + e_i \tag{8}$$

where the percentage change in the crude birth rate between 1881 and 1911 is the dependent variable and the percentage change in literacy rates between 1856 and 1866 is our variable of interest. $\boldsymbol{X}$ is the vector of control variables (see Appendix for a detailed description of the variables). The time lag of twenty five years between the dependent and the explanatory variable prevents from having a direct simultaneity between the variables.

We estimate equations (6) - (8) by using quantile regression approach. The motivations for preferring quantile method to ordinary least squares (OLS) have been presented in Section 3. Based on quantile approach (with and without instrumentation), our main incentive is to investigate: *(a)* to what extent the level of male education at time t is correlated with the level of parental fertility at time t; and *(b)* to what extent the level of girls education at time t is correlated with the level of parental fertility at time t.

Indeed, investigating the relationships from a gendered perspective allows us to compare the respective effects of boys and girls education on fertility and the effect of fertility respectively on boys' education and on girls' education. We keep in mind that we suspect a bi-causal relationship between fertility and education. Unobserved characteristics affecting schooling choices are potentially correlated with unobservable factors influencing the decision to have children (and inversely). Estimating a causal relationship may consequently be biased by some potential endogeneity of each of our variables of interest. This is accounted for by employing an instrumental variable quantile regression approach. Nonetheless, our main motivation in this paper is not to measure the exact causation but to have intuitive results on the fertility-education nexus.[11]

To control for the main determinants of fertility and education The covariates used in the regression analysis are: *(i)* proxies for the level of industrialization specified as the level of urbanization[12] and the population density; *(ii)* employment opportunities measured by the share of people making their living of agriculture and the share of people employed in manufacturing; *(iii)* the share of Protestants; and *(iv)* the life expectancy at age 0.

3.2 Estimation approach: (Instrumental variable) quantile regression

Limitations of OLS with respect to representativeness of heterogeneity of slope estimates especially in the presence of cross-sectional heteroscedasticity across the distribution – are well known. Moreover, as reflected in Section 3, the distributions of both education and fertility are significantly multimodal necessitating the use of an alternative estimation method rather than the conventional OLS. One can, for instance

[11] The central challenge in estimating the causal relation between education and fertility decisions is that unobserved characteristics affecting schooling choices are potentially correlated with unobserved factors influencing the decision to have children (and conversely). In addition, the presence of error in available measures of schooling can also introduce a bias towards zero. Given, the presence of error in available measures of schooling can also introduce a bias towards zero and possible problems of endogeneity and omitted variables, our results do not tend necessarily to have a causal interpretation.

[12] The level of urbanization is defined as the share of people living in towns populated by more than 2000 inhabitants.

employ non-parametric method and compare the distribution of the dependent variable and the regressor. However, these methods inherit the natural limitation of focusing on the *mean of the distribution* and its changes in the shape of the distribution. What is required, however, is the effect of the regressor on the entire distribution of the dependent variable. Quantile regression approach has been proved very useful in this regard (Koenker and Bassett, 1978, for instance). In quantile regression, by specifying different covariate effects at different quantile levels we allow covariates to affect not only the center of the distribution (that is mean-based OLS estimation), but also its spread and the magnitude of extreme events. Indeed, by using quantile model we allow for unobserved heterogeneity and heterogeneous covariate effects. In addition, quantile regression allows for some conditional heteroskedasticity in the model (Koenker and Portnoy, 1996), and is a method that is more robust to outliers

Recalling the quantity-quality trade-off problem in eq. (6) and denoting, fertility as (F), Education as (E), and other variables as (X), we can re-write the vectorial notation as follows:

$$\begin{aligned} F &= \beta E + \gamma X' + \varepsilon \\ X &= f(z,u) \\ \varepsilon &= \mu + u \end{aligned} \tag{9}$$

We assume that Education (E) not only affects Fertility (F) but also life expectancy, urbanization, and many other variables (denoted in our equation as X). z is a vector of instruments which drive education but are uncorrelated with u and ε. Moreover, μ are country specific factors affecting the evolution of F and E. As evident, we are interested in estimating β, the causal effect of education on fertility, at different quantiles of the conditional distribution of fertility. The following possibilities arise:

OLS based regression

In a typical least squares approach, one may focus on estimating:

$$E(F_i|E_i, X_i) = \beta E_i + \gamma X_i \tag{10}$$

In eq. (10), β captures the 'average' response of fertility due to a small change in educational attainment and other variables. What is missing in this estimate is the possibility of *heterogeneous* response of fertility to changes in the explanatory variables.

It is now well-known that average response of the dependent variable is less informative of the actual dynamics that occurs between the regressors and the full range of distribution of the dependent variable. Indeed, this is the case in the present context. As demonstrated before, the unconditional distribution of fertility is strongly bimodal. Thus, it seems that the analysis that focuses on the (conditional) mean of the distribution might miss important distributional effects of education and other variables on fertility. To capture this effect, quantile regression will offer a wholesome view of the effect of education on the entire distribution of fertility (or vice versa as in Eq. 8). Given the cross-sectional nature of our data, we adopt the following *cross-sectional quantile regression* framework.

Quantile estimation

$$Q_{F_i}(\tau|E_i, X_i) = \beta(\tau) + \gamma(\tau)X_i \quad (11)$$

The parameter $\beta(\tau)$ captures the effect of education at the τ-th quantile of the conditional distribution of fertility. This model can be estimated by solving the following minimization problem:

$$\min_{\beta,\gamma} \sum_{i=1}^{N} \rho_\tau(F_i - E_i - \gamma X_i) \quad (12)$$

where $\rho_\tau(u)$ is the standard quantile regression check function (see, e.g., Koenker and Bassett, 1978; Koenker, 2005). The partial effects for education on fertilty can be obtained by $\frac{\partial Q_t(F_i|E_i)}{\partial E_i}$.

Endogeneity issue

Two types of endogeneity problems can plague regressions of education on fertility. One type is the simultaneity bias introduced by the reverse causality of education and fertility (eq. 8). A second type of endogeneity problem arises from omitted variable bias. While including policy variables helps reduce the problem of the endogeneity of education, it is still quite plausible that a third variable jointly causes both fertility and education – perhaps religious, cultural or geographic factors. In order to mitigate the problems of endogeneity, we innovate upon the previous literature by employing an instrumental variables approach in our cross-sectional quantile regression (see for instance, Chernozhukov and Hansen (2005) and Harding and Lamarche (2009) for detailed estimation procedures). The question may arise on the choice of instruments. Because we have two different channels (fertility to education and the reverse) for quantifying quantity-quality trade-off, several possible instruments can be considered. In case of fertility-education channel (equation 6), there are a number of possibilities for instrumenting education. For instance, one can use enrollment in 1851, distance to Mainz, share of male (female) spouse signing the contract 1816-20, land ownership inequality in 1835, agricultural inequality, public primary schools for 100 boys and girls.

Similarly, when we consider the reverse channel, i.e., education-fertility relationship, the possible instruments for fertility are crude birth rate in 1821, adult sex ratio 15-45 , share of dependent children in 1851, children and non-married sex ratio in 1821, 1831, and 1836. As we know, all instruments may not identify the dependent variable and may suffer from weak-identification problem. Moreover, many of them may not be strictly exogenous. The possibility of weak correlation of the instruments with other regressors in the two different channels we are interested in estimating can make estimated coefficients unreliable. Therefore, we have performed a Principal Component Analysis of the instruments and have chosen the best instruments based on the highest factor loading. The results are also supported by Sargan's overidentification test. Accordingly, we have chosen the adult sex ratio and the share of dependent children as instruments for fertility, whereas the distance to Mainz and the share of male (female) spouse signing their marriage contract in 1816-20 have been chosen as instruments for education.

4. Results

4.1 From Education to Fertility

Two types of results are presented, viz., quantile regression estimates without accounting for endogeneity bias, and quantile regression estimates accounting for possible endogeneity. Estimations have been performed for both men and women at 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} quantiles. To minimize space, we have reported in all Tables lower quantile ($\tau = 25^{th}$), median quantile ($\tau = 50^{th}$ – generally regarded as an approximate to OLS estimates), and an upper quantile ($\tau = 75^{th}$).

We begin with the case where the dependent variable is fertility (crude birth rate). In all tables, the results are presented in three columns (quantile estimation for each case). Beginning with the restrictive model where only fertility and education variables are considered (column 1), we continue to add more explanatory variables with education: the role of agriculture, industry, urbanization, and population density (column 2), the role of share of Protestants (column 3), and the potential role of life expectancy at birth (column 4).

Overall, looking at all columns, across quantiles, and for both men and women, we find evidence of a quality-quantity trade-off in the short-run, although the magnitudes are observed to vary across the distribution of the dependent variable in question. The 50th quantile – which approximates OLS estimates – shows that the coefficient for education is significant at the 0.1% and negative for both genders. As per the estimates of median quantile, we observe in Table 2 that in more densely populated environments, fertility rates are significantly lower (at 0.1%), whereas in more urbanized counties, fertility rates are higher (at 5%). In line with the latter result, counties with a larger share of male employed in manufacturing exhibit significantly higher fertility rates (at 5%). This result may be due to a positive income effect. The male wages are likely to be higher in counties where the industry is more developed what is expected to increase the demand for children. Contrary to what has been found by Becker *et al.* (2010) for Prussia, fertility is significantly higher (at 1%) in counties where the share of Protestants is larger (see Table 2 and Table 3). Life expectancy at age 0, however, is negatively associated with fertility. The life expectancy at age 0 is expected to capture the variations in infant mortality. According to the adaptation hypothesis, the decline in infant mortality might have induced individuals to act such as maintaining a sustainable number of offspring by reducing their fertility. Whatever the specification of equation (6), the coefficient of education remains strongly significant and negative for both boys and girls. These results seem to confirm the existence of a negative effect of child quality on the child quantity.

Are the results found at median quantile (50th quantile) significantly different than at low (10th) and high (75th) quantiles? Do we observe a consistency in the estimated coefficients? The direction and magnitude of effects can be gauged by examining the sensitivity of results at various quantiles of the dependent variable. For the restricted model (column 1), as well as for broader models (column 2 through column 4), the effect of education has been found to be both negative and significant at 1% level in Table 2. In comparison to the median quantile, both lower and upper quantile estimates of the effect of education on fertility have been found to be small and negative with magnitude of effects at higher quantile observed to be smaller than the one obtained at lower quantile (column 1-column 3). Similar patterns are observed in Table 3 (for women). A monotonic decline in the magnitude of coefficients (although negative) is noted in column 4 for both tables where the most general model is estimated. The heterogeneity in the estimated coefficient of education on fertility, as observed in Tables 2 and 3, clearly demonstrates that OLS based estimates may under-represent the significant variability in the estimates, that is, the response of negative effect of education on fertility being smallest at higher quantile and largest at smaller quantile (column 4, the most general model). Moreover, the R^2 value is found to be greatest for the most general model (with a value of 0.402 at 50th quantile) in comparison to 0.123 (for the restricted model, column 1). Of course, within quantile heterogeneity in R^2 is also observed, implying that the same explanatory variable can have variable predictive power for counties at smaller quantile of fertility distribution than at median and higher quantiles.

While quantile estimates in Tables 2 and 3 are reflective of the general trend in the empirical literature in quantity-quality trade-off, these may not be taken seriously if there is a possibility of endogeneity bias in the relationship between fertility and education, and vice versa. In the preceding section, we have provided the mechanism and logic of the use of instrumental variable while performing quantile regressions. Table 4 and 5 report the IV estimates of equation (6) where the dependent variable is the crude birth rate. Clearly, as distinct from Tables 2 and 3, we find that, for each model specification and quantile, the estimated coefficients of education on fertility are consistently smaller at higher than at lower quantile.

In Tables 4 and 5, interesting insights emerge on the variable effect of education on fertility when education is being instrumented by distance to Mainz. First, we observe that the effect of urbanization on fertility rates has moved from being negative but insignificant at lower quantile (column 4) to becoming positive and significant at higher quantile (for male). In comparison to the estimates at median quantile – where it was observed that at more densely populated environments fertility rates are significantly lower, whereas in more urbanized counties fertility rates are higher – in IV regression, the results seem consistent at 25th quantile. The trend seems to get reversed and in some cases the effects disappear at higher quantile, depicting once again the necessity of using full distributional assumption than undertaking inference at only 'mean' based estimates.

Table 2: Quantile regression results from education to fertility: Men

	Crude Birth Rate											
Dependent Variable	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Boys enrollment	-1.998***	-10.005***	-7.774**	-1.941***	-10.436***	-9.801***	-2.153***	-11.330***	-10.961***	-1.125*	-6.708***	-7.880***
	(.613)	(2.455)	(2.496)	(0.649)	(2.651)	(2.582)	(.649)	(2.579)	(2.573)	(0.684)	(2.521)	(1.975)
Male in agriculture				2.108**	5.053	-0.338	1.741*	3.503	-2.349	1.302	1.660	-3.517
				(1.043)	(5.471)	(4.337)	(1.061)	(5.508)	(4.202)	(0.846)	(4.198)	(3.817)
Male in industry				2.583**	12.040**	2.014	2.578**	12.018***	1.987	1.056	5.162	-2.588
				(1.027)	(4.781)	(4.951)	(0.997)	(4.462)	(5.117)	(1.153)	(4.080)	(6.365)
Urbanization				20.561***	83.342**	130.658**	13.754**	54.622	93.411**	10.476*	39.340	82.977**
				(7.353)	(37.846)	(41.879)	(6.988)	(37.590)	(42.463)	(5.890)	(34.226)	(40.870)
Population density				-0.412**	-1.686**	-3.192***	-0.265*	-1.066	-2.388**	-0.248**	-0.992	-2.340**
				(0.159)	(0.834)	(0.927)	(0.148)	(0.820)	(0.936)	(0.126)	(0.772)	(0.918)
Share Protestants							0.043**	0.184**	0.239***	0.024	0.093	0.176**
							(0.016)	(0.086)	(0.070)	(0.021)	(0.087)	(0.070)
Life expectancy										-0.144**	-0.699***	-0.489***
										(0.028)	(0.101)	(0.110)
Constant	26.123***	31.832***	35.002***	24.211***	26.941***	35.674***	24.548***	28.363***	37.517***	30.031***	54.859***	56.023***
	(.313)	(1.480)	(1.664)	(1.005)	(5.145)	(4.609)	(1.020)	(5.112)	(4.462)	(1.238)	(5.653)	(6.579)
N	86	86	86	86	86	86	86	86	86	85	85	85
R^2	0.101	0.123	0.090	0.167	0.180	0.244	0.191	0.201	0.291	0.362	0.402	0.423
F	10.62***	16.6***	9.70***	7.57***	19.61***	7.12***	7.18***	17.79***	11.08***	9.82***	37.78***	11.05***

Quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Boys enrollment rate is the share of boys aged 6-14 enrolled in public primary schools.
Source: County-level data from the *Statistique Générale de la France.*

Table 3: Quantile regression results from education to fertility: Women

Dependent Variable	Crude Birth Rate											
	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Girls enrollment	-1.594**	-7.603***	-5.105***	-1.714**	-8.895***	-7.371***	-1.778***	-9.136***	-7.700***	-0.642	-3.926*	-4.142**
	(0.542)	(2.252)	(2.044)	(0.549)	(2.228)	(1.911)	(0.540)	(2.213)	(1.866)	(0.599)	(2.264)	(1.453)
Female in agriculture				1.467*	1.928	-4.183	1.311	1.356	-4.963	1.005	0.205	-5.737
				(0.848)	(4.258)	(3.922)	(0.847)	(4.269)	(3.379)	(0.665)	(3.368)	(3.557)
Female in industry				3.448**	13.814***	0.245*	3.459**	13.857***	0.303	1.601	5.583	-5.335
				(1.093)	(5.486)	(4.035)	(1.081)	(5.247)	(3.872)	(1.103)	(4.226)	(4.298)
Urbanization				18.229***	75.696**	119.843**	12.925**	55.631	92.474**	4.985	18.543	67.118
				(6.428)	(36.11)	(41.88)	(5.902)	(35.123)	(42.018)	(5.652)	(36.588)	(43.667)
Population density				-0.368***	-1.528*	-2.958**	-0.248*	-1.074	-2.339***	-0.130	-0.521	-1.961**
				(0.142)	(0.809)	(0.934)	(0.130)	(0.787)	(0.939)	(0.125)	(0.825)	(0.981)
Share Protestants							0.037***	0.142*	0.194***	0.016	0.040	0.124
							(0.013)	(0.085)	(0.078)	(0.016)	(0.091)	(0.089)
Life expectancy										-0.141***	-0.677***	-0.463***
										(0.024)	(0.087)	(0.138)
Constant	25.609***	29.112***	32.609***	24.474***	27.256***	35.497***	24.537***	27.494***	35.822***	30.300***	54.880***	54.568***
	(0.210)	(1.066)	(2.044)	(0.645)	(3.223)	(3.267)	(0.641)	(3.205)	(3.171)	(1.032)	(4.770)	(7.303)
N	86	86	86	86	86	86	86	86	86	85	85	85
R^2	0.101	0.123	0.090	0.167	0.180	0.244	0.191	0.201	0.291	0.362	0.402	0.423
F	10.62***	16.6***	9.70***	7.57***	19.61***	7.12***	7.18***	17.79***	11.08***	9.82***	37.78***	11.05***

Quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Girls enrollment rate is the share of girls aged 6-14 enrolled in public primary schools.
Source: County-level data from the *Statistique Générale de la France.*

Table 4: IV Quantile regression results from education to fertility: Men

Dependent Variable	Crude Birth Rate											
	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Boys enrollment	-4.533**	-4.463***	-10.041***	-3.250**	-4.137***	-9.762***	-3.280*	-4.167***	-9.529***	-6.677***	-6.743***	-7.859***
	(2.307)	(1.066)	(1.161)	(1.782)	(0.020)	(2.288)	(1.698)	(0.020)	(2.482)	(1.941)	(1.776)	(2.648)
Male in agriculture				7.777*	4.827	2.979	11.740***	5.756*	0.596	9.776***	17.430***	2.109
				(4.413)	(3.667)	(3.188)	(4.702)	(3.066)	(4.261)	(3.859)	(7.264)	(3.676)
Male in industry				14.469*	6.121	4.949	14.269*	7.112	2.098	-1.853	-8.964	12.528***
				(7.970)	(6.117)	(7.020)	(8.496)	(6.003)	(7.601)	(5.950)	(6.281)	(5.017)
Urbanization				103.513**	63.360**	83.544**	121.726***	70.332**	42.225*	-3.083	39.537*	35.038*
				(44.141)	(32.513)	(30.343)	(48.729)	(34.722)	(24.672)	(32.926)	(21.443)	(21.757)
Population density				-5.004***	-1.283*	-1.939**	-3.367	-1.409*	-1.887	-1.385	-0.206	-1.812
				(2.788)	(0.735)	(0.680)	(3.027)	(0.782)	(2.671)	(2.049)	(1.875)	(2.026)
Share Protestants							0.098	0.161*	0.169*	0.083	0.003	0.086*
							(0.132)	(0.088)	(0.095)	(0.089)	(0.082)	(0.052)
Life expectancy										-0.532***	-0.649***	-0.508***
										(0.095)	(0.101)	(0.093)
Constant	26.906***	29.172***	34.587***	21.149***	24.801***	31.018***	13.850***	23.426***	33.955***	48.184***	47.726***	49.964***
	(1.273)	(0.541)	(0.590)	(4.636)	(3.113)	(4.083)	(4.450)	(3.067)	(3.328)	(5.038)	(4.610)	(5.170)
N	86	86	86	86	86	86	86	86	86	85	85	85
R^2	0.112	0.129	0.107	0.174	0.184	0.231	0.202	0.240	0.301	0.379	0.425	0.410
F	12.35***	16.87***	10.66***	9.36***	19.55***	8.19***	7.68***	17.98***	12.01***	9.83***	38.98***	11.56***

Instrumental variable quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Boys enrollment rate is the share of boys aged 6-14 enrolled in public primary schools.
Source: County-level data from the *Statistique Générale de la France.*

Table 5: IV Quantile regression results from education to fertility: Women

Dependent Variable	Crude Birth Rate											
	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Girls enrollment	-3.233**	-5.552***	-9.692***	-6.707**	-7.952***	-10.062***	-5.223**	-7.466***	-9.160***	-1.736	-4.859**	-4.572*
	(1.91)	(2.479)	(2.816)	(2.949)	(2.503)	(3.022)	(2.653)	(2.763)	(2.986)	(2.352)	(2.350)	(2.512)
Female in agriculture				0.186	2.357	-1.233	0.034	3.104	-0.934	2.162	-2.370	-0.437
				(3.725)	(3.431)	(3.816)	(3.353)	(3.811)	(3.738)	(3.209)	(2.636)	(2.819)
Female in industry				14.355**	11.446***	5.838	12.400**	10.718**	3.806	14.018**	1.159	-0.153
				(6.928)	(4.862)	(9.203)	(5.356)	(5.590)	(9.053)	(7.140)	(6.607)	(7.065)
Urbanization				72.608*	58.786*	30.082	59.245*	57.088*	21.346	-42.442**	-4.534	26.184
				(42.55)	(32.049)	(43.595)	(34.745)	(35.350)	(43.138)	(20.843)	(31.173)	(33.333)
Population density				-1.549	-1.587	-1.881	-0.554	-1.107	0.072	3.693**	-0.076	4.876
				(2.796)	(2.240)	(2.865)	(2.325)	(2.546)	(2.844)	(1.764)	(2.031)	(1.979)
Share Protestants							0.100	0.145*	0.061	0.131**	0.039	-0.077
							(0.100)	(0.090)	(0.120)	(0.092)	(0.085)	(0.104)
Life expectancy										-0.428***	-0.628***	-0.429***
										(0.107)	(0.089)	(0.099)
Constant	25.542***	28.812	32.958***	26.109***	27.367***	34.378***	24.985***	26.184***	32.372***	42.196***	52.850***	47.471***
	(0.948)	(0.858)	(0.975)	(3.445)	(3.258)	(3.530)	(3.009)	(3.701)	(3.504)	(4.508)	(4.281)	(4.577)
N	86	86	86	86	86	86	86	86	86	85	85	85
R^2	0.100	0.125	0.102	0.184	0.210	0.201	0.187	0.201	0.307	0.354	0.442	0.406
F	11.34***	16.9***	9.88***	8.74***	16.32***	8.90***	7.68***	16.22***	12.21***	10.02***	31.61***	11.80***

Instrumental variable quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Girls enrollment rate is the share of girls aged 6-14 enrolled in public primary schools.
Source: County-level data from the *Statistique Générale de la France*.

4.2 From Fertility to Education

The discussion of results in the preceding section focused on education-fertility channel with the relationship running from education to fertility. To further qualify evidence on quality-quantity hypothesis, we present, in this section, results by considering reverse causality, i.e., from fertility to education. Tables 6 and 7 report Instrumental variable quantile regression estimates of the education equation (7), where boys and girls enrollment rates are each in turn function of the crude birth rate. Unlike the education-fertility channel, we do not present here the Quantile regression results without treatment of endogeneity bias, as we have argued before that possible endogeneity can plague OLS or quantile estimates. Hence, we are inclined to present only IV quantile estimates. The reason for undertaking reverse causality has been stated earlier; however, at this point we should note that we are not interested in testing causality of quantity-quality trade-off hypothesis. This can be an interesting exercise which we reserve for future research. In what we present in terms of estimation strategy of the trade-off is the observed empirical approaches undertaken in the extant literature (e.g. Becker *et al.*, 2010).

Accordingly, following the reverse form of causality[13], the school enrollment rate is the dependent variable and the crude birth rate is our variable of interest. To treat possibility of endogeneity of fertility with other regressors, we have instrumented crude birth rate with adult sex ratio. Tables 6 and 7 report the estimates where boys and girls enrollment rates are each in turn function of the crude birth rate. Column 1 displays the estimation results without any control variables. Columns 2 to 4 report estimation results adding different set of control variables. As before, we present estimates for three quantiles (25^{th}, 50^{th}, and 75^{th}). Regardless the specification and distribution heterogeneity, the coefficient of fertility is significant and negative at least at the 1% level what confirms the significant and robust association from fertility to education.

Tables 6 and 7 present interesting findings with respect to Instrumental variable quantile regressions. Overall results indicate stronger effects of fertility decline on the likelihood of female empowerment with respect to education. Both at 50^{th} and 25^{th} quantile in Tables 6 and 7 (without introduction of controls, i.e., the restricted model) clearly show that fertility decline exerted greater effects on girls' enrollment rate that on

[13] Test of causality in cross-sectional regression of the type we have presented in this paper can be performed either by matching or by spatial causality test. We reserved this for future research.

boys' enrollment rate. Of course, when controlling for the role of men and women in agriculture and industry, as well as the effect of urbanization and population density (column 2 in Table 6 and 7), the results yet point at the larger role of women, than men. Our interquartile difference test for men-women differences in results in each quantile also rejects the null hypothesis of no significant effect in favor of greater effects of women (at 5% levels: results not reported here). Moreover, a striking result merits attention: while urbanization seems to have exerted significant effect on boys' enrollment, while controlling for fertility, the same variable does not appear to affect girls' enrollment at all. [This might be because urbanization often motivates the migration of men workers more than the migration of women, rightly so in the historical episodes this study is based on.] Contrastingly, those women who might have already been residing in urban environment are found to experience a boost toward enrollment in public primary schools by participating in industry work. In addition, higher life-expectancy for women had larger positive and significant effects on the enrollment rates than the life expectancy of men for all quantiles. Conversely, higher share of Protestants had positive and significant effects on the propensity to invest in boys' enrollment rates (at 25^{th} and 75^{th} quantiles in Table 6); but not to invest in girls' education.

The estimates of equation (6) and equation (7) confirm the existence of a mutual negative and significant relationship between fertility and education, supporting the existence of a child quantity-quality trade-off in 1851 France. Hence, counties in which the increase in education has been more important account for larger changes in fertility, and conversely. These results are coherent with the interpretation of the unified growth theory (Galor and Moav, 2002; Galor, 2005b; Diebolt and Perrin, 2013). Yet, the decisions about quality and quantity of children being taken simultaneously, the analysis does not allow us to conclude about the causality between education and fertility.

Table 6: IV Quantile regression results from fertility to education: Men

	Boys enrollment rate											
Dependent Variable	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Crude Birth Rate	-0.017***	-0.015**	-0.039**	-0.017***	-0.019**	-0.038**	-0.017***	-0.023***	-0.043***	-0.015**	-0.021**	-0.058**
	(0.004)	(0.007)	(0.014)	(0.004)	(0.008)	(0.012)	(0.003)	(0.008)	(0.010)	(0.005)	(0.009)	(0.018)
Male in agriculture				-0.006	-0.101	-0.222	-0.040	-0.134	-0.312	-0.069	-0.133	-0.584
				(0.187)	(0.190)	(0.322)	(0.161)	(0.222)	(0.336)	(0.159)	(0.201)	(0.360)
Male in industry				0.315	0.331	0.095	0.379	0.332	0.041	0.398	0.319	-0.468
				(0.388)	(0.578)	(0.669)	(0.388)	(0.601)	(0.596)	(0.403)	(0.602)	(0.760)
Urbanization				3.015	5.576**	6.425**	1.222	4.569**	0.443	0.975	3.096	2.718
				(2.552)	(2.841)	(3.229)	(2.344)	(2.369)	(2.369)	(2.059)	(2.553)	(3.150)
Population density				-0.075	-0.136	-0.163	-0.031	-0.113	-0.026	-0.025	-0.078	-0.096
				(0.087)	(0.122)	(0.157)	(0.085)	(0.123)	(0.173)	(0.087)	(0.131)	(0.156)
Share Protestants							0.009*	0.007	0.018***	0.010**	0.007	0.015**
							(0.005)	(0.006)	(0.007)	(0.004)	(0.005)	(0.006)
Life expectancy										0.002	0.0009	-0.021
										(0.005)	(0.008)	(0.016)
Constant	0.850***	0.923***	1.733***	0.854***	1.053***	1.864***	0.873***	1.163***	2.060***	0.739**	1.079**	3.623***
	(0.115)	(0.232)	(0.395)	(0.228)	(0.282)	(0.338)	(0.229)	(0.330)	(0.378)	(0.343)	(0.542)	(0.988)
N	86	86	86	86	86	86	86	86	86	85	85	85
R^2	0.100	0.125	0.102	0.173	0.147	0.195	0.217	0.174	0.238	0.221	0.176	0.232
F	11.34***	16.9***	9.88***	9.39***	74.20***	28.73***	3.60**	16.22***	12.21***	10.59***	38.22***	12.56***

Instrumental variable quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Boys enrollment rate is the share of boys aged 6-14 enrolled in public primary schools. Instrument for CBR is Adult sex ratio.
Source: County-level data from the *Statistique Générale de la France.*

Table 7: IV Quantile regression results from fertility to education: Women

	Girls enrollment rate											
Dependent Variable	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Crude Birth Rate	-0.020**	-0.018**	-0.022*	-0.02**	-0.020***	-0.024**	-0.021***	-0.021***	-0.026***	-0.019**	-0.025**	-0.051**
	(0.006)	(0.011)	(0.005)	(0.005)	(0.010)	(0.005)	(0.005)	(0.010)	(0.004)	(0.009)	(0.017)	(0.006)
Female in agriculture				-0.277*	-0.300**	-0.501**	-0.282*	-0.307**	-0.528**	-0.230**	-0.253**	-0.412*
				(0.126)	(0.255)	(0.162)	(0.128)	(0.259)	(0.101)	(0.124)	(0.246)	(0.126)
Female in industry				0.584**	0.569**	0.114	0.583**	0.568**	0.110	0.682**	0.668**	0.306*
				(0.276)	(0.430)	(0.248)	(0.274)	(0.429)	(0.234)	(0.263)	(0.169)	(0.276)
Urbanization				1.532	2.279	3.670	1.268	1.963	2.390	1.327	2.024	2.520
				(2.152)	(3.712)	(2.025)	(2.152)	(3.128)	(2.156)	(2.307)	(3.259)	(2.152)
Population density				-0.044	-0.061	-0.099	-0.038	-0.054	-0.069	-0.034	-0.050	-0.063
				(0.048)	(0.084)	(0.045)	(0.048)	(0.070)	(0.048)	(0.051)	(0.073)	(0.048)
Share Protestants							0.002	0.002	0.009	0.002	0.002	0.010
							(0.005)	(0.101)	(0.004)	(0.004)	(0.008)	(0.005)
Life expectancy										0.012**	0.012**	0.020**
										(0.005)	(0.009)	(0.005)
Constant	0.792***	0.902***	1.139***	0.961***	1.101***	1.493***	0.972***	1.116***	1.554***	0.878**	0.272**	0.987**
	(0.181)	(0.186)	(0.333)	(0.193)	(0.369)	(0.338)	(0.193)	(0.195)	(0.365)	(0.349)	(0.110)	(0.419)
N	86	86	86	86	86	86	86	86	86	85	85	85
R^2	0.100	0.114	0.09	0.213	0.240	0.125	0.219	0.243	0.140	0.247	0.268	0.109
F	9.84**	7.94**	3.63*	12.11***	4.12**	3.60**	10.00**	7.87***	3.40**	8.25***	6.60***	4.99***

Instrumental variable quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Girls enrollment rate is the share of girls aged 6-14 enrolled in public primary schools.
Source: County-level data from the *Statistique Générale de la France*.

5. Long-run Effect of Human Capital on Fertility Transition

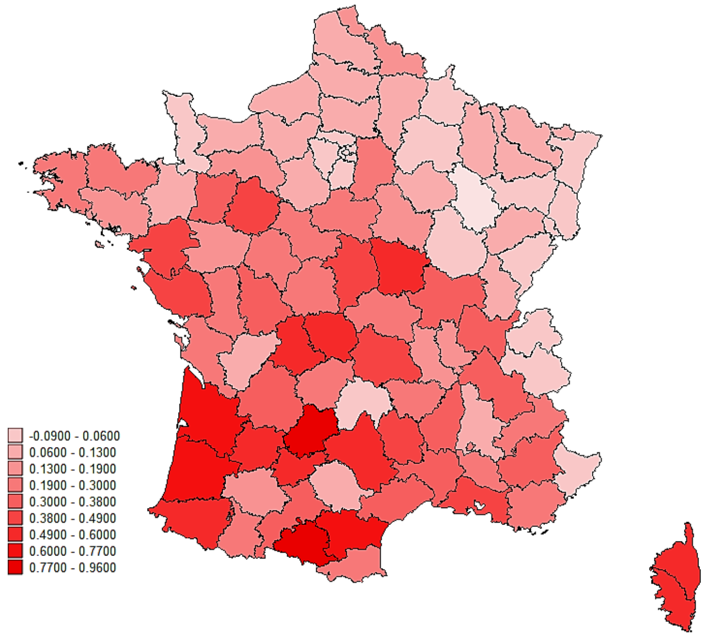
From the study of the short-run relationship between education and fertility, our results show that the correlation goes in both directions of causation. This suggests the existence of a child quantity-quality trade-off in France during the French demographic transition. However, these results may hide a more complex underlying relationship, as advanced by Diebolt and Perrin (2013). Henceforth, we test in this section the hypothesis that women endowments in human capital affect their own choices of fertility, and subsequently that of future generations. The objective of this study is then to determine whether the endowments in human capital in time t affect the level of fertility in period $t+1$.

This motivates us to model the long-run effect of investment in human capital on fertility. We empirically test the effect of the percentage change in human capital investments between 1856 and 1866 on the variations in fertility between 1881 and 1911 across French counties. The motivation of such choice of data is to account for the effect of education on several generations of individuals.

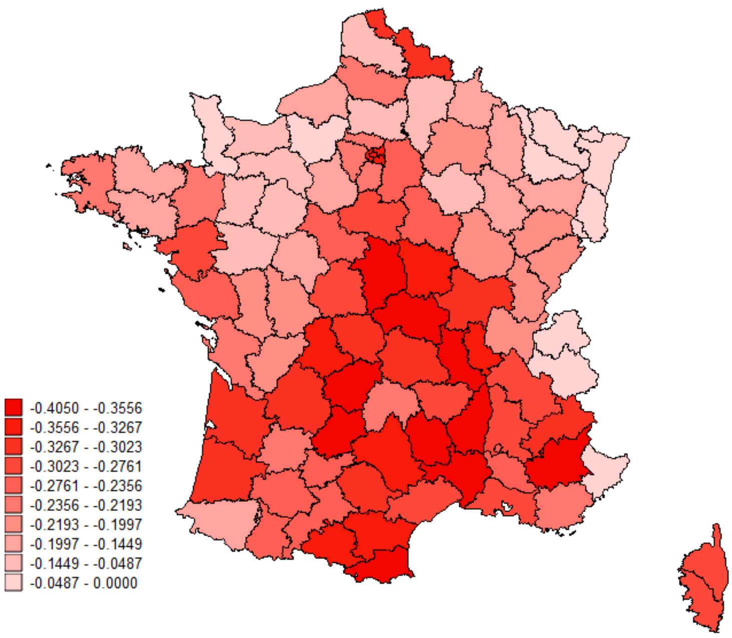
Figures 3a and 3b give us an insight on the geographical distribution of changes in female literacy rates between 1856 and 1865 and the subsequent changes in crude birth rates between 1881 and 1911. Contrary to the agricultural and rural areas, the most industrialized area of France (Northeast) display lower variations in female literacy rates over the period studied. Comparatively, we see that counties experiencing stronger improvement in female literacy rates over the period 1856-1865 tend also to experience a steeper fertility decline measured by the percentage change in crude birth rate over the period 1881-1911.

Figure 3: Geographical Distribution of the Percentage Change in Education and Fertility

(3a) Female Human Capital, 1856-65



(3b) Crude Birth Rate, 1881-1911



Sources: Using data from Statistique Générale de la France – Enseignement Primaire; Census

We estimate equation (8) using quantile regressions. We use various specifications to study how male and female endowments in human capital affect their future fertility, introducing successively the following covariates: *(i)* the crude birth rate in 1851; *(ii)* proxies for the level of industrialization specified as the level of urbanization and the population density; *(iii)* employment opportunities measured by the share of people making their living of agriculture and the share of people employed in manufacturing; *(iv)* the share of Protestants; *(v)* the life expectancy at age 0; and *(vi)* the crude birth rate in 1881.

Long-run estimates

Tables 8 and 9 report the estimation results on the hypothesis that increasing educational investments have played a significant role in the fertility transition. Columns 1 to 4 present various specifications of equation (8) for both boys (Table 8) and girls (Table 9). Hence, we control for socio-economic factors adding successively control variables for employment opportunities and urbanization (column 1), religion (column 2), life expectancy (column 3) and crude birth rate in 1881 (column 4).[14]

We find very interesting results from a gendered perspective. The Quantile estimates show that the percentage change in literacy rates is negatively associated with the fertility transition. This result is strongly significant for women only. This result is in line with Diebolt and Perrin (2013) and supports the hypothesis that women behavior is at the chore of the demographic transition. It suggests that the more women are educated today, the fewer children they have tomorrow. Table 9 shows particularly strong results for all specifications (at 0.1%).

Contrary to what found by Galloway *et al.* (1998) and Becker *et al.* (2010), our coefficients do not indicate that the fertility transition is stronger in urbanized area. Contrary also to the results found on the short-run, the coefficients indicate that the fertility transition is stronger in areas where individuals are more oriented toward agriculture.[15] Similarly, the transition is also stronger in areas with a higher share of Protestants. In the complete specification reported in column 4 (Table 9), we observe that an increase in the variation of the female literacy rate by 10% is likely to decrease

[14] In order to test the robustness of our results, we add the initial level of birth rate in 1881.

[15] Note that agricultural areas are also those where education levels were historically the lowest and where fertility was the most important (in comparison with industrialized areas).

the variation of the birth rate by 1.5 percentage point. In terms of explanatory power, the richest model (column 4 – Table 10) accounts for more than 64% of the variation across counties of the variations in the crude birth rate.

Our results indicate that the variations in female endowment in human capital have a robust and significant impact on the fertility transition contrary to male endowment in human capital. This result is consistent with the intuition of the unified growth model of Diebolt and Perrin (2013) briefly presented in Section 1.2, according to which female endowed with a higher amount of human capital tend to limit their fertility due to a larger opportunity cost of having higher than female endowed with lower amount of human capital.

Table 8: Long-run results for education and fertility: Boys

	Crude Birth Rate (% change 1881-1911)											
Dependent Variable	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Male literacy	-0.028	-0.274*	-0.252*	-0.061	-0.301*	-0.271*	-0.063	-0.305*	-0.087	-0.075	-0.204	-0.002
	(0.149)	(0.157)	(0.152)	(0.150)	(0.159)	(0.156)	(0.151)	(0.160)	(0.160)	(0.167)	(0.167)	(0.162)
Crude birth rate 1851	-0.019***	-0.017***	-0.014***	-0.018***	-0.016***	-0.013***	-0.017**	-0.013***	-0.103**	-0.016***	-0.024***	-0.020***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.008)	(0.006)	(0.005)
Male in agriculture	-0.231*	-0.210**	-0.194**	-0.220*	-0.201*	-0.188*	-0.221*	-0.203*	-0.185*	-0.213*	-0.266**	-0.238**
	(0.124)	(0.107)	(0.098)	(0.126)	(0.108)	(0.098)	(0.128)	(0.107)	(0.098)	(0.131)	(0.114)	(0.102)
Male in industry	-0.088	0.148	0.297*	-0.091	0.145	0.296*	-0.080	0.174	0.702***	-0.071	0.101	0.639***
	(0.276)	(0.185)	(0.161)	(0.283)	(0.187)	(0.162)	(0.289)	(0.210)	(0.142)	(0.294)	(0.193)	(0.128)
Urbanization	-0.620	-1.880	-2.487*	-0.505	-1.784	-2.422*	-0.512	-1.803	-1.032	-0.538	-1.585	-0.844
	(1.464)	(1.387)	(1.311)	(1.491)	(1.388)	(1.312)	(1.517)	(1.141)	(0.878)	(1.540)	(1.235)	(0.893)
Population density	-0.004	0.045	0.058	-0.009	0.041	0.056	-0.011	0.036	-0.036	-0.006	0.001	-0.066
	(0.114)	(0.113)	(0.100)	(0.114)	(0.113)	(0.100)	(0.114)	(0.114)	(0.075)	(0.122)	(0.092)	(0.057)
Share Protestants				-0.002	-0.002	-0.001	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Life expectancy							0.001	0.004	0.008*	0.001	0.006	0.010**
							(0.005)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
Crude birth rate 1881										-0.001	0.015**	0.013**
										(0.005)	(0.007)	(0.006)
Constant	0.419***	0.411***	0.338**	0.404**	0.398***	0.330**	0.317**	0.157	0.537	0.329**	0.574***	0.139**
	(0.122)	(0.113)	(0.110)	(0.126)	(0.115)	(0.110)	(0.156)	(0.306)	(0.277)	(0.139)	(0.119)	(0.062)
N	82	82	82	82	82	82	82	82	82	82	82	82
R^2	0.341	0.391	0.369	0.347	0.396	0.372	0.348	0.400	0.420	0.349	0.462	0.456
F	7.61***	15.27***	14.64***	7.65***	14.81***	12.45***	6.42***	12.56***	11.04***	5.83***	14.09***	11.43***

Quantile regressions. Dependent variable: Percentage change in crude birth rate 1881-1911. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Male literacy rate is the percentage change in the share of men able to read and to write between 1856 and 1865.
Source: County-level data from the *Statistique Générale de la France.*

Table 9: Long-run results for education and fertility: Girls

	Crude Birth Rate (% change 1881-1911)											
Dependent Variable	(1)			(2)			(3)			(4)		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Female literacy	-0.164***	-0.272***	-0.164***	-0.223**	-0.270***	-0.160**	-0.165**	-0.262***	-0.154**	-0.230***	-0.233***	-0.122*
	(0.027)	(0.061)	(0.068)	(0.069)	(0.061)	(0.079)	(0.076)	(0.059)	(0.066)	(0.071)	(0.056)	(0.070)
Crude birth rate 1851	-0.156***	-0.015***	-0.013***	-0.016***	-0.015***	-0.015***	-0.011*	-0.011***	-0.008**	-0.012*	-0.021***	-0.017***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.006)	(0.004)	(0.003)	(0.007)	(0.005)	(0.005)
Female in agriculture	-0.240**	-0.131*	-0.221**	-0.135	-0.132*	-0.241**	0.050	-0.127	-0.216**	-0.123	-0.163*	-0.266***
	(0.075)	(0.078)	(0.074)	(0.101)	(0.079)	(0.076)	(0.101)	(0.079)	(0.075)	(0.101)	(0.088)	(0.077)
Female in industry	0.578***	0.002	0.236	-0.125	0.011	0.598***	-0.057	0.070	0.310*	-0.096	0.027	0.646***
	(0.156)	(0.206)	(0.166)	(0.306)	(0.205)	(0.158)	(0.272)	(0.218)	(0.177)	(0.315)	(0.213)	(0.156)
Urbanization	-1.303	-1.582	-2.358**	-0.289	-1.505	-1.121	1.544	-1.289	-2.049*	-0.333	-0.973	-0.527
	(0.889)	(1.122)	(1.134)	(1.281)	(1.126)	(0.886)	(1.245)	(1.186)	(1.113)	(1.364)	(1.095)	(0.800)
Population density	-0.035	0.034	0.035	-0.028	0.028	-0.049	-0.026	0.012	0.011	-0.0224	-0.019	-0.101
	(0.084)	(0.093)	(0.087)	(0.099)	(0.094)	(0.085)	(0.109)	(0.095)	(0.086)	(0.111)	(0.074)	(0.063)
Share Protestants				-0.003	-0.001	-0.003*	-0.005**	-0.001	-0.0008	-0.002	-0.002	-0.004**
				(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Life expectancy							0.004	0.005	0.005*	0.007	0.007*	0.009**
							(0.005)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)
Crude birth rate 1881										-0.004	0.014**	0.013***
										(0.006)	(0.006)	(0.005)
Constant	0.481***	0.348**	0.354***	0.325***	0.346**	0.478***	0.185**	0.128**	0.208**	0.276**	0.112***	0.116
	(0.122)	(0.106)	(0.099)	(0.123)	(0.107)	(0.122)	(0.892)	(0.062)	(0.098)	(0.101)	(0.005)	(0.005)
N	82	82	82	82	82	82	82	82	82	82	82	82
R^2	0.418	0.466	0.404	0.418	0.468	0.429	0.379	0.481	0.423	0.425	0.535	0.489
F	5.61***	23.79***	14.75***	12.48***	23.92***	11.56***	5.96***	23.10***	12.14***	9.071***	17.91***	9.097***

Quantile regressions. Dependent variable: Percentage change in crude birth rate 1881-1911. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Female literacy rate is the percentage change in the share of men able to read and to write between 1856 and 1865.
Source: County-level data from the *Statistique Générale de la France.*

Conclusion

This paper documents the existence of a quantity-quality trade-off in France during the 19th century. The objective of this paper is twofold: *(i)* investigating both directions of causation of the short-run relationship between education and fertility (i.e. the child quantity-quality trade-off) during the French demographic transition; and *(ii)* studying the long-term effect of endowment in human capital on the subsequent level of fertility. We contribute to the literature of unified growth theory by shedding light on these two types on relationships from a gendered renewed approach.

Using an original county-level dataset of 86 county observations for the year 1851 built up from the *Statistique Générale de la France*, we find in Section 3 evidence of the existence of the child quantity-quality trade-off during the French demographic transition. This result corroborates the predictions and interpretations of the unified growth literature in line with the seminal work of Galor and Weil (2000).

However, this result may hide a more complex relationship linking education and fertility that is the long-run relationship between the female endowment in human capital and the level of fertility, as predicted by Diebolt and Perrin (2013a, 2013b) whose intuitions are briefly presented in Section 1. Hence, using 19th century French data, we have tested in Section 4 the hypothesis that the rise in female endowment in human capital has played a key role in the fertility transition. In line with Diebolt and Perrin (2013b), our results suggest that women with a higher level of human capital have stronger preferences for a lower number of children. In particular, we find the existence of a negative and significant effect of the variations in female literacy rates (1856-66) on the fertility transition between 1881 and 1911. Counties with higher improvements in female literacy display stronger fertility decline in France at the turn of the 19th century.

From our empirical investigation, we find that the quantity-quality trade-off was possibility driven by women endowment in human capital of the previous generation. By extension, as demographic transition is considered necessary condition to allow economies to move from stagnation to sustained growth, female human capital is likely to be a key ingredient for economic transition. Indeed, female empowerment increases returns to education for girls because of complementarities between technological changes and human capital. Girls invest more in their own education and limit their fertility because of a greater opportunity cost of having children. As a consequence, girls with higher endowments in human capital have fewer children what ultimately leads to the fertility transition.

Further research needs to extend this case study to wider panel data investigation to confirm the intuition that women may have been an important factor of economic growth in developed countries and may still be in developing areas.

Appendix A. – County-level Data for France in the 19th Century

The data used in this paper are mainly extracted from books published by the *Statistique Générale de la France* (SGF) on population, demographic and public education censuses, between 1800 and 1925. Almost all data are available for 86 counties.

1851 Census

- **Crude birth rate.** Number of birth over total population (per one thousand inhabitants).
- **Girls (Boys) enrollment rate.** Number of girls (boys) enrolled in public primary schools over the total number of girls (boys) aged 6-14.
- **Female (Male) in industry.** Number of women (men) employed in manufacturing over total number of women (men) aged 15-60. Manufacturing refers to all types of industry: textile, metal sector and other factories (food, wood, construction…).
- **Female (Male) in agriculture.** Number of women (men) employed in agriculture over total number of women (men) aged 15-60. Agriculture refers to all positions within agricultural sector: owners, farmers, sharecroppers and others.
- **Urbanization.** Number of towns populated with more than 2000 inhabitant (per km^2).
- **Population density.** Number of people per km^2.
- **Life expectancy at age 0.** Updated C7 tables published in Bonneuil (1997). Calculation of life expectancy by calculating the area under the survival function.

1861 Census

- **Share Protestants.** Number of Protestants over total people within the different religions (per a hundred people). Protestants refers to all types of Protestants: Lutherans, Calvinists and other Protestant sects.

1881 Census

- **Crude birth rate.** Number of birth over total population.

Percentage Changes

- **Crude birth rate (1881-1911) - % change.** Percentage variation of the number of birth over total population in 1881 compared to 1911.
- **Female (Male) literacy rate (1856-66) - % change.** Percentage variation of the female (male) literacy rate between 1856 and 1866. The literacy rate consists in number of individuals able to read and to write over total population.

Appendix B. – Robustness Checks

An additional exercise is to check if our findings of quantity-quality trade-off, especially the instrumental role of female empowerment are sensitive to the addition of control variables and/or the introduction of alternative dependent variables. As a first step towards achieving this aim, we have re-estimated the education-fertility channel by replacing first the dependent variable. Accordingly, we have replaced crude birth rate with marital fertility rate. Our second strategy is to retain the original dependent variable, crude birth rate but add extra control variables, such as infant mortality, child mortality, male and female wages in agriculture in 1852. Table A reports these results. Instead of estimating each set of equation, we have only presented the estimation results for the full model for both men and women. Column 1 reports the results with respect to a change of the dependent variable in the female and male estimations. Column 2 reports the results with additional control variables.

As such, changing dependent variable does not alter our main finding of a negative relationship between fertility and education, although the results appear weaker in magnitudes at low and high quantiles than the one we observed when using the crude birth rate as dependent variable. Moreover, other control variables in this regression setting also present weaker results despite the fact that population density, for instance, indicate negative effect (although insignificant), whereas the positive impact of urbanization is perceived at lower quantile (in case of women). Life-expectancy, as earlier, is significantly negative and indicates that in the face of fertility-reducing effect of life-expectancy, enhancing education reduced fertility. This result is more acute at the lower quantile for women. When we added more control variables while maintaining crude birth rate as the main dependent variable, the strategy does not improve the results much. The insignificance and weaker results for the effect of education on fertility seem to have overweighed by likely correlation between these additional variables with education. Instrumentation did not help much. Therefore, this robustness exercise, while pointing at the capital importance of crude birth rate and marital fertility rate as relevant variables for quantity-quality trade-off, must be pursued with caution concerning the choice of other variables.

Table A: Robustness of estimates: education and fertility channel: Men and Women

	Men						Women					
Dependent Variable	(1) MFR			(2) CBR			(1) MFR			(2) CBR		
	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
Enrollment	-0.098**	-0.446*	-0.422***	-0.009	-0.112*	-0.088	-0.159***	-0.432***	-0.560***	-0.012	-0.127*	-0.089
	(0.003)	(0.230)	(0.003)	(0.008)	(0.642)	(0.007)	(0.002)	(0.002)	(0.003)	(0.007)	(0.599)	(0.007)
Employ. in agriculture	0.522	-0.133	0.541	0.535	-0.129	0.512	0.265	0.225	0.061	0.535	-0.157	0.512
	(0.376)	(0.201)	(0.534)	(0.465)	(0.206)	(0.522)	(0.418)	(0.390)	(0.440)	(0.465)	(0.206)	(0.522)
Employ. in industry	-1.296***	0.319	0.330	-0.971	-0.878	0.371	-1.535*	-1.069	-1.307	-0.971	-0.699	0.371
	(0.349)	(0.602)	(0.893)	(1.104)	(0.734)	(0.798)	(0.933)	(0.874)	(0.984)	(1.104)	(0.505)	(0.798)
Urbanization	3.477	3.096	2.531	8.464	12.98***	26.411***	9.159**	6.149	3.819	8.464	14.97***	26.411***
	(5.916)	(2.553)	(2.087)	(5.477)	(2.082)	(9.945)	(4.795)	(4.475))	(5.055)	(5.477)	(3.860)	(9.945)
Population density	-0.124	-0.078	-0.130	-0.211	-1.171**	-0.615**	-0.261**	-0.195**	-0.151	-0.211	-0.985**	-0.615**
	(0.132)	(0.131)	(0.114)	(0.235)	(0.268)	(0.217)	(0.108)	(0.101)	(0.114)	(0.235)	(0.342)	(0.217)
Share Protestants	0.012*	0.007	0.037***	0.010*	0.005	0.023	0.020	0.034**	0.037***	0.009*	0.004	0.023
	(0.005)	(0.005)	(0.012)	(0.015)	(0.005)	(0.012)	(0.023)	(0.011)	(0.012)	(0.015)	(0.005)	(0.012)
Life expectancy	-0.065***	0.0009	-0.099***	-0.075***	-0.021	-0.086*	-0.072***	-0.057***	-0.053***	-0.078***	-0.088*	-0.086*
	(0.011)	(0.008)	(0.015)	(0.013)	(0.045)	(0.049)	(0.014)	(0.013)	(0.015)	(0.013)	(0.038)	(0.049)
Child mortality				15.658	25.145	28.517				17.398	29.233	28.517
				(13.218)	(17.167)	(18.888)				(13.666)	(18.260)	(18.888)
Wage in agriculture				-0.702***	-0.686	-0.056				-0.679***	-0.534*	-0.056
				(0.285)	(0.779)	(0.606)				(0.211)	(0.278)	(0.606)
School				-0.285	-0.554	-1.474***				-0.305	-0.634	-1.474***
				(0.240)	(0.408)	(0.437)				(0.240)	(0.405)	(0.437)
Constant	5.555**	5.616***	7.042***	5.662**	5.616***	10.645***	5.719***	5.751***	5.751***	4.981***	4.660**	10.645***
	(0.781)	(0.726)	(0.838)	(1.104)	(0.726)	(2.660)	(0.791)	(0.834)	(0.834)	(1.104)	(2.390)	(2.660)
N	85	85	85	85	85	85	85	85	85	85	85	85
R^2	0.406	0.454	0.454	0.267	0.483	0.502	0.421	0.409	0.409	0.450	0.493	0.522
F	63.93 ***	35.96***	35.96***	4.55**	14.34**	13.83***	13.17***	11.27***	11.27***	6.38**	16.39**	18.44***

Instrumental variable quantile regressions. Dependent variable: crude birth rate. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Crude birth rate is defined as the number of birth (in 1000 s) over the total population. Girls enrollment rate is the share of girls aged 6-14 enrolled in public primary schools. Column 1 for both boys and girls use marital fertility rate (mfr1851) as a measure of fertility. Whereas column 2 uses CBR as the measure but we include additional controls for robustness check.
Source: County-level data from the *Statistique Générale de la France.*

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