Within the Calculus of Conscious Choice: Industrialization, Religion, and Fertility Decline in Early 1800s France

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Abstract

I examine how religious norms moderated the impact of early industrialization on fertility decline in France. Using plausibly exogenous variation in the adoption of steam engines and mechanized cotton spinning during the First Industrial Revolution, I find that industrialization reduced marital fertility, but only in less religious regions. This decline was driven by increased human capital formation and structural transformation. These findings show that industrialization was a key driver of the fertility transition, but that its early effects were mediated by prevailing social norms. The results underscore the importance of considering both economic incentives and cultural constraints in shaping demographic change.

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1 Introduction

The fertility transition marks a pivotal shift in economic history, enabling the escape from Malthusian stagnation and the onset of sustained per capita income growth (Galor and Weil, 2000; Guinnane, 2011). Understanding the drivers of this transition is key to understanding the growth process. Unified Growth Theory emphasizes the Second Phase of the Industrial Revolution as the catalyst for fertility decline (Galor, 2005; Galor, 2024).[2] While most European fertility transitions followed this second phase, France's fertility decline began more than a century earlier, presenting a striking exception to the broader European pattern (Blanc, 2024). This anomaly has led economists to focus on social and cultural explanations (Murphy, 2015; Blanc and Wacziarg, 2020; Beach and Hanlon, 2023), while attributing industrialization's role primarily to the late 19th and 20th centuries. As a result, the potential influence of the First Industrial Revolution on fertility behavior remains underexplored, despite the fact that it introduced many of the same economic incentives seen in later periods.

This paper shows that the economic incentives generated from the First Industrial Revolution contributed to France's early fertility transition, but that their effects were mediated by prevailing social norms. Specifically, I exploit the expansion of two flagship innovations from this period: steam engines and mechanized cotton spinning. Steam engines increased human capital formation (De Pleijt et al., 2020; Franck and Galor, 2022), which would incentivize lower fertility through the quality-quantity tradeoff (Becker and Lewis, 1973; Bleakley and Lange, 2009; Galor, 2012). Mechanized spinning, through the Spinning Jenny and similar innovations, transformed cotton production by shifting work from the home to the factory floor (Mokyr, 2001) where it is more difficult to raise children (Goldin, 1990; Galor and Weil, 1996; Wanamaker, 2012).

During this period, France exhibited significant regional variation in the weight of religious adherence (Perrin, 2021). This offers a unique opportunity to study how industrialization's effects on fertility varied with the prevailing religious intensity across different regions within the same country. I compile data on the number of steam engines used in each French department from the French Bureau of Statistics' industrial surveys conducted between 1839 and 1847 (Chanut et al., 2000). To measure mechanized spinning production, I use data on the number of cotton spindles per 1,000 inhabitants in 1812, following the approach of Juhász (2018). For religiosity, I use the share of refractory clergy—the clergy who refused to swear allegiance to the Revolutionary government and confirmed their loyalty to the Catholic Church—in each department (Tackett, 1986). This measure is a well-established proxy for regional religious intensity (Squicciarini, 2020; Blanc, 2024).

2. The Second Industrial Revolution is typically dated from 1870-1914 (Mokyr and Strotz, 1998).

To address the endogeneity of technology adoption, I first estimate partial correlations while controlling for baseline institutional, demographic, and economic factors that could drive both industrialization and fertility. Beyond this, I exploit two sources of plausibly exogenous variation. I first leverage the fact that steam engines in France experienced a gradual diffusion across departments, beginning with the first successful commercial installation in the northern Nord department. Franck and Galor (2022) demonstrated that the distance from Fresnes-sur-Escaut in Nord serves as a plausible instrument for steamship adoption.[3] For the rise of mechanized spinning, I follow Juhász (2018) and exploit a natural experiment from the Napoleonic blockade that provided the conditions for nascent cotton spinning mechanization to flourish.

I begin by estimating the relationship between fertility and industrialization while ignoring any regional heterogeneity in the underlying religious norms. This exercise finds no effects on fertility, which would support the notion that economic incentives played little role in fertility decline prior to the second phase of industrialization. However, including an interaction with religiosity reveals a clear pattern: industrialization reduces marital fertility, but this effect diminishes with religious intensity until it is fully offset in the most religious regions.[4] A 10% increase in the number of steam engines lowers fertility by .6 percentage points in the absence of religious norms, but this effect reverses in highly religious areas. Similarly, an increase of one spindle per 1,000 inhabitants decreases fertility by 0.3 percentage points in secular regions, but this too is fully offset in highly religious areas. At median religiosity, a one-standard-deviation increase in spindles per capita reduces fertility by 10%.

Exploring mechanisms, I first confirm that steam engines increased literacy (Franck and Galor, 2022). Further, steam engines led to improved life expectancy at birth (a proxy for infant mortality) and induced structural transformation by shifting employment from agriculture to industry— both factors that incentivize fewer births (Ager et al., 2018; Ager et al., 2020). Mechanized spinning, in contrast, did not raise literacy, consistent with its limited demand for skilled labor (O'Rourke et al., 2013; Squicciarini and Voigtländer, 2015), but did contribute to industrial employment growth. I also find no evidence that any of the economic channels are muted by higher levels of religiosity. This aligns with Squicciarini (2020)'s finding that religiosity does not have a strong influence on economic outcomes until the second phase of industrialization. Accordingly, religiosity affects fertility by restricting household responses to the changing economic environment, rather than by impeding economic development. Finally, I find evidence of increased marriage rates, consistent with historical accounts that new wage labor opportunities obviated the need to save for a dowry, lowering the barriers for marriage. In low-religiosity regions, industrialization therefore encouraged marriage while reducing marital fertility, standing in contrast to the European Marriage Pattern, where

3. This distance strongly predicts the adoption of steam engines across France. In contrast, distances from other major cities such as Marseille, Lyon, or London have no such predictive power.

4. The analysis focuses on marital fertility, the key margin that characterized the fertility transition.

fertility limitation primarily occurred through delayed marriage (Voigtländer and Voth, 2013).

These findings align with Coale (1973)'s 'Ready, Willing, and Able' model from the European Fertility Project, which propounds that fertility control must be 'within the calculus of conscious choice' before any changes in the economic environment can shift fertility behavior.[5] Moreover, my findings confirm the predictions of Unified Growth Theory by showing that early industrialization and the rise in demand for human capital were indeed a catalyst for fertility decline. I further show that economic channels besides human capital formation also played a key role, as spinning capacity lowered fertility without inducing human capital accumulation. Beach and Hanlon (2023) found that the fertility transition in England, the birthplace of the Industrial Revolution, only began following a sharp shift in the underlying cultural norms in the 1870s. My results suggest that the lack of fertility responses to economic incentives, such as those provided by the First Industrial Revolution in England, is potentially the result of the cultural exclusion of fertility control from the household's choice set. Economic factors that were present across Europe in the late 18th and early 19th century may have had more of an influence in generating changes in fertility in France, as it secularized earlier (Blanc, 2024).

This paper contributes to the literature on the drivers of the historical fertility transition. Existing research has focused on the rise in demand for human capital during the Second Industrial Revolution (Galor, 2012; Franck and Galor, 2015) or on the role of cultural and institutional changes (González-Bailón and Murphy, 2013; Cummins, 2013; Daudin et al., 2019; Beach and Hanlon, 2023; Gay et al., 2023; Blanc, 2024; Melki et al., 2024). I add to this by demonstrating that the First Industrial Revolution created the economic incentives to lower fertility, but that their effect depended on preexisting religious norms. Closest to my work, Spolaore and Wacziarg (2022) provide a theoretical framework in which cultural and economic factors are complements, rather than substitutes, in explaining the fertility transition.[6] While they empirically examine the cultural diffusion of modern fertility norms across linguistic barriers, I establish how industrialization's effect varied with regional religious adherence.

This paper also contributes to the broader literature on religion's role in economic growth. Prior work has shown how religion influences long-term economic outcomes via human capital accumulation (Becker and Woessmann, 2009; Caicedo, 2019; Squicciarini, 2020; Okoye and Pongou, 2024).[7] My results highlight religion's role in moderating economic change, suggesting that traditional norms may have slowed the transition to modern growth despite the onset of industrialization.

5. The European Fertility Project was a landmark interdisciplinary effort conducted at Princeton University's Office of Population Research in the 1960s and 1970s to document and explain the fertility transition.

6. Similarly, De La Croix and Perrin (2018) conducted a quantitative exercise to show that a parsimonious rational choice model alone cannot offer a comprehensive explanation of France's fertility decline. Easterlin (1978) and Brown and Guinnane (2002) have also argued the importance of considering both factors.

7. My work is also related to a literature that examines how social and cultural norms impact fertility in modern settings (Munshi and Myaux, 2006; Bassi and Rasul, 2017; Chabé-Ferret, 2019; Iyer et al., 2024).

The rest of the paper proceeds as follows. Section 2 briefly discusses the conceptual framework, Section 3 describes the data used in this project, Section 4 discusses my empirical approach, Section 5 discusses the results of the estimation, and finally Section 6 concludes.

2 Background

The natural starting point regarding the historical fertility transition is the European Fertility Project (Coale and Watkins, 1986). Specifically, Coale (1973) posited the “Ready, Willing, and Able” model. Couples first had to be ready, where choosing their desired level had to be ‘within the calculus of conscious choice’. Second, couples had to be willing, when the costs and benefits of children incentivize them to have fewer children. And finally, couples had to be able to do so, such as having access to methods of fertility control.[8]

Traditionally, economists since Becker (1960) have focused on ‘willing’, positing that the economic changes of the type that would occur from industrialization would increase the costs of children and lower fertility. More recently, the economics literature has turned to the “Ready” component, examining how secularization or changing/diffusing social norms precipitated or contributed to fertility decline (e.g., Beach and Hanlon, 2023; Blanc, 2024). Spolaore and Wacziarg (2022) developed a theoretical framework that explicitly ties these two channels together in the spirit of Coale (1973), where a higher price of children alone cannot generate a decline in fertility. First, beliefs and norms that regulate fertility within marriage must change to allow households to respond to changes in their economic environment.

This framework forms the basis of the following analysis. Namely, I argue that the technological advancements during the first phase of industrialization provided the incentives to lower fertility. However, if a region adopting these technologies had strict religious norms, then households would remain inframarginal to these incentives.[9] Only in areas where strict norms have fallen below a certain threshold will the economic incentives from early industrialization induce fertility decline. In the next section, I discuss the relevant technological innovations.

2.0.1 Steam Engines

Steam engines in France were first used in Fresnes-sur-Escaut in the Nord Department in 1732, and gradually diffused to the rest of France, with disruptions occurring up until 1815 (Franck and Galor, 2022). They were used across industries, helping to drain water from mines, activate spinning machines, and forge

8. Relatedly, Carlsson (1966) delineated two views: innovation, which encapsulates the diffusion of norms/access and knowledge of contraception, and adjustment, whereby fertility control responds to changes in the economic and social environment. The authors of the European Fertility Project largely concluded in favor of the innovation view with a few exceptions such as Lesthaeghe and Surkyn (1988).

9. There may also be a Malthusian effect increasing fertility if household incomes rise.

hammers and other metals. Thus steam engines were complementary to the rise of textile manufacturing and mechanized spinning, however the median cotton spinning mill in this time period did not utilize steam power (Chanut et al., 2000). Steam engines were used more intensely in spinning mills in the early adopting northern departments, with the first reported usage in Nord in 1820. However, a large number of departments still used hand jennies (Dunham, 1928).

The adoption of steam engines can affect fertility through multiple channels. The most relevant channel is by increasing the demand for human capital. As emphasized by Unified Growth Theory (Galor, 2012), the rise in demand for human capital would induce lower fertility through the quality-quantity tradeoff. While early industrialization is often seen as a deskilling process (e.g., Goldin and Sokoloff, 1982), both De Pleijt et al. (2020) and Franck and Galor (2022) demonstrated that steam engines increased the demand for human capital during this period in England and France, respectively. Further, Franck and Galor (2015) found that steam engine adoption in the second phase of industrialization promoted fertility decline, with human capital formation as the likely channel. The rise of steam engines early in the 19th century provided the same incentives for parents to lower fertility.

Steam engines could also promote fertility decline through structural transformation, that is, a decline in employment in agriculture and a shift into industry where childrearing is costlier. For example, Ager et al. (2020) found that structural transformation in the late 19th century U.S. reduced fertility for agricultural households by lowering income (as children are normal goods) and lowered fertility for households that transitioned to manufacturing by increasing the direct and implicit costs of children. To the extent that steam engines foster these sectoral changes, similar mechanisms are likely at play. And finally, if these new technologies increased prosperity and infrastructure, these could also lower fertility by reducing infant mortality (Notestein, 1945; Doepke, 2005; Ager et al., 2018).[10]

2.1 Mechanized Cotton Spinning

The rapid expansion of mechanized spinning began in France in the 1810s. Traditionally, cotton spinning was done at home in the 'cottage industry', where workers spun cotton one thread at a time with a simple wheel. This industry was characterized by the 'putting-out' system, whereby merchants would sell material to households, who would then spin the raw material into thread and sell it back to the merchant at a later date for a piece rate. The invention of multiple technologies, such as the water frame and the Spinning Jenny, allowed for multiple spindles to be used at once, substantially increasing labor productivity. Now, one worker could spin more than one thread at a given time. These machines required large capital investments,

10. Since households have preferences over surviving children rather than the number of births, theoretically reductions in infant mortality would reduce the number of births, but not necessarily the number of surviving children. Ager et al. (2018) and Galor (2012) provide empirical and theoretical treatments of this point.

the use of mills and factories, and the organizing and monitoring of labor. These innovations constituted a fundamental transformation in the structure of society, making obsolete the putting-out system and cottage industry while expanding wage labor in factories (Gullickson, 1986; Mokyr, 2010).

Unlike steam engines, it is not apparent that the rise of textile manufacturing would raise the demand for human capital. Goldin and Sokoloff (1982) document a substitution from skilled to unskilled labor during this period in the US, partly driven by textiles and the large scale division of labor resulting from mechanization. O'Rourke et al. (2013) argue this point further in the case of early textile industrialization in France. Indeed, Squicciarini and Voigtländer (2015) demonstrated that knowledge elites were more important than general human capital in early French industrialization and textile manufacturing. However, economic theory and empirical evidence across time and place offer many channels outside of the quality-quantity tradeoff for textile manufacturing to lower fertility. For example, cotton textiles usually heavily employed women. The rising opportunity cost of female time then would raise the price of children, lowering fertility (Brown and Guinnane, 2002; Heath and Mobarak, 2015; Galor and Weil, 1996). Further, the transition of work from the household to the factory decreased the compatibility of work and child rearing (Rindfuss et al., 1996; Wanamaker, 2012). And finally, similar to steam engines, mechanized cotton spinning could induce structural transformation or lower infant mortality.

3 Data

The main unit of observation is the French department. There are a total of 83 departments that were continuously a part of France during the period of interest.[11] Due to data availability on main controls and treatment variables, however, the number of departments range from 59 observations to 73 in the main specifications, although I show that the results are robust to dropping controls with large numbers of missing values.

3.1 Marital Fertility

My main dependent variable is the Princeton European Fertility Project's index of marital fertility, I_g (Coale and Watkins, 1986). This is the main source of data on fertility in Europe during this time period and is used extensively in the literature (e.g., Murphy, 2015; Franck and Galor, 2015; Spolaore and Wacziarg, 2022; Blanc, 2024; Blanc and Wacziarg, 2024).[12] For each department, the index I_g measures the

11. The departments of Savoie and Haute-Savoie were annexed to French territory in 1860. Belfort was only recognized as a department in 1922. Hence, I do not include these departments in the analysis. I further combine Tarn et Garonne, formed in 1806, with Tarn in all specifications. I also do not merge Muerthe and Moselle into a synthetic department as in Combes et al. (2011), since the annexation of large portions of these departments only occurred in 1871, after the time period of interest here.

12. Brown and Guinnane (2002) and Guinnane et al. (1994) express concerns regarding the index, specifically when conducting aggregated analysis that may mask cultural heterogeneity across place and when using the methodology to draw conclusions

fertility of a population relative to the maximum level of fertility that could occur without any reproductive restrictions. This latter measure is approximated by the fertility rate of Hutterites, an Anabaptist sect that did not practice any fertility control. Specifically, the index in department d is given by:

$$(I_g)_d = \frac{B_d^m}{\Sigma_j M_{dj} G_j} \tag{1}$$

where B_d^m is the total number of births to married women in department d, M_{dj} is the number of married women in age cohort j, and G_j is the age specific fertility rate of Hutterites for cohort j. By using the age cohorts of married women with the age specific rate for the Hutterites, the denominator captures what the total number of children would be if women practiced the age-specific fertility schedule without any fertility control (i.e., the natural rate of fertility). I_g ranges from 0 if there are no births in a given department and year to 1 if women are attaining the natural rate of fertility. Importantly, this measure captures the theoretically relevant measure of fertility: fertility within marriage, the margin by which parents altered their fertility choices with changing social attitudes, and the margin that distinguishes the fertility transition from previous periods.

Figure 1 shows the spatial distribution of marital fertility across France in 1831 and the change in marital fertility between 1831 and 1866, the last year of data prior to the Second Phase of the Industrial Revolution. Darker shades represent higher levels of the index. In 1831, the average value of the index was .51, with a standard deviation of .19. This decreases to an average of .49 in 1866, with a standard deviation of .12.

3.2 Religiosity Data

My main measure of religiosity is the share of the refractory clergy in each French department in 1791.[13] This is standard in the literature as a measure of religiosity across departments (e.g., Murphy, 2015; De La Croix and Perrin, 2018; Squicciarini, 2020; Spolaore and Wacziarg, 2022; Blanc, 2024). The 1790 Civil Constitution of the Clergy was a social reform which attempted to restructure the French Church and required clergy to take an oath of allegiance to the Constitution. Those that refused to swear the oath and instead remain loyal to the Church are referred to as the 'refractory clergy.' Squicciarini (2020) and Blanc (2024) validate this as an effective measure of religiosity, showing that is strongly correlated with measures of religiosity prior to the French Revolution as well as with readership of Catholic newspapers in the late 19th century and church attendance in the 1950s. Tackett (1986) describes how the decisions of the clergy

regarding the origins of the fertility transition. I explicitly model cultural heterogeneity (within a country), and also am not looking at the origins of the French demographic transition, making these concerns less relevant in my case.

13. These were obtained from the Oath Statistics by Department tables in Appendix II of Tackett (1986).

reflected the underlying wishes of the population that they represented, and the oath was made prior to any major negative consequences that would arise with the French Revolution (e.g., the Reign of Terror) and prior to any strong reaction or punishment from the National Assembly. Thus, the share of the refractory clergy represents a strong measure of the underlying religiosity of the department.

Figure 2 shows the large degree of heterogeneity in the share of refractory clergy across the departments. On average, 43% of clergy were refractory, with a standard deviation of 23%. The regions of Brittany in the northwest attain the highest levels of religiosity, while the departments in the southeast region of Provence-Alpes-Côte d'Azur have the lowest.[14] Further, Table 1 Panel A shows that the share measure is uncorrelated with economic, institutional, and demographic characteristics. Note, that since the share is constrained between 0 and 1, the regressions in Table 1 represent movements from a share of 0 to 100%, suggesting that the point estimates are both statistically and economically insignificant in magnitude.

3.3 Steam Engines

I take data on steam engines from Franck and Galor (2022), who compiled the number of steam engines used in each French department from French bureau of statistics industrial surveys between 1839 and 1847 (Chanut et al., 2000). While steam engines were introduced to France as early as 1732, this remains the earliest survey comprehensively documenting their use. Further, the diffusion of the steam engine was not rapid in the 1700s. A single steam engine in Fresnes-sur-Escaut was reported in operation in 1737-1739 period. Figure 2 shows that their usage is concentrated more heavily in the northern departments near Fresnes sur Escaut. The average number of steam engines was 31, with a standard deviation of 70. These ranged from 0 in the departments of Cantal, Côtes-du-Nord, Creuse, Hautes-Alpes, Haute-Loire, Lot, and Pyrénées-Orientales to 565 in the Nord department. Following Franck and Galor (2022), I use the log of the number of steam engines as the main measure of this variable.

3.4 Cotton Textile Spinning Data

My main measures of cotton spinning capacity are from Juhász (2018), who digitized data from a variety of primary sources, including Champagny's survey and the "Enquêtes industrielles" for 1807 and 1812. Following Juhász (2018), I use the number of spindles per 1000 inhabitants as my main measure of the cotton industry to account for the fact that larger departments may have higher spinning capacity simply due to their size.[15] Figure 2 shows the spatial distribution of spindles in 1812. On average, there

14. Comparing the spatial distribution of religiosity with that of the marital fertility index in 1831 (Figure 1), one can see visually the relationship between religion and fertility decline as established by Blanc (2024) and Murphy (2015).

15. Unlike steam engines, I do not take the log of the number of spindles as 32 departments did not adopt any spindles during 1812. A log transform to account for this relatively higher percentage of zeros would raise econometric and interpretative

were 39 spindles per 1000 inhabitants in 1812, ranging from 0 to 368 spindles per 1000 in the department of Seine-Inférieure (later renamed Seine-Maritime) along the Channel.

4 Empirical Strategy

Franck and Galor (2022) and Franck and Galor (2015) provide in depth descriptions and empirical validations for my empirical strategy for steam engines and Juhász (2018) does the same for mechanized spinning. In this section, I discuss the elements most relevant for my research question of interest.

4.1 Distance from Fresnes-sur-Escaut and Steam Engines

Franck and Galor (2022) show that the distance from Fresnes-sur-Escaut in Nord serves as a plausible instrument for the adoption of steam engines, as it strongly predicts their adoption across France, whereas distances from other major cities such as Marseille, Lyon, or London, have no such predictive power.

In column 1 of Appendix Table 3, I replicate this first stage relationship using the controls mentioned in Section 3, while including an interaction between the distance to Fresnes-sur-Escaut with the share of refractory clergy. This shows a clear negative relationship between the distance and the adoption of steam engines. Table 1 shows directly the correlations between the distance measure and the baseline controls that I use in the analysis, controlling for an indicator for Paris and for a department bordering the sea. The measure is statistically significantly related to wheat suitability and the pre-industrial urban population, although small in magnitude. Thus I will check the sensitivity to including all of these variables in the analysis. Appendix Figure 1 shows a map of this measure.

4.2 Napoleonic Trade Protection and Mechanized Cotton Spinning

In order to provide evidence in support of a causal relationship with mechanized spinning, I exploit a natural experiment from the Napoleonic blockade from 1806-1813 following Juhász (2018). Napoleon used France's land-based power to try to block British goods from entering the continent. This hindered trade from Britain along the northern coast of the French Empire, increasing the effective trade distance, and thereby the costs, of entering French markets in the region. Juhász (2018) shows that this blockade shifted the larger market for British exports from the north of the country to the south. Given the large learning by doing externalities present in cotton textile factories (Juhász et al., 2024), this protection greatly expanded mechanized cotton spinning in the North.

concerns (Cohn et al., 2022).

Juhász (2018) uses the fact that trade diminishes with geographic distance to quantify the trade shock with the log change in the shortest actual trade route between London and each department of France after the imposition of the blockade. This naturally creates larger effective distance changes in the north of the country near the English Channel, and lower in the south, where the effective distance was already high. Juhász (2018) shows that this measure effectively predicts the rise in spinning capacity, and that this rise in spinning capacity led to persistently higher increases in spinning capacity as late as 1887. Further, she establishes that this trade shock measure is not correlated with spinning capacity in the period prior to the blockade, nor does it predict any changes in capital-labor ratios (factor prices) or the expansion in wool and leather tanning, two industries that were not traded heavily with Britain or for which there was no major technological change.

I use the natural logarithm of the change in the effect distance from Britain after versus before the blockade. In Table 1, I show that the trade shock measure is largely uncorrelated with the controls used in the analysis with the exception of wheat suitability. Note, that since the effective distance is measured as the logarithm of the change, the point estimates are small (inelastic) in magnitude.

Appendix Table 4 replicates the first stage findings of Juhász (2018), showing that the trade shock has strong predictive power over the expansion of mechanized cotton spinning, controlling for the baseline covariates in 1. Appendix Figure 1 shows a map of this measure.

4.3 Baseline Controls

In addition to the instrumental variables discussed above, I also control for confounding economic, demographic, geographic, and institutional factors that may influence technological adoption and also incentivize changes in fertility. I create indicators for whether the department belongs to Paris or borders the sea to measure access to trade markets. I use the urban population in the pre-industrial time period as a standard measure of development in the pre-industrial era (e.g. Ashraf and Galor, 2011) and the geographical soil suitability for wheat to capture agricultural activity in a key sector during this period. To capture cultural factors and pre-existing human capital, I use the literacy rate, measured by the share of grooms who could sign the marriage license in 1786-1790, and the log of *Encyclopedie* subscriptions per capita to capture upper-tail knowledge elites, who were instrumental for the onset of the first phase of industrialization (Squicciarini and Voigtländer, 2015) and in the diffusion of the Enlightenment (Darnton, 1973). Finally, I use life expectancy at birth in 1806 calculated by Bonneuil (1997) as proxy for infant mortality.

4.4 Regression Specification

I use 2SLS to estimate the effect of industrialization and religiosity on fertility. My analysis begins by estimating regressions of the following form:

$$Fertility_{d,y} = \beta_0^k + \beta_1^k \text{Ind}_d^k + X_d^{k'} \gamma^k + \tau^k + \eta_{d,y}^k \tag{2}$$

$$\text{Ind}_d^k = \pi_0^k + \pi_1^k Z_d^k + X_d^{k'} \omega^k + \xi^k + \epsilon_d^k \tag{3}$$

Where $k \in \{\text{Steam, Spinning}\}$ indicates which industrial technology is under study. Fertility is the I_g index of marital fertility in department d in year y, X_d^k are vectors of geographic, institutional, and pre-industrial economic characteristics of departments, τ^k and ξ^k are vectors of year fixed effects to capture any national trends common to all departments over this time period, and Z^k represents the instrumental variable used in the estimation.

When estimating the effect of steam engines, Ind_d^{steam} is the log of the number of steam engines in a department, and Z_d^{steam} is the aerial distance (in kilometers) between Fresnes-sur-Escaut and the administrative center of department, following Franck and Galor (2021) and Franck and Galor (2022). I also include fixed effects for sea border departments as well as for Paris as controls.[16]

For the spinning technologies, $\text{Ind}_d^{spinning}$ is equal to number of spindles per 1000 inhabitants in 1812 and $Z_d^{spinning}$ equals ΔDistance, the log change in effective trade distance measuring the trade cost shock discussed in Section 4.2. Thus, this equation estimates the effect of the change in effective distance on fertility, scaling the effect by the increase in mechanized cotton spinning due to the increase in trade distance. $X_d^{spinning}$ includes those variables in Table 1 as well as the pre-existing number of spindles in 1803 to capture any geographic persistence in the location of mechanized spinning prior to the blockade.

Note that in both estimating equations, the main independent variable of interest varies only cross-sectionally at the department level. The identifying assumption for consistent estimates of the causal effect would require that, conditional on the controls, the relevant instruments are uncorrelated with any other unobservables that affect fertility, or the error term η^k. For instance if areas with a higher level of pre-industrial development are more likely to adopt new technologies and also have higher fertility (e.g. a Malthusian effect), then the OLS estimates would be biased upwards, which can be seen by examining the difference between the OLS and IV estimates.[17] Franck and Galor (2022) provide evidence that the distance from Fresnes-sur-Escaut is unrelated to the level and growth rate of economic development in the

16. Since spindle data is unavailable for Paris, the department is not included in the spindle regressions.

17. Of course in the presence of heterogeneous effects, the differences may simply reflect the local average treatment effect on the *marginal* department.

pre-industrial period. Juhász (2018) further presents a battery of tests showing that the measure of effective trade distance is exogenous with respect to their outcomes of interest, and many placebo tests showing that the trade protection measure does not affect other (less traded) industries, capital-labor ratios, or the quality of machines, supporting the exclusion restriction. While my study requires that these instruments are exogenous with respect to fertility decisions, these results are nevertheless important for the validity of the instruments in this setting. I will also provide additional supporting evidence of the identifying assumptions.

4.4.1 Accounting for Underlying Social Norms

To examine the interaction of economic incentives and religiosity during this period, I estimate a modified version of (2) and (3), interacting the industrialization measure with the share of refractory clergy in 1791 as follows:

$$\begin{aligned} Fertility_{d,y} = \beta_0^k + \beta_1^k \text{Ind}_d^k + \beta_2^k \text{Ind}_d^k \times \text{Refractory}_{d,1791} \\ + \beta_3^k \text{Refractory}_{d,1791} + X_d^{k'}(\gamma_1^k + \gamma_2^k \text{Refractory}_{d,1791}) + \tau^k + \eta_{d,y}^k \end{aligned} \tag{4}$$

$$\begin{aligned} \text{Ind}_d^k = \pi_0^k + \pi_1^k Z_d^k + \pi_2^k Z_d^k \times \text{Refractory}_{d,1791} \\ + \pi_3^k \text{Refractory}_{d,1791} + X_d^{k'}(\omega_1^k + \omega_2^k \text{Refractory}_{d,1791}) + \xi^k + \epsilon_d^k \end{aligned} \tag{5}$$

$$\begin{aligned} \text{Ind}_d^k \times \text{Refractory}_{d,1791} = \alpha_0^k + \alpha_1^k Z_d^k + \alpha_2^k Z_d^k \times \text{Refractory}_{d,1791} \\ + \alpha_3^k \text{Refractory}_{d,1791} + X_d^{k'}(\theta_1^k + \theta_2^k \text{Refractory}_{d,1791}) + \zeta^k + \kappa_d^k \end{aligned} \tag{6}$$

Where Z_d^k and $Z_d^k \times Refractory_{d,1791}$ are the excluded instruments for the two endogenous variables, Ind_d^k and $\text{Ind}_d^k \times Refractory_{d,1791}$ in (4). Note, since β_2^k is capturing the interaction effect, any confounding factor must not only be correlated with industrialization, but its relationship with marital fertility must also vary across areas with different levels of religiosity. Thus (4) includes the controls by themselves and their interaction with the religiosity measure.[18]

4.4.2 Hypothesis

If technological advancement during the first phase of industrialization did in fact provide the economic incentives to lower fertility, but this effect was masked by the presence of religions norms, then we would expect a priori that $\beta_1^k \approx 0$ in (2), but in equation (4), $\beta_1^k < 0$ and $\beta_2^k > 0$. In other words, in the absence

18. Note that OLS can provide consistent estimation of β_2^k if religiosity is jointly independent of the industrialization and any omitted variable (Nizalova and Murtazashvili, 2016). This is theoretically possible, as the share of refractory clergy is uncorrelated with the number of spindles as well as the number of steam engines.

of religiosity, the economic incentives from the First Industrial Revolution lower fertility, but the effects diminish as religiosity increases.

5 Results

5.1 Preliminary Results

The main variation in cotton spinning is measured in 1812, but the variation in marital fertility only begins in 1831. Once crucial assumption for interpretation of any results is that departments with more mechanizing spinning capacity in 1812 also have higher mechanized spinning capacity in the subsequent decades. Indeed, this is one of the major findings of Juhász (2018): Areas that expanded their spinning capacity in 1812 due to the trade protection from the Blockade also had significantly higher spinning capacity as far as 1887.[19] In Appendix Table 1, I estimate the full interacted specification in (4), but using the number of spindles per capita in 1840 as the dependent variable of interest. Column (2) shows that an additional spindle per 1000 in 1812 led to an increase of about 2.2 spindles per 1000 by 1840. Column (1) performs the same exercise with the number of steam engines, which were also used in the textile industry. Notably, in neither specification does the effect significantly vary with religiosity. This is consistent with Squicciarini (2020) who shows that religiosity only begins to affect industrialization during the second phase of industrialization (1870 onwards), with no discernible effect on industrialization during the first phase. Thus the economic incentives emerge across departments regardless of their underlying religiosity. This also implies that any fertility effect associated with increased religiosity does not stem from religiosity hindering industrialization, rather from the difference in the strength of the religious norms present in the department.

5.2 Fertility

Table 2 reports the estimated coefficients from the uninteracted specifications (2) and (3) using the marital fertility index as the dependent variable. I focus on the period of the First Industrial Revolution (prior to 1870). The first two columns show the OLS and 2SLS results using the log of the number of steam engines in the 1839-1847 period as the main independent variable, and the following columns report the same using the number of spindles per capita as the main independent variable.[20]

First examining steam engines, while the OLS specification suggests an increase in fertility, these results decrease and are both economically and statistically insignificant in the 2SLS specification. These changes

19. Specifically, she finds that areas with one more spindle per 1000 inhabitants in 1812 had 5 more spindles per 1000 in 1887 (Table 4).

20. Appendix Table 2 reports the coefficients from all variables.

in coefficients from the instrumental variables are consistent with a story of upward bias in the OLS results. For example, a lower skilled workforce not captured by literacy can increase the incentive to adopt new technologies and factories to employ this labor while also leading to higher fertility (i.e., the quality-quantity tradeoff). The spindle results show a similar null- effect of industrialization on marital fertility. These results, ignoring any heterogeneity in the underlying level of religiosity, would then suggest little role for economic incentives during the first phase of industrialization in promoting fertility decline.

Table 3 then allows for heterogeneous effects by the underlying religiosity of the department. The table reports OLS and 2SLS estimates from (4). The first three columns use steam engines as the main explanatory variable. Columns (1) uses no controls, column (2) adds controls with both main effects and interacted with the religiosity measure, and column (3) reports 2SLS estimates with the full set of controls. Columns (4)-(6) are reported analogously, using spinning capacity as the main explanatory variable.[21]

These results confirm a clear relationship. Early industrialization reduced marital fertility, consistent with economic theory, however this decline is muted with higher levels of religiosity. The baseline OLS results in columns (1) and (2) show a clear negative partial correlation between steam engines and fertility, with the effect diminishing with higher levels of religiosity.[22] Focusing on the 2SLS estimates in column (3), an increase in the number of steam engines by 10% led to a decrease in the marital fertility index by about .6 percentage points in the absence of religious norms. A movement from 0 to 100% in the share of refractory clergy completely reverses this relationship, resulting in an increase in fertility, consistent with a Malthusian effect. However, these are both out of sample estimates, as the share of refractory clergy measure ranges from 4% in the department of Var in the Provence-Alpes-Côte d'Azur region to 87% in the department of Morbihan in Brittany.

Figure 3 Panel A reports margins plots of the 2SLS estimates of equation (4), showing the effect of steam engines on fertility at the 10th, 25th, 50th, 75th, and 90th percentile of the religiosity measure, with the bands representing 95% confidence intervals. An increase in the number of steam engines decreases fertility at lower percentiles but shows a Malthusian effect in regions with higher religiosity. At the 75th and 90th percentiles, there is a statistically significant increase in fertility.

Turning to spinning capacity, Table 3 shows the same pattern in both the partial correlations in columns (4) and (5) as well as the 2SLS estimates. Focusing on column (6), an increase in spinning with no religiosity - i.e. no refractory clergy - of 1 spindle per 1000 inhabitants decreases fertility by .3 percentage points, which is fully offset when going from none to all refractory clergy ($\beta_1 + \beta_2$), where there is a .3 percentage point

21. The bottom row reports first stage F statistics from Sanderson and Windmeijer (2016), which is more appropriate with multiple endogenous variables as it accounts for the partial correlations of the other endogenous variable in the regression.

22. Note also that the coefficient on the main effect of the share refractory, which here represent *conditional effects*, are still positive and significant across all specifications, consistent with the findings of Blanc (2024) and Murphy (2015).

increase in fertility. Turning to Figure 3, the increase in spinning capacity reduces fertility at the median level of religiosity. The point estimate implies that a one standard deviation increase in spinning capacity (about 76 spindles per 1000 inhabitants) at median religiosity decreases marital fertility by 5 percentage points, constituting a 10% reduction off of mean value of the index in 1831.

Appendix Table 5 presents reduced form estimates, i.e., regressions of the marital fertility index directly on the instruments. These specifications have the benefit of relaxing any exclusion restrictions assumptions needed for identification and, in the case of the trade shock, still retain a meaningful economic interpretation, namely the effect of trade protection on fertility. If it were the case that the trade shock only meaningfully affects fertility through its effect of spinning capacity, then this is capturing the same relationship as the 2SLS results.[23] Consistent with the 2SLS results, increased exposure to the trade shock lowers marital fertility, and this effect is offset with higher levels of religiosity.[24]

I report additional robustness checks in the appendix. Appendix Table 6 shows that the results remain robust to adjusting standard errors for arbitrary spatial correlation (Colella et al., 2019), using a 50, 100, and 250km radius around each department's centroid. Further, the number of departments in each specification is limited to those that contain non-missing values of all controls. Among the controls, the literacy measure contains the most missing values. Appendix Table 7 reports 2SLS estimates dropping only literacy as a control, increasing the number of departments in the sample to 80 for the steam engine regressions and 64 for the spindles regressions, showing similar results.

Appendix Tables 8 and 9 re-estimate the (4) for each available year of the marital fertility index, rather than pooling all years together. They show across all years a similar relationship, with effect sizes for both the negative effect of steam engines and spindles with no religiosity generally increasing in magnitude over time, with the effect being fully reversed by higher levels of religiosity. These suggest widening gaps in marital fertility across regions with different levels of religiosity over this time period as industrialization continues.

5.2.1 Further Robustness

Franck and Galor (2022) and Franck and Galor (2015) present a battery of robustness checks supporting the exogeneity of the distance from Fresne instrument, including showing that it is unrelated to many measures of pre-industrial development in France. Further, Juhász (2018) provides evidence that factor prices were not differentially changing across higher and lower trade shock departments, no effect on other

23. I discuss potential channels further in Section 5.2.1.

24. Column 2 shows that the distance to Fresnes-sur-Excaut instruments are opposite signs to that of the steam engine regressions in Table 3. Recall that being further away from to Fresnes-sur-Escaut implies being less likely to adopt steam engines, hence the signs would be expected to be the opposite sign of the 2SLS results. In other words, both the reduced form and first stage coefficients are of opposite signs in the case of steam engines.

industries that would likely have been impacted by turmoil resulting from the Napoleonic wars, and no changes in other industries such as wool, yarn, or leather.[25,26]

Of course while the outcome variable is different (with the exception of Franck and Galor (2015), who study fertility during the second phase of industrialization), all of these still lend evidence in favor of the empirical strategy used in this setting. I add to these by providing additional robustness checks. First, Appendix Table 10 shows that the results remain robust to inclusion of additional controls. I add a control for the draft dodging rate during Napoleonic Period, defined as the proportion of people effectively drafted who dodged the draft, taken from Rouanet and Piano (2023), as mobilizations for the war effort may impact labor availability and therefore technology adoption, and may impact fertility (e.g. Doepke et al., 2015). I further control for a measure of national identity and for fiscal status in the *Ancien Regime* to capture revolutionary ideals and state legitimacy, and the share of carboniferous area in a department, to capture additional geographic characteristics and access to raw materials that could affect the diffusion of steam engines and development.

I then turn to additional possible threats to the exclusion restriction of the 2SLS strategy. If the instruments affect marital fertility through channels other than expanding steam engines and/or mechanized spinning capacity, then the effects of these channels would be falsely attributed to these technologies when scaling the reduced form estimates by the first stage. One way to check the validity of the empirical strategy is by regressing the fertility rate on the instruments in the period prior to the adoption of the technologies. Unfortunately, the marital fertility index only began in 1831, a few decades after the measurement of these technologies. For steam engines, while the marital fertility indices are defined in the period prior to their measurement (1839-1847), these years do not represent a true 'pre' period since their adoption began as early as 1732. However, I can conduct an exercise using a different measure of fertility, namely the Coale Fertility Index computed by Bonneuil (1997), which is a modified version of the index that includes the fertility of all women rather than only that of married women, and is available in the years prior to the Napoleonic Blockade of 1812. Thus while it does not capture directly the relevant margin of fertility control within marriage, it nonetheless can speak to whether the instruments, conditional on the controls used in the analysis, are picking up any other factors besides the expansion of textile manufacturing that could influence family formation.

Appendix Table 11 shows the results of regressing this index from 1806 and 1811 on the instruments. While the distance to Fresnes-sur-Excaut has a relation to the fertility index during this period, it is smaller

25. Recall, these are not implying that there were no overall changes in the economy as the result of the blockades, however there are no discernible changes across higher and lower trade shock departments.

26. This also suggests that the direct mechanism found in Bignon and Garcıa-Peñalosa (2021) studying the Meline Tariffs of 1892 are likely not present for the trade shock studied here.

in magnitude and of the opposite signs of the results on marital fertility (Appendix Table 5). For the trade shock, there is a statistically insignificant and smaller in magnitude effect on the fertility index in this 'pre-period'.

5.3 Mechanisms

The historical literature supports many channels as potential mechanisms for driving fertility decline. Here, I perform an exploratory analysis with the available data to examine which channels are at play.

5.3.1 Marriages

Turning to the 1851 Census, I create the share of women who are married as the dependent variable. Appendix Table 12 reports 2SLS estimates of (2) and (4) for both steam engines and spinning capacity. In both cases, an increase in industrialization is associated with an increase in the share of women who are married, and this effect diminishes the higher the underlying level of religiosity. This is consistent with Perrin (2021) who demonstrated that marriages increase in the midst of France's demographic transition and with historical literature that documents that increases in wage labor opportunities from spinning mills and textiles allowed couples to avoid postponing marriage until a sufficient dowry was established (Accampo, 1989; Gullickson, 1986). Thus in areas with weaker religious norms, industrialization led more women to get married and have fewer children within marriage.[27]

5.3.2 Human Capital and Health

Table 4 shows the 2SLS estimates testing human capital and health channels. I first replicate Franck and Galor (2022) in Columns (1) and (2) with my specification, finding that steam engines increase literacy measured by the share of literate conscripts in 1859–1868, with no differential effect by religiosity. Columns (3) and (4) use life expectancy at birth in 1861 as the dependent variable as a proxy for infant mortality. Steam engines increase life expectancy at birth when religiosity is low but this effect is offset with higher religiosity, following a similar pattern to that of marital fertility and marriages. At median religiosity, steam engines increase both literacy and life expectancy.

In contrast, spinning capacity shows no discernible effect on human capital or health (Panel B), suggesting that these were not drivers of fertility reduction from these technologies.[28] This difference may be

27. Due to limited data on marriages, I am unable to explore age of marriage or birth spacing, so I leave further investigation for future research. Historical demographic work has found that even as women began marriages at earlier ages, they began stopping births earlier in their lives (Accampo, 1989).

28. The lack of a negative finding on literacy also suggests that even if mechanized spinning during early industrialization did not increase the demand for human capital, it also was not a deskilling process, supporting the conclusions of Diebolt et al. (2021).

because steam engines involved larger capital investments across multiple industries, and De Pleijt et al. (2020) found that steam engines expanded skilled occupations in England. Juhász (2018) shows that the improvements in mechanized spinning capacity occurred primarily through the ability to add more spindles to existing machines, making it less conducive to human capital investment.[29]

5.3.3 Structural Transformation and Labor Force

Table 5 examines structural transformation - workers moving from agriculture to industry. Steam engines clearly drive this transition, with a 10% increase reducing the share of all workers in agricultural employment by 1.1 percentage points (1.7% of the mean). Steam engines also increase the share of workers in industrial employment. Neither effect is mediated by religiosity. For mechanized spinning, while the coefficient is negative for agriculture, it's not statistically significant, though there is a significant increase in industrial sector employment share.

Appendix Table 13 shows both technologies decreased male and female labor force participation, aligning with accounts of cottage industry workers unable to transition to factory work. However, these effects were economically small given the high baseline rates (93% for men, 91% for women). A 100% increase in steam engines reduced female participation by just 2.8%. Creating industry-specific employment shares from the 1861 Census, I find that both steam engines and spindles increased male and female employment in the fabric industry. For the leather industry, which did not experience similar technological changes, steam engines had no significant impact, but spinning capacity reallocated men away from this industry. These occupational shifts likely mediated the observed fertility decline (Mookherjee et al., 2012).

6 Conclusion

This paper shows that the economic incentives induced by the First Industrial Revolution did indeed contribute to France's early fertility transition, but their effect was moderated by prevailing religious norms. In areas where secularization had progressed, innovations like steam engines and mechanized cotton spinning significantly reduced marital fertility through multiple channels, such as increased demand for human capital, shifts from agriculture to industry, and reduced infant mortality. This demonstrates that the economic mechanisms emphasized by Unified Growth Theory and the economics literature more broadly were operational earlier than previously recognized. Economic incentives created the conditions for fertility decline, while cultural factors determined whether households could respond to these incentives. This offers insights to the

29. Gullickson (1986) documents in the town of Auffray, the workers receiving the lowest levels of education in the 1840s were those who worked in new spinning mills (p. 122).

broader relationship between industrialization, social norms, and demographic change during the transition to modern economic growth.

The results also suggest that economic modernization alone may be insufficient to induce demographic transitions in contexts where traditional cultural norms remain strong. This helps explain why France experienced fertility decline over a century before other European countries despite similar economic developments. Future research could further explore the specific mechanisms through which religious norms constrained fertility responses, and examine how similar interactions between economic incentives and cultural norms have influenced demographic patterns in other historical and contemporary contexts.

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7 Tables and Figures

Table 1: Correlations Between Main Variables and Covariates

Panel A: Share Refractory

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Urban Population,1700	Wheat Suitability	Knowledge Elites	Literacy	Life Expectancy
Share Refractory	-0.267	-0.717	-0.524	-0.0452	2.218
	(0.836)	(0.558)	(1.142)	(0.152)	(2.715)
Observations	80	80	80	73	80
R-squared	0.173	0.106	0.054	0.024	0.033

Panel B: Distance to Fresne

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Urban Population,1700	Wheat Suitability	Knowledge Elites	Literacy	Life Expectancy
Distance to Fresnes	-0.170**	0.245***	-0.131	-0.00150	-0.207
	(0.0805)	(0.0443)	(0.0844)	(0.0131)	(0.251)
Observations	80	80	80	73	80
R-squared	0.215	0.382	0.070	0.023	0.033

Panel C: Blockade Trade Shock

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Urban Population,1700	Wheat Suitability	Knowledge Elites	Literacy	Life Expectancy
ΔDistance	0.379	-0.985***	0.0505	0.0540	0.982
	(0.281)	(0.116)	(0.302)	(0.0466)	(0.843)
Observations	80	80	80	73	80
R-squared	0.191	0.519	0.051	0.041	0.040

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table reports partial correlations between the share of refractory clergy, the change in effect trade distance, and the distance of a department from Fresnes-sur-Excaut with economic, demographic, and institutional characteristics. The *département* is the unit of observation. This is done by regressing the variable in the top of the column on the relevant measure, controlling for an indicator for Paris and for whether the department borders the sea. The dependent variables are the log of the urban population in the pre-industrial period, the soil suitability for wheat, the log of *Encyclopedie* subscriptions per capita, the literacy rate, measured by the share of grooms who could sign the marriage license in 1786-1790, and life expectancy at birth in 1806.

Table 2: Industrialization and Fertility

	Steam Engines		Mechanized Spinning	
	(1)	(2)	(3)	(4)
VARIABLES	OLS	2SLS	OLS	2SLS
log(Steam Engines)	0.0135**	0.00408		
	(0.00621)	(0.0104)		
Spindles			8.94e-05	-0.000365
			(0.000127)	(0.000349)
Observations	365	365	472	472
R-squared	0.351	0.346	0.221	0.192
$\bar{Y}$	0.48	0.48	0.49	0.49
Controls	YES	YES	YES	YES
Departments	73	73	59	59
Kleibergen-Paap *F-Statistic*		181.79		126.65

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table reports OLS and 2SLS estimates of the effect of industrialization on fertility, where the *département* is the unit of observation, corresponding to equation (2). The first two columns examine the impact of steam engines, where the main independent variable is the log number of steam engines in 1839-1847, and the second two columns use the number of spindles per 1000 people in 1812. The dependent variable in all columns is the marital fertility index.

Table 3: Industrialization, Religiosity, and Fertility

	Steam Engines			Mechanized Spinning		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	OLS	OLS	2SLS	OLS	OLS	2SLS
log(Steam Engines)	-0.0239*	-0.00168	-0.0572***			
	(0.0133)	(0.0117)	(0.0185)			
log(Steam Engines) x Share Refractory	0.0207	0.0447*	0.169***			
	(0.0226)	(0.0232)	(0.0352)			
Spindles				-0.00114***	-0.00150***	-0.00300***
				(0.000231)	(0.000191)	(0.000552)
Spindles x Share Refractory				0.00193***	0.00315***	0.00599***
				(0.000392)	(0.000336)	(0.00114)
Share Refractory	0.177***	0.607***	0.814***	0.122***	0.708***	1.104***
	(0.0594)	(0.169)	(0.175)	(0.0261)	(0.134)	(0.246)
Observations	365	365	365	472	472	472
R-squared	0.216	0.550	0.508	0.235	0.549	0.499
$\bar{Y}$	0.48	0.48	0.48	0.49	0.49	0.49
Controls	NO	YES	YES	NO	YES	YES
Departments	73	73	73	59	59	59
S-W *F-Statistic* Instrument 1			107.47			94.60
S-W *F-Statistic* Instrument 2			69.13			71.32

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table reports OLS and 2SLS estimates of the effect of industrialization on fertility, allowing for the effect to vary with the underlying level of religiosity. The *département* is the unit of observation. The first two columns examine the impact of steam engines, where the main independent variable is the log number of steam engines in 1839-1847, and the second two columns use the number of spindles per 1000 people in 1812. The dependent variable in all columns is the marital fertility index. Sanderson Windmeijer first stage F- Statistics are reported in the final row.

Table 4: Mechanisms: Literacy and Life Expectancy

Panel A: Steam Engines

VARIABLES	(1) Share of Literate Conscripts, 1859-68	(2) Share of Literate Conscripts, 1859-68	(3) Life Expectancy, 1861	(4) Life Expectancy, 1861
log(Steam Engines)	0.122***	0.0239	2.539***	5.429***
	(0.0388)	(0.0657)	(0.848)	(2.058)
log(Steam Engines) x Share Refractory		0.202		-7.604**
		(0.139)		(3.296)
Observations	73	73	73	73
R-squared	0.067	0.322	0.549	0.633
Controls	YES	YES	YES	YES
Departments	73	73	73	73
Effect at Median Religiosity		0.10***		2.46***
Standard Error		(0.03)		(1.05)

Panel B: Mechanized Spinning

VARIABLES	(1) Share of Literate Conscripts, 1859-68	(2) Share of Literate Conscripts, 1859-68	(3) Life Expectancy, 1861	(4) Life Expectancy, 1861
Spindles, 1812	0.000697	0.00422	0.0250	0.0795
	(0.00110)	(0.00268)	(0.0217)	(0.0517)
Spindles, 1812 x Share Refractory		-0.00711		-0.174
		(0.00609)		(0.125)
Observations	59	59	59	59
R-squared	0.198	0.276	0.508	0.658
Controls	YES	YES	YES	YES
Departments	59	59	59	59
Effect at Median Religiosity		0.00		0.01
Standard Error		(0.00)		(0.03)

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table reports 2SLS estimates of the effect of industrialization on literacy and life expectancy at birth. Literacy is measured as the share of conscripts who were literate over 1859-1868, and life expectancy at birth were taken by Bonneuil (1997), used as an estimate of infant mortality. The *département* is the unit of observation. Panel A examines the impact of steam engines, where the main independent variable is the log number of steam engines in 1839-1847, and Panel B uses the number of spindles per 1000 people in 1812.

Table 5: Mechanisms: Structural Transformation

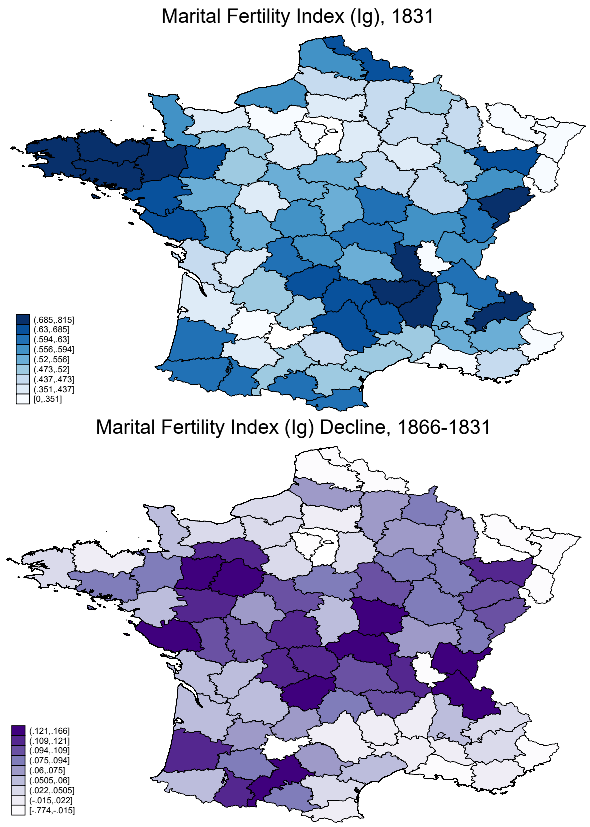
Panel A: Steam Engines				
	(1)	(2)	(3)	(4)
VARIABLES	Agriculture	Agriculture	Industry	Industry
log(Steam Engines)	-0.106***	-0.133***	0.100***	0.128***
	(0.0222)	(0.0419)	(0.0202)	(0.0403)
log(Steam Engines) x Share Refractory		0.0443		-0.0451
		(0.0922)		(0.0860)
Observations	73	73	73	73
R-squared	0.542	0.599	0.443	0.469
$\bar{Y}$	0.62	0.62	0.29	0.29
Controls	YES	YES	YES	YES
Departments	73	73	73	73
Effect at Median Religiosity		-0.12***		0.11***
Standard Error		(0.02)		(0.02)

Panel B: Mechanized Spinning				
	(1)	(2)	(3)	(4)
VARIABLES	Agriculture	Agriculture	Industry	Industry
Spindles, 1812	-0.000809	-0.000865	0.00112**	0.00128
	(0.000631)	(0.00110)	(0.000522)	(0.000895)
Spindles, 1812 x Share Refractory		0.000771		-0.000580
		(0.00216)		(0.00173)
Observations	59	59	59	59
R-squared	0.660	0.700	0.589	0.666
$\bar{Y}$	0.62	0.62	0.29	0.29
Controls	YES	YES	YES	YES
Departments	59	59	59	59
Effect at Median Religiosity		-0.00		0.001**
Standard Error		(0.00)		(0.0006)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

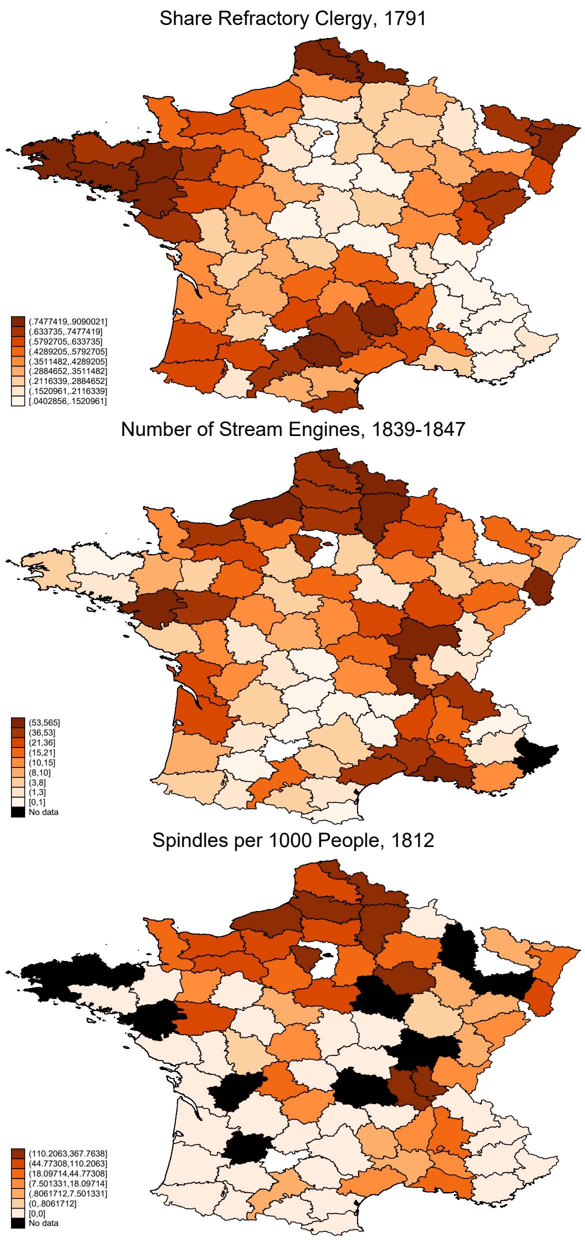
Table reports 2SLS estimates of the effect of industrialization on the share of workers in agricultural and industrial employment. The *département* is the unit of observation. Panel A examines the impact of Steam Engines, where the main independent variable is the log number of steam engines in 1839-1847, and Panel B uses the number of spindles per 1000 people in 1812.

Figure 1: Marital Fertility Index



Figures plot the level of the Marital Fertility Index from Coale and Watkins (1986) across the French Departments. Panel A plots the index in 1831, the earliest year available, and Panel B plots the total decline in fertility during the First Industrial Revolution, measured as the department Index value in 1866 minus that of 1831.

Figure 2: Religiosity and Industrialization



Figures plot the variation in the main independent variables measuring religiosity and industrialization across departments. Panel A plots the share of refractory clergy in 1791, panel B plots the number of steam engines in 1839-1847, and panel C plots the number of spindles per 1000 people in 1812.

Figure 3: Margins Plot of the Effect of Industrialization on Fertility at Different Percentiles of Religiosity

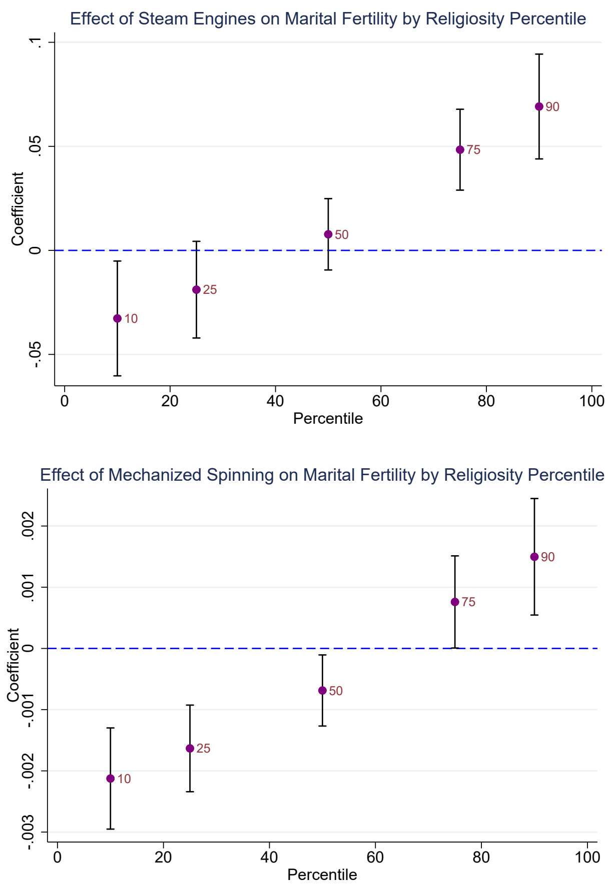


Figure plots 2SLS estimates of $\beta_1 + \beta_2 *$Share Refractory in equation (4), evaluated at the 10th, 25th, 50th, 75th, and 90th percentile of religiosity. Panel A looks at the effect of steam engines and Panel B looks at mechanized spinning capacity. Bands represent 95% confidence intervals. The dependent variable in both figures is the Marital Fertility Index.

Online Appendix

Tables

A.1: Zeroth Stage: Spindles in 1840

	(1)	(2)
VARIABLES	Spindles, 1840	Spindles, 1840
log(Steam Engines)	96.81***	
	(31.63)	
log(Steam Engines) x Share Refractory	50.98	
	(67.95)	
Spindles, 1812		2.166***
		(0.606)
Spindles, 1812 x Share Refractory		-0.0533
		(1.954)
Share Refractory	347.3	-60.28
	(311.2)	(354.6)
Observations	365	472
R-squared	0.269	0.822
Controls	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

A.2: 2SLS Estimates: All Controls Shown

VARIABLES	(1) Marital Fertility Index	(2) Marital Fertility Index
Spindles, 1812		-0.00300***
		(0.000552)
Spindles, 1812 x Share Refractory		0.00599***
		(0.00114)
log(Steam Engines)	-0.0572***	
	(0.0185)	
log(Steam Engines) x Share Refractory	0.169***	
	(0.0352)	
Share Refractory	0.814***	1.104***
	(0.175)	(0.246)
Spindles, 1803		0.00214***
		(0.000769)
Urban Population,1700	-0.0200**	-0.0425***
	(0.00975)	(0.00943)
Wheat Suitability	0.0600***	0.0102
	(0.0122)	(0.00966)
Knowledge Elites	0.0136*	-0.00977
	(0.00767)	(0.00820)
Literacy	0.0557	0.0775
	(0.0531)	(0.0581)
Life Expectancy	-0.00308	0.00492*
	(0.00212)	(0.00258)
Spindles, 1803 x Share Refractory		-0.000355
		(0.00242)
Urban Population,1700 x Share Refractory	0.0105	0.0682***
	(0.0208)	(0.0210)
Wheat Suitability x Share Refractory	-0.0294	0.0780***
	(0.0226)	(0.0230)
Knowledge Elites x Share Refractory	-0.0371**	0.00172
	(0.0149)	(0.0166)
Literacy x Share Refractory	-0.278***	-0.299**
	(0.106)	(0.124)
Life Expectancy x Share Refractory	-0.0178***	-0.0339***
	(0.00465)	(0.00755)
Observations	365	472
R-squared	0.508	0.499

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.3: First Stage Steam Engine Regressions

VARIABLES	(1) log(Steam Engines)	(2) log(Steam Engines) × Share Refractory, 1791
Distance to Fresnes	-0.322***	-0.0268
	(0.0424)	(0.0204)
Distance to Fresnes x Share Refractory	0.128	-0.203***
	(0.0917)	(0.0601)
Observations	365	365
Controls	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

A.4: First Stage Spindle Regressions

VARIABLES	(1) Spindles, 1812	(2) Spindles, 1812 × Share Refractory, 1791
ΔDistance	51.70***	5.466*
	(8.126)	(3.140)
ΔDistance x Share Refractory	-30.09*	20.92**
	(16.73)	(8.793)
Observations	472	472
Controls	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

A.5: Reduced Form Regressions

VARIABLES	(1) Marital Fertility Index	(2) Marital Fertility Index
Distance to Fresnes	0.0139***	
	(0.00511)	
Distance to Fresnes x Share Refractory	-0.0415***	
	(0.00946)	
ΔDistance		-0.122***
		(0.0241)
ΔDistance x Share Refractory		0.216***
		(0.0420)
Observations	365	472
R-squared	0.551	0.517
Controls	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.6: Standard Errors Adjusted for Spatial Autocorrelation

Panel A: Steam Engines

	(1)	(2)	(3)
VARIABLES	50km	100km	250km
log(Steam Engines)	-0.0572**	-0.0572*	-0.0572*
	(0.0270)	(0.0303)	(0.0320)
log(Steam Engines) x Share Refractory	0.169***	0.169**	0.169**
	(0.0638)	(0.0672)	(0.0838)
Observations	365	365	365
R-squared	0.508	0.508	0.508

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B: Spindles

	(1)	(2)	(3)
VARIABLES	50km	100km	250km
Spindles, 1812	-0.00300**	-0.00300***	-0.00300**
	(0.00119)	(0.00104)	(0.00144)
Spindles, 1812 x Share Refractory	0.00599**	0.00599**	0.00599**
	(0.00269)	(0.00251)	(0.00303)
Observations	472	472	472
R-squared	0.499	0.499	0.499

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.7: Dropping Literacy Allowing for More Observations

VARIABLES	(1) Marital Fertility Index	(2) Marital Fertility Index
log(Steam Engines)	-0.0497**	
	(0.0216)	
log(Steam Engines) x Share Refractory	0.139***	
	(0.0368)	
Spindles, 1812		-0.00221***
		(0.000544)
Spindles, 1812 x Share Refractory		0.00408***
		(0.00106)
Observations	640	512
R-squared	0.493	0.501
Controls	YES	YES
Departments	80	64

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.8: Steam Engines and Religiosity, by Year

VARIABLES	(1) Year: 1846	(2) Year: 1851	(3) Year: 1856	(4) Year: 1861	(5) Year: 1866
log(Steam Engines)	-0.0673	-0.0470*	-0.0510*	-0.0544*	-0.0662**
	(0.0647)	(0.0263)	(0.0278)	(0.0311)	(0.0327)
log(Steam Engines) x Share Refractory	0.184*	0.138**	0.156**	0.171**	0.194**
	(0.111)	(0.0567)	(0.0633)	(0.0702)	(0.0770)
Observations	73	73	73	73	73
R-squared	0.606	0.583	0.563	0.543	0.558
Controls	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

A.9: Spindles and Religiosity, by Year

VARIABLES	(1) Year: 1831	(2) Year: 1836	(3) Year: 1841	(4) Year: 1846	(5) Year: 1851	(6) Year: 1856	(7) Year: 1861	(8) Year: 1866
Spindles, 1812	-0.00278	-0.00307*	-0.00346**	-0.00334**	-0.00272**	-0.00288**	-0.00293**	-0.00279**
	(0.00177)	(0.00171)	(0.00168)	(0.00165)	(0.00137)	(0.00136)	(0.00141)	(0.00126)
Spindles, 1812 x Share Refractory	0.00667*	0.00699**	0.00772**	0.00742**	0.00438	0.00464	0.00480	0.00534*
	(0.00376)	(0.00355)	(0.00348)	(0.00336)	(0.00301)	(0.00305)	(0.00323)	(0.00294)
Observations	59	59	59	59	59	59	59	59
R-squared	0.607	0.627	0.608	0.607	0.457	0.430	0.412	0.543
Controls	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.10: More Controls

VARIABLES	(1) Marital Fertility Index	(2) Marital Fertility Index
log(Steam Engines)	-0.0497**	
	(0.0239)	
log(Steam Engines) x Share Refractory	0.129***	
	(0.0403)	
Spindles, 1812		-0.00237***
		(0.000624)
Spindles, 1812 x Share Refractory		0.00345**
		(0.00148)
Share Refractory	0.372**	0.448
	(0.183)	(0.295)
Spindles, 1803		-0.000202
		(0.00102)
Urban Population,1700	-0.0133	-0.0401***
	(0.00975)	(0.00950)
Wheat Suitability	0.0415***	0.0108
	(0.0115)	(0.00885)
Knowledge Elites	-0.00218	-0.0186**
	(0.00680)	(0.00736)
Literacy	0.0891	0.101*
	(0.0583)	(0.0517)
Life Expectancy	-0.00361*	-0.000185
	(0.00214)	(0.00296)
Draft Dodging Rate	-0.00170	0.000455
	(0.00109)	(0.000781)
Spindles, 1803 x Share Refractory		0.00791**
		(0.00324)
Urban Population,1700 x Share Refractory	0.00617	0.0744***
	(0.0197)	(0.0209)
Wheat Suitability x Share Refractory	-0.0315	0.0170
	(0.0206)	(0.0302)
Knowledge Elites x Share Refractory	-0.00610	0.0156
	(0.0131)	(0.0150)
Literacy x Share Refractory	-0.242**	-0.222**
	(0.109)	(0.0997)
Life Expectancy x Share Refractory	-0.00846	-0.0124
	(0.00528)	(0.00979)
Draft Dodging Rate x Share Refractory	0.00113	-0.00468***
	(0.00212)	(0.00153)
Sea Department	0.0332***	0.0222
	(0.0121)	(0.0138)
Patriotic	-0.0328***	-0.0125
	(0.0103)	(0.0105)
Pays d'élections	-0.0244*	-0.00590
	(0.0127)	(0.0130)
Carboniferous Area	0.229***	0.334***
	(0.0640)	(0.0568)
Paris	-0.183**	
	(0.0733)	
Observations	365	472
R-squared	0.574	0.542
Controls	YES	YES
Departments	73	59

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.11: Relationship Between Instruments and Overall Fertility, 1806 and 1811

VARIABLES	(1) Fertility Index, 1806	(2) Fertility Index, 1811	(3) Fertility Index, 1806	(4) Fertility Index, 1811
Distance to Fresnes	-0.00235	-0.0116**		
	(0.00506)	(0.00542)		
Distance to Fresnes x Share Refractory	0.0228*	0.0314***		
	(0.0116)	(0.0115)		
ΔDistance			-0.0460	-0.0178
			(0.0368)	(0.0358)
ΔDistance x Share Refractory			0.00127	-0.0238
			(0.0691)	(0.0678)
Observations	73	73	59	59
R-squared	0.727	0.710	0.733	0.724
Controls	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

A.12: Effect of Industrialization on Marriages

VARIABLES	(1) Share Married	(2) Share Married	(3) Share Married	(4) Share Married
log(Steam Engines)	0.0102	0.0376**		
	(0.00986)	(0.0151)		
log(Steam Engines) x Share Refractory		-0.0785**		
		(0.0326)		
Spindles, 1812			0.000197	0.00127**
			(0.000255)	(0.000497)
Spindles, 1812 x Share Refractory				-0.00325**
				(0.00133)
Observations	73	73	59	59
R-squared	0.278	0.534	0.177	0.232
Controls	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

A.13: Mechanisms: Labor Market Effects by Gender

	Panel A: Steam Engines											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Female Labor Force	Female Labor Force	Male Labor Force	Male Labor Force	Women in Fabric	Women in Fabric	Men in Fabric	Men in Fabric	Women in Leather	Women in Leather	Men in Leather	Men in Leather
log(Steam Engines)	-0.0255***	-0.0363***	-0.0157**	-0.0214*	0.0520***	0.0520*	0.0470***	0.0448*	2.71e-05	0.000540	-2.40e-05	4.94e-05
	(0.00777)	(0.0134)	(0.00615)	(0.0125)	(0.0122)	(0.0280)	(0.0117)	(0.0253)	(0.000349)	(0.000590)	(0.000380)	(0.000717)
log(Steam Engines) x Share Refractory		0.0217		0.0136		0.0149		0.0158		-0.000773		0.000345
		(0.0304)		(0.0278)		(0.0569)		(0.0501)		(0.00122)		(0.00141)
Share Refractory		-0.295*		-0.180		0.467		0.394		-0.0115		-0.00984
		(0.155)		(0.154)		(0.318)		(0.286)		(0.00911)		(0.0100)
Observations	73	73	73	73	73	73	73	73	73	73	73	73
R-squared	0.143	0.339	0.212	0.379	0.115	0.105	0.048	0.038	0.142	0.208	0.189	0.262
$\bar{Y}$	0.91	0.91	0.93	0.93	0.05	0.05	0.04	0.04	0.00	0.00		0.00
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Departments	73	73	73	73	73	73	73	73	.	73	73	.
Effect at Median Religiosity		-0.03		-0.02		0.06***		0.05***		0.00		0.00
Standard Error		(0.01)		(0.01)		(0.01)		(0.01)		(0.00)		(0.00)

	Panel B: Mechanized Spinning											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Female Labor Force	Female Labor Force	Male Labor Force	Male Labor Force	Women in Fabric	Women in Fabric	Men in Fabric	Men in Fabric	Women in Leather	Women in Leather	Men in Leather	Men in Leather
Spindles, 1812	-0.000434*	-0.000876*	-0.000369*	-0.000766*	0.000963**	0.000712	0.000821***	0.00114*	-1.43e-05	-3.70e-05	-1.87e-05	-5.75e-05**
	(0.000258)	(0.000524)	(0.000224)	(0.000444)	(0.000374)	(0.000758)	(0.000281)	(0.000665)	(1.07e-05)	(2.31e-05)	(1.23e-05)	(2.76e-05)
Spindles, 1812 x Share Refractory		0.000858		0.000684		0.00109		-0.000433		5.02e-05		8.94e-05
		(0.00145)		(0.00136)		(0.00216)		(0.00128)		(5.43e-05)		(6.30e-05)
Share Refractory		-0.166		-0.203		0.186		-0.131		-0.00722		-0.00208
		(0.331)		(0.347)		(0.484)		(0.249)		(0.0145)		(0.0167)
Observations	59	59	59	59	59	59	59	59	59	59	59	59
R-squared	-0.021	0.277	0.016	0.106	0.376	0.333	0.500	0.514	0.107	0.118	0.073	0.034
$\bar{Y}$	0.91	0.91	0.93	0.93	0.05	0.05	0.04	0.04		0.00		0.00
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Departments	59	59	59	59	59	59	59	59	59	59	59	59
Effect at Median Religiosity		-0.00**		-0.00**		0.001**		0.001***		-0.00		-0.00*
Standard Error		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)

*** p<0.01, ** p<0.05, * p<0.1

Table reports 2SLS estimates of the effect of industrialization on overall male and female labor force participation in 1861, as well as the share of female workers and the share of male workers in different occupations in 1861. The *département* is the unit of observation. Panel A examines the impact of steam engines, where the main independent variable is the log number of steam engines in 1839-1847, and Panel B uses the number of spindles per 1000 people in 1812.

Figures

A.1: Instruments