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Auteurs

Claude Diebolt, Audrey-Rose Menard, Faustine Perrin

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Faculté des sciences économiques et de gestion
Pôle européen de gestion et d'économie (PEGE)
61 avenue de la Forêt Noire
F-67085 Strasbourg Cedex

Secrétariat du BETA
Géraldine Del Fabbro
Tél. : (33) 03 68 85 20 69
Fax : (33) 03 68 85 20 70
g.delfabbro @unistra.fr
www.beta-umr7522.fr

Behind the Fertility-Education Nexus: What Triggered the French Development Process?

Claude Diebolt, Audrey-Rose Menard, Faustine Perrin*

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Abstract

The education-fertility relationship is a central element of the models explaining the transition to sustained economic growth. In this paper, we use a three-stages least squares estimator to disentangle the causality direction of this relationship. Controlling for a wide array of socio-economic, cultural, and geographical determinants, our cliometric contribution on French counties during the nineteenth century corroborates the existence of a single negative causal link from fertility to education. We put forward the hypothesis that in France a decrease in fertility is strongly associated to greater schooling.

Keywords Education ▪ Family ▪ Fertility ▪ Growth Theory ▪ Nineteenth-Century ▪ France

JEL Classification N33, O10, I25, J13

* Diebolt: Bureau d'Economie Théorique et Appliquée, University of Strasbourg. Address: 61 avenue de la Forêt Noire, 67085 Strasbourg Cedex, E-mail: cdiebolt@unistra.fr. Menard: Bureau d'Economie Théorique et Appliquée, University of Strasbourg. Address: 61 avenue de la Forêt Noire, 67085 Strasbourg Cedex, E-mail: amenard@unistra.fr. Perrin: Department of Economic History, Lund University. Address: Box 7083, SE-22007 Lund, E-mail: faustine.perrin@ekh.lu.se.

1. Introduction

The demographic-economic "paradox" suggests that, although more resources would enable the production of more offspring, the fertility decline arises naturally as a consequence of economic progress. Despite cross-country variations in terms of timing and speed of economic and demographic changes, developed countries experienced similar trends. The simultaneity of economic and demographic developments raises questions about the causal relationship between population and economic growth. In this line of research, growth theorists, Oded Galor ahead, have developed unified growth models emphasizing the importance of parental trade-off between the number and "quality" of children in the transition to sustained economic growth (see Galor 2005, 2011 for literature reviews).

Previous literature evaluates the existence of the negative association between education and fertility in various economies, highlighting the role of specific determinants of fertility decline and educational investments. Yet, the literature does not disentangle the direction of causality between education and fertility, and leaves aside potentially crucial determinants. As a main vehicle of socialization and of the transmission of behavior and values, family structure and family-related issues deserve further attention. This paper aims at understanding and explaining the mechanisms underpinning economic and demographic developments through the lens of the education-fertility link. In particular, it explores the causal relationship between education and fertility; and empirically investigates novel and additional determinants likely to affect this relationship during the transition to sustained economic growth.

The peculiarity of the French development process and its historical context makes France an interesting case to study the education-fertility relationship. While France was the most populated country in Europe at the dawn to the nineteenth century, it became the first European country to experience the demographic transition, about a century prior to others. Additionally, the education system was modernized during the French Revolution and witnessed the implementation of several laws in favor of primary education over the nineteenth century. Finally, the strong regional heterogeneity in educational investments, fertility behaviors, and economic performances makes France a perfect candidate for cross-county analyses.

We use the particularly good supply of French data for the nineteenth century to investigate the causal relationship between fertility and education in 1851. As already pointed out by existing literature, the education-fertility relationship is subject to endogeneity problems. Fertility and education may be decided at the same period. We use a simultaneous equations model to investigate how education and fertility interact and cause each other. The empirical analysis accounts for various economic, demographic, socio-cultural and geographic characteristics that may have affected the education-fertility relationship during the development process (e.g. infant mortality, child labor, life expectancy, income per capita (Galor, 2012), evolution of marriage patterns (De Moor and Van Zanden, 2010); age at marriage (Foreman-Peck, 2011); or rise in gender equality (Diebolt and Perrin, 2013)). Hence, we examine the contribution of economic forces and cultural and ideological factors to the timing of fertility transition across French counties. In particular, we contribute to the literature by assessing the roles of the family structure, of marriage behaviors, and gender equality in the access to resources and opportunities.

We find a strong and unconditional effect of fertility on education. No matter the controls of socio-economic, cultural, and geographical characteristics of French counties, a decrease in fertility has caused higher schooling in France during the development process. However, we find any causal explanation running from education to fertility.

The remainder of the paper is organized as follows. Section 2 provides the literature background. Section 3 presents our data. Section 4 develops our empirical strategy. Section 5 addresses the issue of education-fertility causality. Section 6 investigates the diffusion hypothesis. Section 7 reports some robustness checks. Finally, section 8 summarizes our results and provides concluding remarks.

2. Background

The relationship between education and fertility lies on several channels. First, because it increases potential wages, education increases the opportunity costs of not working in order to have and raise children. Due to this substitution effect, more education should decrease fertility. But additional wages could also enable parents to raise more children. Following the quantity-quality theory, this income effect can be weakened if parents use the supplement of income to invest in their offspring's education. Second, education may vehicle information on contraception, delaying the age of first born and/or increasing birth spacing. Third, parents can decide to have fewer children in order to invest more in their education. Therefore, from a theoretical point of view, the relationship could go either way.

The empirical literature has investigated both directions of the education-fertility relationship (see Diebolt et al. (2015) for detailed review). Findings based on modern data diverge (e.g. Delancey (1990), Hanushek (1992) and Knodel et al. (1987, 1990)), but those using historical data (scarcer, however) emphasize a negative relationship between fertility and education. Becker et al. (2010, 2012) explored the relationship between the quantity-quality trade-off of children and fertility restraint in Prussia during and before the demographic transition, respectively. They confirm a negative correlation between education and fertility. In the same line, Diebolt et al. (2015) controlled for gender biases and the existence of cluster dynamics in their French data, and obtained similar findings during the French demographic transition.

Other determinants of fertility behaviors and educational investments have been debated in the empirical literature. Brown and Guinnane (2002) found that differences in occupations and Catholicism have been decisive for the decline of fertility across Bavaria during the period 1880-1910. In 407 *Kreise,* Galloway et al. (1994) upheld that religion has been by far the most important indicator of fertility levels in Prussia between 1875 and 1910. Religions may vehicle and diffuse new ideas, norms, or technologies throughout the society, say social interactions, that in turn can provided the means to control fertility. On the contrary, sex ratio among the married population, teachers per child, female labor force participation in non-traditional sectors, income, and urbanization had any significant influence on fertility during the Prussian transition. In a related paper, Galloway et al. (1998) stressed that fertility rates were not different in urban areas compared to rural areas. However, the fertility rate in urban areas is better predicted by the proportion of Slavic-speaking people, the female labor force participation, communication networks, infant mortality, and the married sex ratio than in rural areas. Likewise, they observed that higher income only decreases fertility in rural areas. Wanamaker (2012) investigated the case of South Carolina between 1881 and 1900. Higher child mortality and opportunity costs of raising children (including those resulting from increased population density) have explained the low fertility observed during that period. In this line, Dribe (2009) evidenced that lower child mortality, higher urbanization, and more teachers in basic education have caused a decline in marital fertility in Sweden between 1880 and 1930. Following Murphy (2015), income and literacy have reduced the size of French families during the demographic transition.

Income can not only predict a reduction of fertility. But it can also be decisive for determining the level of schooling. Using Indian data from the beginning of the twentieth century, Chaudhary (2007) highlighted the role of private revenues (as a substitute for public funds) for the development of schooling. Besides, technological changes and industrialization (see Field, 1979)) that increase the demand for skills can increase the level of education. According to the unified growth theory, an increase in the return to education, due to technological development, gives family incentives to shift toward greater quality of their children.

In this paper, we expand this existing historical literature by going further in the analysis of the French education-fertility relationship during the demographic transition. We estimate in particular the causal relationships and investigate the prediction power of possible determinants that have not yet been considered.

3. French county-level data

We investigate the relationship between education and fertility using French county-level data for the mid-nineteenth century. We have constructed a dataset to assess regional variations across the 86 French counties (*départements*). Our data come from various sources published on the behalf of the French Statistical Office (*Statistique Générale de la France*), among which the Population, Education and Occupation censuses. We measure education as the enrollment rates in primary schools, defined as the number of children attending school divided by the number of children aged 5-15. To measure fertility behavior, we use the general fertility rate in 1851, namely the number of living births per women aged 15-45. The geographical pattern of girls' enrollment rate in primary education and general fertility rate are shown in Figure 1.[1]

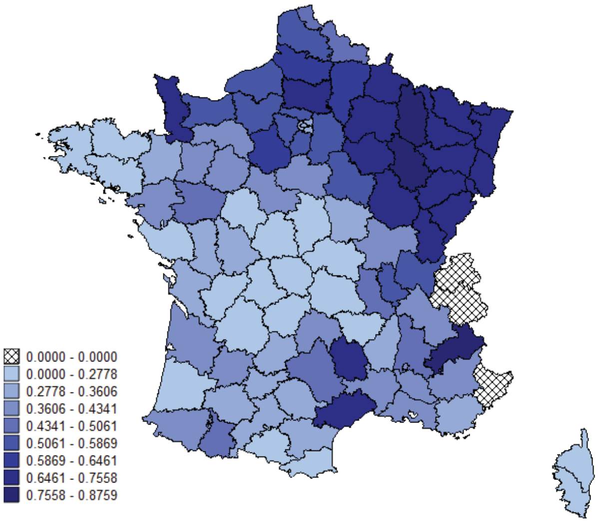
The joint evolution of fertility and education in Western countries during the development process can result from various factors, such as the adaptation/reaction of individuals to socio-economic factors (Becker, 1960); and/or changes in attitudes, diffusion of ideology, and culture (Coale and Watkins, 1986;

[1] The geographical distribution of boys' enrollment rate is strongly similar to that of girls; the correlation coefficient is 0.94 and significant at the 1% probability level.

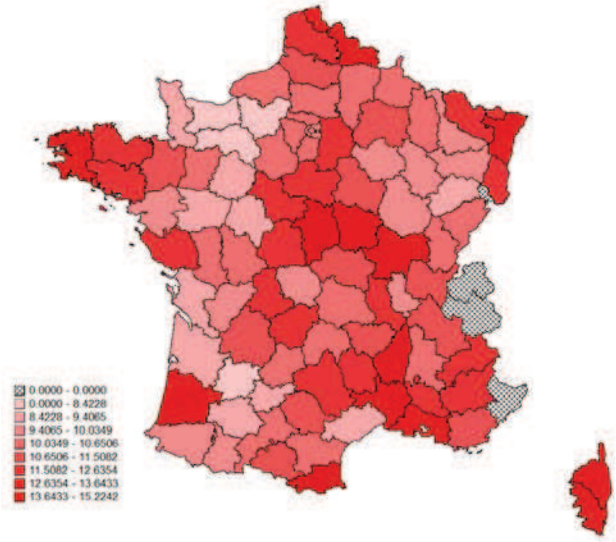
Becker and Woessmann, 2009). Further variables are therefore integrated in the regressions analysis to control for economic, socio-cultural, institutional and geographic aspects.

Figure 1. *Education and Fertility, France 1850-51*

(a) Girls' Enrollment in Primary Schools



(b) General Fertility Rate



Source: Using data from *Statistique Générale de la France*

Our covariates include: *(i)* the occupational structure, measured by the share of people employed in industry and in agriculture, migration and temporary male migration, tax and total expenditures, gender wage gap in industry and in agriculture; *(ii)* the urbanization level, captured by the share of urban residents and the population density; *(iii)* the level of industrialization, measured by the horse power per capita; *(iv)* the infrastructure level, measured by the railroads and the towns with no schools, and by the share of doctors and midwifes; *(v)* socio-cultural specificities, such as the share of Protestants, landownership inequality, gender gap index, definitive celibacy, family structure; *(vi)* demographic characteristics measured by the life expectancy at birth, sex ratio at birth, share married women; illegitimate urban and rural births; and *(vii)* geographic indicators, distance to Mainz, Wittenberg, Geneva, dialects, latitude and longitude.

Table 1 presents the descriptive statistics for our variables and shows the existence of important variations across counties at the early stage of the demographic transition. It highlights the pertinence of the French history underpinnings. And it asks an important question: Which factors explain such heterogeneity in education and fertility developments?

Table 1. *Summary Statistics*

	Obs.	Mean	Std. Dev.	Min	Max
Education					
School enrollment	86	0.4749	0.1827	0.1763	0.8756
Female school enrollment	86	0.4412	0.1910	0.0928	0.8758
Male school enrollment	86	0.5072	0.1801	0.1968	0.8753
Enrollment public schools	86	0.4075	0.2062	0.1197	0.9267

Female literacy rate	86	49.5267	23.8386	15.9	95.4
Male literacy rate	86	66.4884	19.2923	28.9	98.4
Female enrollment public	86	0.2929	0.2110	0.0029	0.8096
Male enrollment public	86	0.4436	0.1727	0.1554	0.8608
Reading skills	86	65.7477	18.2284	26.1	96.3
Fertility					
General fertility rate	86	10.9478	1.5715	7.5263	15.2241
Crude birth rate	86	10.9478	1.5715	7.5263	15.2242
Child-women ratio	86	0.4771	0.0768	0.2611	0.6929
Ig Index	86	0.4966	0.1092	0.298	0.747
Economic					
Population density	86	1.0118	3.1665	.2187	29.9067
Share urban	86	0.3241	0.15627	0.1299	0.9081
Share in agriculture	86	0.6474	0.1625	0.0403	1.0379
Share female in agriculture	86	0.58584	0.1712	0.0351	0.999
Share male in agriculture	86	0.7103	0.1648	0.0452	1.0759
Share in industry	86	0.0444	0.0716	0	0.5671
Share female in industry	86	0.0340	0.0669	0	0.5268
Share male in industry	86	0.0549	0.0779	0	0.6102
Horse power	86	4087.40	9724.19	0	82123.30
Migration (1856-60)	86	1.9579	0.05294	1.7424	2.0808
Temporary male migration	86	2.0010	0.0467	1.8251	2.1026
Tax expenditures	86	0.9217	0.2426	0.4472	1.8181
Total expenditures	86	610.4767	129.9641	324	1118
Gender wage gap in industry	86	0.2268	0.1617	0.0166	0.7968
Gender wage gap in agriculture	86	0.5203205	0.0885452	0.2678707	0.6980301
Demographic					
Life expectancy at age 0	86	38.7918	6.1147	25.8	50.8
Female life expectancy at age 0	85	40.5556	4.8336	27.5056	49.8460
Male life expectancy at age 0	85	38.0806	4.4244	26.4543	48.9596
Share married women	86	0.5345	0.0575	0.4305	0.6414
Sex ratio at birth 1800-35	86	0.9373	0.0120	0.9066	0.9668
Sex ratio 1821	86	1.0145	0.05711	0.8382	1.1472
Illegitimate urban births	86	12.0701	4.7152	3.0405	26.0125
Illegitimate rural births	86	3.8447	1.8771	1.1571	8.4521
Socio-cultural					
Share Protestant	86	1.9438	4.5392	0.0046	22.1165
Definitive celibacy	86	12.1116	4.2281	5.3141	26.3071
Landownership inequality	86	0.3633	0.1788	0.0407	0.8146
Gender gap index	86	0.6282	0.1152	0.3753	0.8337
Infrastructures					
Towns with no schools	86	7.9090	8.3203	0	32.8076
Railroads	85	104.2353	77.1542	0	324
Share of doctors	86	1.4766	0.7067	0.4553	5.0704
Share of midwifes	86	0.7115	0.4084	0.1153	2.0129
Geographic					
Dialects	86	2.0674	1.1159	1	4
Latitude	86	46.4742	2.1181	41.9192	50.6292
Longitude	86	2.5123	2.6578	-4.0979	8.7386
Distance to Mainz	86	699.04	248.01	181	1222
Distance to Wittenberg	86	969.91	210.76	505	1362
Distance to Geneva	86	237.14	104.26	20	497

Note: Detailed description of variables is provided in appendix.

4. Framework and empirical strategy

As mentioned in Murphy (2015), findings on the education-fertility relationship cannot be interpreted in terms of causality if the potential simultaneity of education and fertility is not controlled for. We therefore use the exogenous variations in education and fertility induced by what we will present as instruments in order to identify the causal effect of both education and fertility. To do so, we employ a simultaneous equations model to investigate how education and fertility possibly interact and how they do cause each other.

4.1. The issue of simultaneity

We estimate the following system of equations:

$$\begin{cases} Education_i = \beta_0 + \beta_1\lambda_i + \beta_a\alpha_i + \beta_2 Ferility_i + \epsilon_i \\ Fertility_i = \beta_4 + \beta_5\lambda_i + \beta_b\delta_i + \beta_6 Education_i + \epsilon_i' \end{cases} \tag{1}$$

where i stands for the county and ϵ_i and ϵ_i' for error terms. $Education_i$ refers to the enrollment in primary schools of county i in 1850. $Fertility_i$ is the number of children from age 0 to 5 of county i in 1851. λ_i refers to the set of common explanatory variables for the level of education and fertility, namely shares in agriculture and in industry, shares of the urban population and of Protestants, population density, life expectancy at birth, an index of the gender gap, horse power, and landownership inequality. δ_i refers to instruments used for fertility, namely the number of towns with no schools, the extent of railroads, and the distance of each county to Mainz. α_i refers to instruments used for education, namely the female definitive celibacy, the share of voting people, and the sex ratio at birth in 1800-35. All instruments are presented in the next sub-section.

In model (1), equations of fertility and education are seemingly related regressions. Our empirical model presents a situation where feedback relationships among fertility and education are undeniably plausible and expected. For instance, and according to the so-called quantity-quality trade-off theory, the quality of children is directly related to the amount spent on them, and the number of children desired is directly related to income (Becker, 1960). As developed by Becker and Lewis (1973), an increase in the quantity of children raises the shadow price (marginal cost) of the quality of children (and conversely). Hence, we presume that the rise in the cost of educating children induces parents to have fewer children. Likewise, we suppose that greater fertility gives less opportunity to educate children. In other words, each equation contains the dependent variable of the other equation among the explanatory variables, which causes a correlation of cross-equation disturbances. We take such feedback relationships into account by proceeding with a simultaneous estimation of the education and the fertility equations.

4.2. Methodology

Parameters in our simultaneous equations model are estimated using the three-stage least squares (3SLS) method (see Zellner and Theil, 1962). The 3SLS uses an instrumental variable approach to produce consistent and asymptotically efficient estimates and a Generalized Least Squares procedure to solve the fact that residuals of the two equations may be correlated. Namely, the 3SLS procedure generalizes the 2SLS procedure by taking into account the correlations between residuals across equations of model (1).[2]

Table 2. *Matrices of Correlations*

Fertility	General fertility rate	Female definitive celibacy	Voting people	Sex ratio
General fertility rate	1.0000			
Female definitive celibacy	-0.1903	1.0000		
Voting people	-0.3678	-0.2011	1.0000	
Sex ratio	-0.0363	0.0483	0.1772	1.0000
Education	School enrollment	Railroads	Towns with no schools	Distance to Mainz
School enrollment	1.0000			
Railroads	0.3728	1.0000		
Towns with no schools	-0.6255	-0.2383	1.0000	
Distance to Mainz	-0.6193	-0.5379	0.3784	1.0000

All exogenous regressors included in our two equations can be used as instruments for endogenous variables because: *(i)* these regressors are not correlated with the residuals of each equation and, by extension, with the dependent variables; and *(ii)* the correlation between these regressors and the instrumented variables is supposed to be different from zero because used as explanatory variables. Besides, we add three excluded instruments for each dependent variable. These sets of excluded instruments include covariates that are – according to the literature and a correlation matrix (see Table 2) – highly correlated to education (respectively to fertility) but not to fertility (respectively to education).

Schooling is instrumented by railroads, distance to Mainz and towns with no schools. Distance to Mainz measures the distance of each French county to Mainz, the city where the printing technic started and diffused. Towns with no schools and railroads measure the extent of infrastructures and may be also correlated with the diffusion of "ideas" and norms. Fertility is instrumented by female definitive celibacy and, as in Becker et al. (2010), by the sex ratio. Sex ratio measures the female-to-male matching possibility. While for most societies, the average sex ratio is 0.9 (see Fisher, 1930), the 1851 average French level was 1.01, revealing a relative "male scarcity". We also originally instrument the general fertility rate by the share of people voting in the whole population in 1846. The voter turnout is used as a proxy capturing

[2] These estimates are more precise than those of a simple 2SLS model since standard errors of the three stage estimates are smaller than those for the two-stage estimates (Wooldridge, 2010).

social capital in terms of degree of civic involvement (see Putnam (1993) for more detail). Existing literature has shown the importance of social capital (measuring personal/communication networks) in explaining reproductive behavior and contraceptive use (e.g. Kohler (2001), Casterline (2001), among others).

We finally run standard tests to evaluate the strength and validity of our instrumentation strategy. Very low correlation between endogenous variables and instruments can indicate weak instruments (namely low predictive power for education or fertility) and may produce upward biased standard errors. Based on the Anderson canonical correlation LM statistic, we run an underidentification test to evaluate whether all the excluded instruments are indeed correlated with the endogenous regressors. The test confirms that our sets of instruments are relevant to explain education and fertility. Besides, we run a weak identification test (using the Cragg-Donald Wald F statistic) to evaluate whether the excluded instruments are enough correlated with the endogenous variables. According to the rule of thumb proposed by Stock and Yogo (2005, p.39) when facing two endogenous variables and three excluded instruments (critical values must exceed 5.91), we do reject the null hypothesis under which excluded instruments have a weak predictive power. Both equations in our model are overidentified, namely we have more excluded instruments (three) than endogenous variables (one). Results of a Sargan test, designed for such specifications, confirm that all instruments are uncorrelated with the error terms. All instruments are correctly excluded from each estimated equation and independent of the error process. Therefore, we can conclude on the validity of our instrumentation strategy.

5. Empirical results

We now apply a 3SLS estimator to jointly determine education and fertility in the French nineteenth century. Based on our instrumentation strategy, we are able to assess the existence of a causal relationship between education and fertility in France during the development process. Relying on the theory, we expect to find a negative association between fertility and education; families with many children will tend to invest less in each child; families making greater investment per child will tend to have fewer children.

5.1. The education-fertility causal relationship

Table 3 reports benchmark results obtained from model (1), using various specifications. Horse power and landownership inequality enter first separately (Columns 2 to 4) and second jointly (Column 5).

The determinants of education

We first have a look at the education equation. Each regression yields similar quantitative answers. Fertility has significant and negative effects on education, across all of our regressions. The IV estimates are at least two times bigger (in absolute value) than the OLS estimates.[3] Durbin-Wu-Hausman tests, which reject the hypothesis that education and fertility are exogenous, confirm that IV estimations are recommended. The estimate indicates that an increase of the general fertility rate by 1 birth per 10 women is in average associated with a decrease of school enrollment rates by more than 10 percentage points. This result implies that a family decides to have fewer children in order to better educate its offspring.

We now turn to discuss to other possible determinants that have affected the level of schooling across French counties. Contrary to the share of urban resident, the population density influences the supply of schools. More densely populated exhibits significantly lower enrollment rates. While Becker et al. (2010) observed that the share of people working in industry was positively correlated to education in Prussia, we find no significant association between the occupational structure in France and the level of schooling. Industries in France relied on children's work, in particular in factory based-textile production where parents and children worked in team at the factory (Tilly and Scott, 1987), making education less attractive. Our results, however, suggest that horse power, a proxy for technological progress, has a positive effect on school enrollment. Technologically advanced counties may demand and need more education because technological changes require a better qualified workforce (Galor, 2011). Hence, new technologies would give parents more incentives to invest in their offspring's education. Likewise, more sophisticated technologies may have required fewer needs for the type of work usually performed by children, giving more opportunities to schooling. While landowners have little interest in public schooling due to low complementarity between land and human capital (as argued in Becker et al., 2010), our estimate for landownership inequality is found to be not significantly negative.

The decision of individuals to invest in education may shift depending on the availability of infrastructures. We therefore control for the share of municipalities with no schools. As expected, creating schools in municipalities with no school before promotes primary school enrollment. Additionally, we control for the length of railroads, capturing county's "market access", which could have an indirect effect on human capital investment (Atack et al., 2012). Transportation networks may increase access to services, and hasten the diffusion of ideas, knowledge and attitudes. However, the estimate for new transportation infrastructures is positive but non-significant across the range of specifications.

Religious, cultural and demographic factors can also explain schooling heterogeneity in France during the development process. In line with Becker and Woessmann (2009) and Becker et al. (2010), we confirm that French counties with larger share of Protestants have a higher propensity to invest in education, stressing the importance of social norms in educating children. The unexpected negative estimate of life expectancy may be due to time-related issues. Adapting educational infrastructures to the population size takes time. This effect cannot be captured by the cross-sectional analysis and may provide a misleading negative effect on schooling. Finally, the closer a county is from Mainz the more its population invests in education. This result supports the existence of a diffusion process having contributed to promote education.

[3] The OLS estimates are available upon request to the authors.

Table 3. *Three-Stage Least-Squares Estimates of Education and Fertility*

Dependent Variable	3SLS Estimates			
	School enrollment			
	(1)	(2)	(3)	(4)
General fertility rate	-0.100***	-0.111***	-0.102***	-0.111***
	(-4.00)	(-3.86)	(-3.88)	(-3.89)
Share in agriculture	-0.150	-0.130	-0.081	-0.058
	(-1.03)	(-0.89)	(-0.47)	(-0.34)
Share in industry	-0.148	-0.329	-0.168	-0.350
	(-0.65)	(-1.35)	(-0.73)	(-1.42)
Share urban	-0.174	-0.174	-0.160	-0.170
	(-1.14)	(-1.15)	(-1.03)	(-1.15)
Population density	-0.016**	-0.045***	-0.015**	-0.043***
	(-2.49)	(-2.64)	(-2.45)	(-2.65)
Share Protestants	0.008**	0.009***	0.008**	0.010***
	(2.44)	(2.69)	(2.41)	(2.66)
Life expectancy at birth	-0.013***	-0.014***	-0.013***	-0.015***
	(-3.56)	(-3.64)	(-3.56)	(-3.75)
Horse power		0.011**		0.011**
		(2.07)		(2.05)
Landownership inequality			-0.075	-0.092
			(-0.56)	(-0.65)
Towns with no schools	-0.008***	-0.007***	-0.007***	-0.006***
	(-4.72)	(-4.00)	(-4.32)	(-3.81)
Railroads	0.072	0.070	0.134	0.129
	(0.41)	(0.43)	(0.74)	(0.70)
Distance to Mainz	-0.275***	-0.231***	-0.290***	-0.242***
	(-4.10)	(-3.52)	(-4.27)	(-3.59)
Constant	2.478***	2.593***	2.491***	2.581***
	(6.52)	(6.11)	(6.26)	(6.11)

Dependent Variable	3SLS Estimates			
	General fertility rate			
	(1)	(2)	(4)	(5)
School enrollment	0.220	-1.282	0.280	-1.374
	(0.14)	(-0.84)	(0.18)	(-0.93)
Share in agriculture	0.316	0.243	1.986	1.652
	(0.22)	(0.19)	(1.22)	(1.11)
Share in industry	2.113	-0.388	1.323	-1.131
	(1.03)	(-0.19)	(0.67)	(-0.59)
Share urban	3.673**	2.503	3.670**	2.390
	(2.03)	(1.48)	(2.10)	(1.47)
Population density	-0.069	-0.352***	-0.049	-0.340***
	(-1.34)	(-3.78)	(-0.97)	(-3.78)
Share Protestants	0.046*	0.058**	0.067**	0.078***
	(1.71)	(2.33)	(2.55)	(3.21)
Life expectancy at birth	-0.077***	-0.092***	-0.078***	-0.094***

	(-2.74)	(-3.53)	(-2.89)	(-3.75)
Horse power		0.103***		0.105***
		(3.51)		(3.73)
Landownership inequality			-2.330**	-2.079**
			(-2.48)	(-2.40)
Female definitive celibacy	-0.121***	-0.092***	-0.120***	-0.091***
	(-3.59)	(-2.78)	(-3.59)	(-2.79)
Voting people	-0.231***	-0.164**	-0.212***	-0.147**
	(-3.07)	(-2.56)	(-3.03)	(-2.49)
Sex ratio at birth (1800-35)	-20.343**	-14.845*	-15.234*	-10.478
	(-2.05)	(-1.81)	(-1.68)	(-1.39)
Constant	34.066***	29.850***	28.905***	25.617***
	(3.82)	(4.08)	(3.50)	(3.77)
Observations	85	85	85	85
R^2 (education equation)	0.4408	0.4112	0.4237	0.4096
R^2 (fertility equation)	0.4197	0.5062	0.4617	0.5425
Education equation				
Underidentification test	0.0000	0.0000	0.0000	0.0000
Weak identification test	6.46	6.46	6.46	6.46
Overidentification test	0.1283	0.3814	0.1145	0.5048
Fertility equation				
Underidentification test	0.0000	0.0002	0.0000	0.0003
Weak identification test	6.46	6.46	6.46	6.46
Overidentification test	0.3278	0.2718	0.0689	0.0220

Notes: Table 3 reports estimates of model (1) applying IV and OLS estimators. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

The determinants of fertility

We now turn to the fertility equation. Controlling for the simultaneity of the decisions for education and fertility, we find no evidence for a significant role of larger school enrollment on fertility rates during the French demographic transition. These empirical results imply that the causality between fertility and education runs only from fertility to education.

Nonetheless, the decision to control the number of children is affected by additional factors. Our estimates confirm that densely populated areas exhibit lower fertility rates (Wanamaker, 2012; Becker et al., 2012). However, contrary to findings about Prussia (Becker et al., 2010, 2012) or Sweden (Dribe, 2009), industrialization did not reduce the demand for children across French counties, as already evidenced by Murphy (2015) and Diebolt et al. (2015). France displays real divergences from the standard model of Western demographic evolution (Chesnais, 1992) and challenges the literature relying on the importance of economic factors in explaining fertility decline. The level of technological progress, measured by horse power per capita, however, appears positively associated with the general fertility rate. We argue that machines became more powerful making the type of people employed in manufacturing evolving toward higher-skilled workers. Men were possibly more incline to perform this type of skilled-jobs, better paid, and – as an income effect – had more resources to take care of supplementary children.

Life expectancy at birth, which is a proxy for health, quality of life, and infant mortality, is a prevalent determinant of the fertility decline (Crafts, 1989; Kalemli-Ozcan, 2003). Estimates of life expectancy across all the regressions are in line with the literature. As life expectancy at birth increases, individuals do not need to produce many children to ensure that some will survive to childhood and take care of them in old days. Religion may also affect individual behaviors regarding family, marriage and sexual practices (Anderson, 1986; McQuillan, 1999). Christianism forbids contraception and sex is not allowed outside marriage. Estimates of the share of Protestants are significant and positive implying that, at the early stage of the French demographic transition, individuals more engaged in religion were likely to have a greater number of children. In like manner, we originally observe that the share of female definitive celibacy reduces the general fertility rate. Definitive celibacy might have been chosen by women as a way of controlling fertility. We show for the first time that the share of voting people, used as a proxy capturing social capital, is negatively associated to the general fertility rate. Finally, we reveal that fertility decreases in areas where landownership inequality is high. Individuals may be likely to avoid the dissemination of inheritance and division of lands among many offspring.

Controlling for the issue of simultaneity, we evidence that the causation between education and fertility during the French demographic transition runs from fertility to education. Namely, a decrease in fertility causes an increase in enrollment rates.

5.2. Do gender differences condition the education-fertility relationship?

5.2.1. Gender differences in the society

Gender differences can possibly condition this education-fertility relationship (see Basu, 2002; Diebolt et al., 2015). For instance, female employment opportunities can increase the family size via an income effect. Besides, parents can provide different education to their boys compared to their girls. While most studies on gender differences are based on modern data, we present new historical evidence on French data (Table 4).

Before going further in the discussion, we address the concern of collinearity. Problems in estimation arise when predictors are linearly related. Standard errors may increase (meaning lower significance levels) and estimated coefficients may have the wrong sign or a suspect magnitude. We test for collinearity between all our female and male variables.[4] Because these variables present a high risk to be collinear, we run the regressions with alternatively a set of male and a set of female variables. For comparison, we also report estimates when both male and female characteristics are included in model (1).

[4] We use the command "collin" in Stata to diagnose the collinearity between male and female regressors. The condition number, used to measure the risk of collinearity, is always bigger than 10, which indicates a high risk of collinearity.

To keep the discussion focused and also conserve on space, Table 4 only reports the variables of interests. The full estimation results are available in the supplementary file, available from the authors upon request. When all gender differentiated regressors are included simultaneously (Columns 1 and 4), estimates are very similar to those reported in Table 3. However, accounting for the risk of collinearity, results reported in Columns 2, 3, 5 and 6 reveal specific gender differences among the determinants of education and fertility.

No matter regression, a decline in fertility causes higher education, for girls and boys. In turn, neither girls nor boys schooling affect parents' fertility. But shares of men and women employed in industry decrease their children's education. This effect is particularly sizeable for women. In textile towns, in which many women were participating to productive activity, evidence suggests that "work was most plentiful and remunerative for young people" (Tilly and Scott, 1989); accordingly, the percentage of families with working children was significantly larger in those areas. Likewise, we evidence that counties with higher shares of women working in industry display lower fertility rates. Industrialization, by increasing female labor force participation, has contributed to reduce the number of children per family.

A gender approach does not condition the causal relationship lying between fertility and education, but helps instead to better apprehend the role of women, in particular in industry, on both education and fertility.

5.2.2. Gender differences in families

We now turn to investigate the relevance of the distribution of gender roles between members of family and the relation between spouses in our study. In particular, we expect that more equality between partners would reduce the size of family (see, among others, Diebolt and Perrin (2013)). At the early stage of industrialization, responsibilities for both economic support and family care were less easily managed by a specialization in the family sphere. Women were likely to increase their participation in the public sphere to be able to contribute to the financial support of families, changing in turn the relation between spouses. The new role of women can have triggered the need for a reduction of family responsibilities, namely, children.

To know whether our data support this hypothesis, we use the gender gap indices provided by Perrin (2014). To avoid the issue of collinearity, we successively add to model (1): *(i)* an overall measure of gender equality – named the Gender Gap Index (GGI); *(ii)* the educational GGI; *(iii)* the economic GGI; and *(iv)* the health GGI. A summary of empirical results is presented in Table 5. The full estimation results are available in the supplementary file, available from the authors upon request.

Table 4. *Three-Stage Least-Squares Estimates of Education and Fertility – Gendered Approach*

Dependent Variable	Girls enrollment			Boys enrollment		
	(1) Both	(2) Female	(3) Male	(4) Both	(5) Female	(6) Male
General fertility rate	-0.121***	-0.109***	-0.109***	-0.115***	-0.105***	-0.104***
	(-3.76)	(-3.77)	(-3.84)	(-3.49)	(-3.53)	(-3.54)
Share female in agriculture	-0.001	-0.001		-0.001	-0.001	
	(-0.50)	(-0.43)		(-0.48)	(-0.46)	
Share female in industry	-2.518*	-0.568**		-2.328*	-0.662**	
	(-1.96)	(-2.10)		(-1.77)	(-2.38)	
Share male in agriculture	0.002		-0.001	0.001		-0.001
	(0.51)		(-0.31)	(0.41)		(-0.37)
Share male in industry	1.846		-0.505*	1.586		-0.596**
	(1.60)		(-1.95)	(1.34)		(-2.22)
Female life expectancy at age 0	-0.028***	-0.026***		-0.031***	-0.026***	
	(-2.77)	(-3.99)		(-2.90)	(-3.88)	
Male life expectancy at age 0	-0.001		-0.025***	0.002		-0.025***
	(-0.13)		(-3.75)	(0.18)		(-3.53)
Constant	3.413***	3.239***	3.110***	3.380***	3.241***	3.069***
	(5.37)	(5.39)	(5.47)	(5.18)	(5.23)	(5.23)
Dependent Variable	**General fertility rate**					
	(1) Both	(2) Female	(3) Male	(4) Both	(5) Female	(6) Male
Girls enrollment	0.636	-0.291	0.042			
	(0.59)	(-0.31)	(0.04)			
Boys enrollment				0.752	-0.317	0.042
				(0.60)	(-0.29)	(0.03)
Share female in agriculture	-0.001	0.014		-0.003	0.012	
	(-0.09)	(1.04)		(-0.16)	(0.93)	
Share female in industry	-18.965**	-2.962*		-18.718**	-2.957*	
	(-2.49)	(-1.66)		(-2.46)	(-1.65)	
Share male in agriculture	0.039*		0.028	0.039*		0.027
	(1.80)		(1.54)	(1.79)		(1.45)
Share male in industry	16.174**		-1.642	16.101**		-1.607
	(2.25)		(-0.88)	(2.23)		(-0.84)
Female life expectancy at age 0	-0.153**	-0.176***		-0.153**	-0.177***	
	(-2.43)	(-6.38)		(-2.42)	(-6.35)	
Male life expectancy at age 0	-0.030		-0.172***	-0.028		-0.171***
	(-0.44)		(-5.62)	(-0.42)		(-5.53)
Constant	17.919***	20.418***	18.459***	17.881***	20.619***	18.549***
	(7.69)	(10.54)	(7.89)	(7.15)	(10.09)	(7.39)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observation	84	84	84	84	84	84
R^2 (education equation)	0.4796	0.5465	0.5125	0.5816	0.4532	0.5306
R^2 (fertility equation)	0.6506	0.6482	0.6357	0.6338	0.6151	0.6136

Notes: Table 4 reports 3SLS estimates of our model using gender characteristics. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively. Data is missing for men and women life expectancy at age 0 in 1856 reducing our sample to 84 counties.

Table 5. *Diffusion Effect – Gender Equality*

Dependent Variable	School enrollment			
	(1) Overall GGI	(2) Education GGI	(3) Economic GGI	(4) Health GGI
General fertility rate	-0.124***	-0.115***	-0.132***	-0.112***
	(-2.96)	(-3.12)	(-3.63)	(-3.87)
GGI	-0.634			
	(-1.13)			
Education GGI		-0.143		
		(-0.74)		
Economic GGI			-0.961**	
			(-1.99)	
Health GGI				-0.302
				(-0.48)
Constant	3.260***	2.766***	3.360***	2.890***
	(3.32)	(4.15)	(4.82)	(3.62)
Dependent Variable	General fertility rate			
	(1) Overall GGI	(2) Education GGI	(3) Economic GGI	(4) Health GGI
School enrollment	1.907	1.667	-0.171	-1.285
	(1.00)	(0.85)	(-0.11)	(-0.87)
GGI	-9.188***			
	(-3.18)			
Education GGI		-3.591***		
		(-2.97)		
Economic GGI			-5.244*	
			(-1.93)	
Health GGI				-0.092
				(-0.02)
Constant	29.035***	26.224***	27.301***	27.090***
	(3.60)	(3.34)	(3.99)	(3.46)
Observations	85	85	85	85
Control variables	Yes	Yes	Yes	Yes
R^2 (education equation)	0.3490	0.3950	0.2929	0.4070
R^2 (fertility equation)	0.5860	0.5897	0.5585	0.5421

Notes: Table 5 reports 3SLS estimates of the variables of interest using gender equality characteristics. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

Gender equality seems to matter for better understanding differences in education and fertility across French counties during the demographic transition. Less gender inequalities in economic opportunities and in the labor force make parents invest more in education (see Column 2). Gender equality was higher in industries that needed an increasing workforce. As mentioned above (see Table 4), a higher share of women in industries strongly reduces educational investments by increasing the supply (and demand) of labor for all family members, including children.

As expected, no matter the measure of gender equality included in model (1) (except for health), fertility decreases with greater equality among spouses. The new role of women in the early stage of industrialization has contributed to the fertility decline across French counties.

6. Can the diffusion hypothesis explain the education-fertility relationship?

The diffusion phenomenon can cause social changes and, therefore, be relevant in explaining the differences in education and fertility across French counties. In particular, new practices and attitudes towards children that seem beneficial to families may diffuse and therefore affect families' decisions on education and fertility (Salles et al., 2010).

6.1. Geographic factors

The diffusion of education and the change of fertility behaviors can be accelerated by the movement of ideas and individuals through the communication channels, as well as by languages and dialects. To assess the possible role of geographic characteristics on our fertility-education relationship, we include various controls. A summary of empirical results is presented in Table 6. The full estimation results are available in the supplementary file, available from the authors upon request.

Knowing the spatial structure of each county can explain both education and fertility variations. We control for latitude and longitude in both equations of model (1) (see Column 3). Longitude improves the prediction of schooling, which gives support to the diffusion hypothesis and confirms that education spread from Northeastern France to the rest of the country. Then, because Becker and Woessmann (2009) evidenced that education in Prussia spread in circles around Wittenberg at times of Martin Luther, we use the traditional distance to Wittenberg as an alternative to the distance to Mainz instead (see Column 2). As for Prussia, French counties closer to Wittenberg display higher school enrollment rates. The distance to Geneva is introduced into model (1) to account for the possible Calvinism expansion (see Column 4). Yet, there is no statistical significance for Calvinist diffusion in France.

Column 1 reports estimates of model (1) when *Dialects* is added into the list of control variables. Different languages between counties can slow down the diffusion phenomenon across the whole country. Hence, to enable the spread of revolutionary ideas, the French language has been diffused through education, via common and free primary school policies. Our data, however, do not reveal that the spread of education among French counties speaking dialects close to French has been faster than elsewhere.

Finally, we decide to drop Paris from the whole sample. The blocked adaptive computationally efficient outlier nominators (BACON) algorithm proposed by Billor et al. (2000) indeed reveals that Paris is a potential problematic outlier.[5] Families in urban industrial society, where the new idea of the small family arose, were prone to decide to reduce the size of families (Notestein, 1953; Houdaille, 1989).

[5] We use the 0.85 percentile of the chi-squared distribution as a threshold to separate outliers from non-outliers.

Existing literature on the French fertility transition suggests that the diffusion of contraceptive information spread from higher to lower social classes and from cities to rural areas (Bideau et al., 1988). Results reported in Column 5 show, however, that the most urbanized county did not drive the fertility decline in France. Lower fertility still causes education with the same magnitude and does not depend on extreme values in the data.

Table 6. *Diffusion effect – Geographic factors*

Dependent Variable School enrollment	Dialect	Latitude-longitude	Distance to Wittenberg	Distance to Geneva	Without Paris
	(1)	(2)	(3)	(4)	(5)
General fertility rate	-0.099***	-0.121***	-0.113***	-0.113***	-0.124***
	(-3.92)	(-3.80)	(-3.97)	(-3.91)	(-4.01)
Dialect	0.019				
	(1.41)				
Latitude		0.001			
		(0.09)			
Longitude		0.026**			
		(2.17)			
Distance to Wittenberg			-0.320***		
			(-4.08)		
Distance to Geneva				0.000	0.000
				(1.59)	(1.41)
Constant	2.379***	2.401**	2.704***	2.533***	2.747***
	(6.29)	(2.51)	(6.49)	(6.17)	(6.10)
Dependent Variable	**General fertility rate**				
	(1)	(2)	(3)	(4)	(5)
School enrollment	-0.874	0.229	-1.206	-1.203	-1.208
	(-0.58)	(0.08)	(-0.86)	(-0.83)	(-0.84)
Dialect	0.158				
	(1.32)				
Latitude		-0.131			
		(-1.34)			
Longitude		-0.005			
		(-0.04)			
Distance to Geneva				0.002*	0.002*
				(1.87)	(1.72)
Constant	26.561***	31.311***	25.523***	25.368***	25.341***
	(3.42)	(3.32)	(3.83)	(3.75)	(4.00)
Observations	85	85	85	85	84
Control variables	Yes	Yes	Yes	Yes	Yes
R^2 (education equation)	0.4989	0.4132	0.3948	0.4149	0.3431
R^2 (fertility equation)	0.5515	0.5426	0.5472	0.5607	0.5610

Notes: Table 6 reports estimates of our variables of interest testing for geographic characteristics. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

6.2. Family structure

The role of institutions has been recognized fundamental to explain economic disparities (Acemoglu, Johnson and Robinson, 2005). However, the role of family, as primary form of institution and social organization, has received little attention. The diversity of traditional family structures may have influenced the trajectory of modernization (Todd, 2011). In this line, regional disparities across French counties in the middle of the nineteenth century can be deepened by differences in structures and organizations of traditional family types.

We use Todd's classification of families to account for the French family characteristics (Le Bras and Todd, 2013). Nine types of families are emphasized according to the different compositions of *(i)* liberty-authority values (parents-children relationships), and *(ii)* equality-inequality values (relationships between siblings). To have a suitable number of observations per type of families for estimation, we have grouped Todd's family types into five classes: stem family, intermediate family, absolute nuclear family, egalitarian nuclear family, cooperative egalitarian family. They are included one at a time in model (1) to solve the issue of collinearity among these variables. A summary of empirical results is presented in Table 7. The full estimation results are available in the supplementary file, available from the authors upon request.

The *stem family,* characterized by extended families with several generations living under one roof and one child inheriting from the house and lands to preserve the lineage, does not statistically influence neither education nor fertility (see Column 1). Similarly, *egalitarian nuclear family*, characterized by an equal division of inheritance among children, does not explain variations across counties (see Column 4).

Intermediate families, that are extended families in which all sons can get married and bring their wives to the family home, apparently do not invest as much as other families into their children's education (see Column 2). On the contrary, *cooperative egalitarian families*, that are extended families but where there is equality among (male) children in inheritance, give more education to their children.

The establishment of the egalitarian system of inheritance may affect fertility in two opposite ways: *(i)* positively, by allowing individuals to marry earlier and establish quicker their own family, which increases in turn the probability of higher fertility rates; or *(ii)* negatively, by reducing the incentive to have children to reduce the partition of properties among them. In *cooperative egalitarian families*, in which children may also serve as assets for old age support, the positive effect outweighs the negative one.

In *absolute nuclear families*, children are totally emancipated in adulthood and the division of inheritance among children usually goes to one single child (often the son). Households organized according to this type of family have fewer children than any other household (Column 3).

Table 7. *Diffusion Effect – Family Structure*

Dependent Variable	School enrollment				
	(1) Stem	(2) Intermediate	(3) Absolute	(4) Egalitarian	(5) Cooperative
General fertility rate	-0.105***	-0.095***	-0.129***	-0.109***	-0.114***
	(-3.85)	(-3.55)	(-3.51)	(-3.88)	(-4.03)
Stem family	0.045				
	(1.04)				
Intermediate family		-0.097**			
		(-2.52)			
Absolute nuclear			-0.142		
			(-1.64)		
Egalitarian nuclear				0.025	
				(0.56)	
Cooperative egalitarian					0.194***
					(3.06)
Constant	2.558***	2.429***	2.716***	2.505***	2.491***
	(6.16)	(6.33)	(5.52)	(5.78)	(6.15)
Dependent Variable	General fertility rate				
	(1) Stem	(2) Intermediate	(3) Absolute	(4) Egalitarian	(5) Cooperative.
School enrollment	-1.391	-1.904	-0.752	-0.312	-0.591
	(-0.96)	(-0.98)	(-0.52)	(-0.16)	(-0.43)
Stem family	0.529				
	(1.54)				
Intermediate family		-0.206			
		(-0.47)			
Absolute nuclear			-1.161**		
			(-2.55)		
Egalitarian nuclear				-0.428	
				(-0.99)	
Cooperative egalitarian					0.919**
					(2.03)
Constant	25.751***	26.482***	23.932***	25.393***	24.270***
	(3.80)	(3.92)	(3.66)	(3.42)	(3.45)
Observations	85	85	85	85	85
Control variables	Yes	Yes	Yes	Yes	Yes
R^2 (education equation)	0.4334	0.4586	0.3160	0.5419	0.4544
R^2 (fertility equation)	0.5491	0.5557	0.5754	0.5421	0.5629

Notes: Table 7 reports 3SLS estimates of our variables of interest using family structure characteristics. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

7. Robustness regressions

We test the sensitivity of model (1) using alternative specifications, estimation techniques and data measurements in order to confirm our results.

7.1. Alternative estimators and sets of instruments

We first present alternative estimation procedures, accounting as well for the issue of endogeneity. These procedures include the use of different estimators and different instrument sets. The 3SLS estimation procedure assumes that the optimal fertility decision and the optimal education decision are not chosen by the same individual. The optimization process described in each equation should be done by different individuals. This is the autonomy requirement. One of the two equations in system (1) is said to be autonomous when this equation has an economic meaning when isolated from the other equation. However, the same individual can be expected to take both the fertility and education decision. Autonomy is not required for the empirical analysis, but we provide IV estimates on each single equation to confirm our benchmark evaluation.

For additional robustness, we run alternative IV regressors, namely the conventional 2SLS estimator, the optimal General Method of Moments (GMM) estimator, and the Limited Information Maximum Likelihood (LIML) estimator (see Table 8). Very low fluctuations in the results indicate that instruments used for education and for fertility are appropriate and that our model is apparently not misspecified.[6] Besides, both significance and magnitude of core estimates remain very similar to the benchmark estimates. The negative causal effect of the decline in fertility on education is confirmed by the 2SLS estimations.

Table 8. *Alternative IV estimators – Separated equations*

Dependent variable	IV		GMM		LIML	
	(1) General fertility rate	(2) School enrollment	(3) General fertility rate	(4) School enrollment	(5) General fertility rate	(6) School enrollment
School enrollment	-1.285		-2.108		-1.193	
	(-0.66)		(-1.16)		(-0.58)	
General fertility rate		-0.114***		-0.110***		-0.126***
		(-3.37)		(-3.43)		(-3.07)
Constant	14.262***	2.774***	15.793***	2.721***	14.132***	2.932***
	(4.77)	(5.56)	(5.71)	(5.73)	(4.55)	(4.94)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	85	86	85	86	85	86
R^2	0.477	0.256	0.485	0.276	0.476	0.171

Notes: Table 8 reports a summary of the 2SLS estimates of the education equation (Columns 1, 3, and 5); and fertility equation (Columns 2, 4, and 6). Full estimations results are available from the authors upon request. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

[6] Overidentification tests are only available with non-robust standard errors when applying the LIML estimator.

Secondly, following Becker et al. (2010), we use alternative sets of instruments. Instruments for education include distance to Wittenberg and landownership inequality. Instruments for fertility include the sex ratio at birth in 1821, the sex ratio of boys and girls born between 1800 and 1835, and the share of married women. Table 9 reports estimates of the variables of interest and of instruments. Though sex ratio instruments are very collinear, estimates of model (1) using these sets of instruments corroborates our findings. Additionally, we drop railroads and sex ratio at birth from our initial sets of instruments because their estimates turn to be not significant in several of our estimation results and both are the less correlated to the respective endogenous variable. Again, results and magnitude of estimates do not differ from those reported in Table 3.

Table 9. *Alternative Instruments*

Dependent Variable	School enrollment		
	(1) Becker et al.	(3) No sex ratio	(4) No railroads
General fertility rate	-0.139***	-0.109***	-0.115***
	(-2.71)	(-3.86)	(-3.97)
Landownership inequality	-0.118		
	(-0.61)		
Distance to Wittenberg	-0.330***		
	(-2.64)		
Railroads		0.117	
		(0.64)	
Constant	3.129***	2.559***	2.650***
	(4.44)	(6.13)	(6.30)
Dependent Variable			
	(1) Becker et al.	(3) No sex ratio	(4) No railroads
School enrollment	-0.093	-1.726	-1.804
	(-0.04)	(-1.25)	(-1.37)
Share married women	5.352*		
	(1.73)		
Sex ratio 1821	-5.552		
	(-1.54)		
Sex ratio 1800-35	-8.937		-7.714
	(-1.01)		(-1.17)
Constant	24.889***	16.048***	23.855***
	(3.12)	(7.14)	(3.90)
Observations	86	85	86
Control variables	Yes	Yes	Yes
R^2 (education equation)	0.1441	0.4224	0.4034
R^2 (fertility equation)	0.4919	0.5423	0.5438

Notes: Table 9 reports 3SLS estimates of the variables of interest using gender equality characteristics. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

7.2. Alternative measurements and additional controls

Findings can be dependent on how we have decided to measure either education or fertility. We therefore employ reading skills, literacy rates and enrollment in public primary schools as alternative measures to school enrollment in primary school. Literacy and public enrollment rates also enable us to disaggregate between men and women's education. Likewise, we use the crude birth rate, the child-women ratio, and the index of marital fertility to measure fertility. Main results are reported in Table 10 and 11.

Table 10. *Alternative measures of education*

Dependent Variable	Female literacy	Male literacy	Public enrollment F	Public enrollment M	Reading
	(1)	(2)	(3)	(4)	(5)
General fertility rate	-11.024***	-9.735***	-0.052***	-0.086***	-6.971***
	(-3.77)	(-3.54)	(-2.61)	(-3.58)	(-3.00)
Constant	255.824***	235.487***	1.860***	2.191***	206.439***
	(5.95)	(5.82)	(6.39)	(6.17)	(6.03)
Dependent Variable	General fertility rate				
	(1)	(2)	(3)	(4)	(5)
Female literacy rate	-0.012				
	(-1.39)				
Male literacy rate		-0.019			
		(-1.32)			
Public enrollment F			-1.393		
			(-1.22)		
Public enrollment M				-1.782	
				(-1.11)	
Reading					-0.017
					(-1.12)
Constant	26.143***	24.904***	23.529**	25.114***	29.619***
	(3.33)	(3.20)	(2.38)	(3.39)	(3.17)
Observations	85	85	85	85	85
Control variables	Yes	Yes	Yes	Yes	Yes
R^2 (education equation)	0.6625	0.5435	0.8094	0.5494	0.6423
R^2 (fertility equation)	0.5636	0.5628	0.5626	0.5468	0.5572

Notes: Table 10 reports a summary of estimates of model (1) using alternative measures of education. Full estimations results are available from the authors upon request. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

No matter which measure of education is used, the causal relationship found in Table 3 holds perfectly. However, introducing alternative measures of fertility does not lead to such definitive conclusions. Both the crude birth rate and the child-women ratio confirm the significant effect from fertility to education (Column 1 and 2, respectively).[7] The index of marital fertility (Column 3), however, presents no statistically significant results on education. As already indicated by Diebolt et al. (2015), the Ig index may be a misleading measure of fertility in specific circumstances, such as in the presence of female delay in age at marriage, which was the case in various places in France during the nineteenth century, where religious believe and practice were important.

Table 11. *Alternative measures of fertility*

Dependent Variable	School enrollment		
	(1)	(2)	(3)
Crude birth rate	-0.069***		
	(-2.83)		
Child-women ratio		-1.833***	
		(-4.33)	
Ig index			0.366
			(1.03)
Constant	3.291***	-0.361***	0.925***
	(4.08)	(-5.00)	(3.54)
Dependent Variable	Crude birth rate	Child-women ratio	Ig index
	(1)	(2)	(3)
School enrollment	-4.054	0.124*	0.001
	(-1.36)	(1.66)	(0.01)
Constant	49.074***	1.357***	0.172
	(4.87)	(2.77)	(0.27)
Observations	85	85	85
Control variables	Yes	Yes	Yes
R^2 (education equation)	0.2275	0.6465	0.6940
R^2 (fertility equation)	0.6356	0.5019	0.6890

Notes: Table 11 reports a summary of estimates of model (1) using alternative measures of fertility. Full estimations results are available from the authors upon request. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

Finally, we add to model (1) diverse possible determinants, either for education or for fertility (see Table 12). First, following Becker et al. (2010) and Murphy (2015), we account for the potential effect of migration on education and fertility levels. For instance, migrants working in a different department than their place of residence may delay their decision to become parents. Besides, to find job, migrants tend to migrate to more urbanized regions that have also lower fertility rates. In turn, migrants may adopt the social norm, including fertility control norms, of these regions (see Bonneuil (1997) and Daudin et al. (2012)). On the other hand, number of studies focusing on developing countries showed that migrants may want to transmit their desire to acquire skills into their offspring's education (e.g. Goldstein, 1973;

[7] The estimate (Column 2) presents a weak positive effect of education on the child-women ratio, however, the effect does not hold when using the alternative measures of education used in Table 10.

Brockerhoff and Yang, 1994). We control for temporary migration (1856-60) of individuals aged from 15 to 69 in 1851 (Column 1) and for the share of foreigners within the population (Column 2). Using our French historical data, we observe that counties with a higher share of foreigners display higher fertility rates and invest more in education than other counties, maybe because foreigners have adopted fertility norms of the hosting county where fertility rates were higher than elsewhere. Conversely, as in Dribe (2009), migration seems to be not relevant in our study.

Then, because income and standard of living can condition the size of families and the educational investments, we control for both the family income (with the amount of family's tax expenditures) and the cost of living (with the family's average expenditures). Yet, none of these variables are statistically significant in our model.

Table 12. *Additional controls*

Dependent Variable	School enrollment						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
General fertility rate	-0.104***	-0.115***	-0.117***	-0.113***	-0.135***	-0.131***	-0.113***
	(-3.29)	(-4.08)	(-3.92)	(-3.94)	(-4.39)	(-4.14)	(-3.94)
Temporary migration	-0.198						
	(-0.53)						
Share of foreigners		0.047***					
		(2.94)					
Wage gap in agriculture			-0.198				
			(-0.91)				
Wage gap in industry				-0.218			
				(-1.57)			
Children wage agriculture					-0.304		
					(-1.01)		
Children wage industry					0.051		
					(0.32)		
Female wage agriculture					0.100		
					(0.40)		
Female wage industry					-0.266*		
					(-1.89)		
Male wage agriculture					0.312*		
					(1.85)		
Male wage industry					-0.042		
					(-0.45)		
Illegitimate urban births						-0.012***	
						(-2.78)	
Illegitimate rural births						0.004	
						(0.38)	
Share doctors							0.054**
							(2.00)
Share midwifes							-0.030
							(-0.66)
Constant	2.862***	2.513***	2.736***	2.615***	2.841***	3.074***	2.586***

	(4.48)	(6.40)	(5.92)	(6.14)	(6.03)	(6.30)	(5.78)

Dependent Variable	General fertility rate						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
School enrollment	-1.362	-2.045	-1.044	-0.325	-2.029	-1.816	-0.044
	(-0.93)	(-1.39)	(-0.68)	(-0.21)	(-1.11)	(-1.28)	(-0.03)
Temporary migration	1.274						
	(0.43)						
Share of foreigners		0.314***					
		(2.92)					
Wage gap in agriculture			-1.119				
			(-0.68)				
Wage gap in industry				-2.400***			
				(-2.63)			
Children wage agriculture					-2.087		
					(-0.94)		
Children wage industry					0.513		
					(0.45)		
Female wage agriculture					1.087		
					(0.59)		
Female wage industry					-0.986		
					(-0.93)		
Male wage agriculture					1.102		
					(0.86)		
Male wage industry					-0.190		
					(-0.27)		
Illegitimate urban births						-0.054*	
						(-1.70)	
Illegitimate rural births						0.056	
						(0.71)	
Share doctors							0.231
							(1.22)
Share midwifes							-0.710*
							(-1.90)
Constant	25.871***	24.333***	25.774***	26.472***	25.397***	22.728***	28.478***
	(2.94)	(3.75)	(3.80)	(3.51)	(4.26)	(3.87)	(3.88)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	85	85	85	85	85	85	85
R^2 (education equation)	0.3917	0.4632	0.3746	0.4229	0.2847	0.3188	0.4272
R^2 (fertility equation)	0.5433	0.5866	0.5456	0.5780	0.5541	0.5570	0.5623

Notes: Table 12 reports a summary of estimates of model (1) using additional controls. Full estimations results are available from the authors upon request. Robust standard errors in brackets. The asterisks ***, **, and * are 1%, 5%, and 10% of significant levels, respectively.

To prop up our findings on gender equality, we follow Schultz (1985) and Galor and Weil (1996) by giving attention to the women-to-men relative wage in both agriculture and industry. We confirm that not only a higher share of women in industry (see Table 6) but also higher wages for women compared to men in industry decrease the number of children per family. When child, female, and male wages are introduced separately in model (1), the role of women wages in industry on fertility and education is again emphasized (see Column 5). Conversely, higher male wages in agriculture seems to be beneficial to schooling (by relaxing the need for children's earnings to augment the family budget).

As evidenced by Hajnal (1965), the pattern of birth control in the early modern period was characterized by late age at marriage, high definitive celibacy, and low illegitimate births. Low share of illegitimate births may reflect a change in people's behavior toward fertility control. Instead, our data reveal that during the French demographic transition, more illegitimate births are associated with larger fertility control and with lower educational investments (see Column 6), which confirms Perrin (2013)'s findings.

Finally, the access to medical care may explain variations in fertility and education across the country (Column 7). Shares of doctors and midwives are introduced in model (1). Counties with higher shares of doctors also invest more in education, certainly due to social interactions and better standard of livings. More midwives, however, have a decisive influence on the number of birth per women in childbearing age, in particular by providing information on how controlling births.

No matter the change in specification and the robustness assessment, our conclusion holds across regressions. A decline in fertility during the French demographic transition has caused an increase in education.

8. Conclusion

Theoretical models have emphasized the role the fertility-education trade-off in the transition from stagnation to sustained growth. Yet, historical empirical evidence is at a premium. Our econometric analysis contributes to this emerging literature. We explore the causal relationship between education and fertility, accounting as well for possible determinants never considered before but important to understand the dynamics of this relationship.

We investigate the Unified Growth Theory predictions using an original county-level dataset for France in the mid nineteenth century. Changes in education and fertility appeared in France when it was still sparsely industrialized. By encompassing the historical development of an industrialized country, the sample period makes empirical results relevant to many countries that are less developed today.

Controlling for the simultaneity of family decisions in terms of fertility and education, we are able to assess the causal effects of both education and fertility. We confirm part of the Unified Growth Theory predictions. In particular, we expose that a decline in fertility during the French demographic transition has caused an increase in educational investments. Results are robust to various specifications and measurements. Besides, we find that the French education-fertility relationship runs from fertility to education only, implying that the education effect on fertility may take time before being effective. We further contribute to the literature by establishing the decisive influence of the women-to-men relative roles, of family structures, and of the diffusions of behaviors on both the size of families and children's education. Specifically, counties with higher gender equality, in particular in terms of occupations and wages, exhibit lower fertility rates. Likewise, extended families in which all bring their wives to the family home are less likely to invest in education. Finally, social interactions have contributed to shape educational and fertility behaviors differences across French counties. Thus, our empirical study confirms that in the short run fertility controls are able to cause children's education improvements.

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Appendix

Table A. *Data Sources and Construction of the Variables*

Variable	Year	Definition	*Sources*
Education			
Female literacy rate	1854	Share of spouses who signed their wedding contract	*Statistique enseignement primaire*
Male literacy rate	1854	Share of spouses who signed their wedding contract	*Statistique enseignement primaire*
Girls enrollment rate in public primary school	1850	Number of girls enrolled in public primary schools divided by girls aged 5-15	*Statistique enseignement primaire and Recensement 1851*
Boys enrollment rate in public primary school	1850	Number of boys enrolled in public primary schools divided by boys aged 5-15	*Statistique enseignement primaire and Recensement 1851*
Girls enrollment rate in primary school	1850	Number of girls enrolled in primary schools divided by girls aged 5-15	*Statistique enseignement primaire and Recensement 1851*
Boys enrollment rate in primary school	1850	Number of boys enrolled in primary schools divided by boys aged 5-15	*Statistique enseignement primaire and Recensement 1851*
School enrollment	1850	Number of children enrolled in primary schools divided by children aged 5-15	
Reading skills	1851-55	Number of people per 100 being able to read	*Statistique enseignement primaire*
Fertility			
Child-women ratio	1851	Number of children aged 0-5 per women of childbearing age (15-45)	*Recensement 1851*
Index of marital fertility Ig	1851	From Princeton European fertility project	*Coale and Watkins (1986)*
General fertility rate	1851	Number of birth (minus stillbirths) per women aged 15-45	*Mouvement de la population 1851 and Recensement 1851*
Sex ratio at births	1800-35	Female births per male births	*Mouvement de la population*
Adult sex ratio	1851	Female-to-male population of working age 15-64	*Recensement 1851*
Economic			
Population density	1851	Number of people per km²	*Recensement 1851*
Share of urban resident	1851	Number of people living in towns of more than 2000 inhabitant per total population	*Recensement 1851*
Landownership inequality	1851	Share of landowners per total agricultural workers	*Recensement 1851*
Horse power	1861	Horse power of steam engines per 1000 people	*Enquête industrielle 1861*
Male in agriculture	1851	Number of male working agriculture divided by male population	*Recensement 1851*
Female in agriculture	1851	Number of female working agriculture divided by female population	*Recensement 1851*
Male in industry	1851	Number of male working industry per male population	*Recensement 1851*
Female in industry	1851	Number of female working industry per female population	*Recensement 1851*
Share in agriculture	1851	Number of people working agriculture per total population	*Recensement 1851*
Share in industry	1851	Number of people working industry per total population	*Recensement 1851*
Female wage in industry	1861	Average of female wages in different industries proportionally to the weight of women in each industry	*Enquête industrielle 1861*
Male wage in industry	1861	Average of male wages in different industries proportionally to the weight of men in each industry	*Enquête industrielle 1861*
Female wage in agriculture	1852	Average female wage in agriculture – not fed	*Enquête agricole 1852*
Male wage in agriculture	1852	Average male wage in agriculture – not fed	*Enquête agricole 1852*
Tax expenditures	1852	Share of the expenses of a 5-members family of daily workers in agriculture dedicated to the taxes	*Enquête agricole 1852*
Total expenditures	1852	Total expenses of a 5-members family of daily workers in Francs	*Enquête agricole 1852*

Health			
Life expectancy at age 0	1851-55	From *Statistique Générale de la France*	*Life table INSEE*
Female life expectancy at age 0	1856	Own calculations	*See Perrin 2014*
Male life expectancy at age 0	1856	Own calculations	*See Perrin 2014*
Quotient mortality age 0	1851	Life tables – Probability of an individual of age 0 to die before age 5	*Bonneuil (1997)*
Share of doctors	1851	Number of male doctors and pharmacists per total population	*Recensement 1851*
Share of midwives	1851	Number of female doctors, pharmacists and midwifes per total population	*Recensement 1851*
Socio-Cultural			
Protestant share	1851	Number of Protestants per 100 people	*Recensement 1851*
Share married women	1851	Number of married women per women in age of being married (age 15 and more)	*Recensement 1851*
Female age at marriage	1855	Female median age at marriage	*Mouvement de la population 1855*
Male age at marriage	1855	Male median age at marriage	*Mouvement de la population 1855*
Illegitimate urban birth	1851	Number of illegitimate births over total number of births in urban areas	*Mouvement de la population 1851*
Illegitimate rural birth	1851	Number of illegitimate births over total number of births in rural areas	*Mouvement de la population 1851*
Female definitive celibacy	1851	Share of women who are still single after age 50	*Recensement 1851*
Family structure	≡	Family structure based on family relations	*Todd and Lebras (2013)*
Share of foreigners	1851	Share of foreign people living in France per total population	*Recensement 1851*
Temporary migration	1856-60	Quotient de migration	*Bonneuil, 1997*
Temporary male migration	1851	Total of married men and women divided by married men	*Recensement 1851*
GGI	1850s	See Perrin 2014 – GGI and sub-indices	*See Perrin 2014 for details*
Infrastructures			
Towns with no schools	1850	Number of municipalities with no schools divided per total number of municipalities	*Statistique enseignement primaire*
Railroads	1854	Lengths of railroads in km	*Recensement 1851*
Voting people	1846	Share of people voting among the total population	*Recensement 1846*
Geographic			
Wittenberg	≡	Distance from Wittenberg to the Capital of the *département*	*Own calculations*
Mainz	≡	Distance from Mainz to the Capital of the *département*	*Own calculations*
Geneva	≡	Distance from Geneva to the Capital of the *département*	*Own calculations*
Latitude	≡	Latitude of the main city (*chef-lieux*)	*GPS*
Longitude	≡	Longitude of the main city (*chef-lieux*)	*GPS*
Dialects	≡	Disparities in language acquisition (1 : oïl ; 2 : oc ; 3 : franco-provencal ; 4 : autre)	*Own construction based on the map of French languages*