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Sascha O. Becker
Francesco Cinnirella
Ludger Woessmann

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Abstract

While women's employment opportunities, relative wages, and the child quantity-quality trade-off have been studied as factors underlying historical fertility limitation, the role of parental education has received little attention. We combine Prussian county data from three censuses—1816, 1849, and 1867—to estimate the relationship between women's education and their fertility before the demographic transition. Despite controlling for several demand and supply factors, we find a negative residual effect of women's education on fertility. Instrumental-variable estimates, using exogenous variation in women's education driven by differences in landownership inequality, suggest that the effect of women's education on fertility is causal.

JEL-Code: N330, J130, J240.

Keywords: demographic transition, female education, fertility, nineteenth century Prussia.

Sascha O. Becker
Department of Economics
University of Warwick
Coventry, CV4 7AL / United Kingdom
s.o.becker@warwick.ac.uk

Francesco Cinnirella
Ifo Institute for Economic Research at the University of Munich
Munich / Germany
cinnirella@ifo.de

Ludger Woessmann
Ifo Institute for Economic Research at the University of Munich
Munich / Germany
woessmann@ifo.de

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1. Introduction

The demographic transition, together with the industrial revolution, is one of the most important events in modern history. It marks the transition from Malthusian stagnation to modern economic growth, which allowed the economies to experience an unprecedented growth of income per capita (Guinnane, 2011). A large theoretical and empirical literature addresses the historical causes of fertility restraint. Much attention has been devoted to the impact of employment opportunities for women outside agriculture, the effect of the female relative wage, and the child quantity-quality trade-off (e.g., Crafts, 1989; Galloway, Hammel, and Lee, 1994; Galloway, Lee, and Hammel, 1998; Brown and Guinnane, 2002; Dribe, 2009; Becker, Cinnirella, and Woessmann, 2010, 2011).

Yet, the role of parental education, and in particular of women's education, has received little empirical attention, despite its obvious possible roles for knowing the means to control fertility (Easterlin and Crimmins, 1985), for relative female earnings, and for shifting preferences from children to newly emerging consumer goods (Guzman and Weisdorf, 2010). In demography and development economics, there is such abundance of evidence on the negative association between mothers' education and fertility that Cochrane (1979) argued that it is "one of the most clear-cut correlations" in the social sciences, although there is no agreement about causality.[1] However, historical evidence on this relationship and its causal structure is fairly limited.

In this paper, we contribute to the knowledge on the determinants of historical fertility by analyzing this neglected channel, the effect of women's education on fertility. We combine Prussian county data from three different censuses (1816, 1849, and 1867) and estimate the relationship between parental schooling and fertility before the demographic transition. Prussia offers an important

[1] For recent examples from development economics with differing results, see Breierova and Duflo (2004), Osili and Long (2008), and Lavy and Zablotsky (2011). See Strauss and Thomas (1995) and Schultz (2008) for reviews. Currie and Moretti (2003), Black, Devereux, and Salvanes (2008), and McCrary and Royer (2011) are examples of recent evidence from developed countries, again with conflicting results. For examples of more descriptive analyses in demography, see Gutmann and Watkins (1990) and Rindfuss, Morgan, and Offutt (1996).

opportunity to analyze this relationship because of her strong focus on primary education starting from the eighteenth century (Melton, 1988) and because of her high-quality data on school enrolment and fertility. As the censuses provide data on school enrolment by gender, we can focus our analysis on female enrolment.

Our results suggest that, despite controlling extensively for demand and supply factors, women's primary education has a significant negative residual impact on fertility. The demand and supply factors taken into account in our analysis include, among others, the women's age at marriage, employment opportunities for women outside agriculture, and mothers' preference for child education, proxied by the primary school enrolment rates at the time when the children enter school age. The relationship is robust to the introduction of measures for child and maternal mortality, and migration. Given the very high correlation between male and female enrolment rates, however, we cannot separately identify the effect of women's and men's education in the regression analysis. Our conclusions on the effect of women's education on their fertility may therefore be more generally interpreted as the effect of parental education on fertility.

The possible existence of unobserved variables that are correlated with both women's education and fertility could bias our estimates, curtailing a causal interpretation. Therefore, we adopt an instrumental-variable approach using landownership inequality in 1816 as an instrument for mothers' education (Galor, Moav, and Vollrath, 2009; Becker, Cinnirella, and Woessmann, 2010). We exploit exogenous variation in primary school enrolment rates driven by the opposition to education of the landed nobility that had no interest in having an educated labor force (Melton, 1988). The instrumental-variable estimates suggest that the negative effect of mothers' education on fertility is causal and that OLS likely underestimates the true effect.

2. Related literature on the historical fertility transition

The European Fertility Project (EFP), coordinated in Princeton in the 1960s and 1970s, aimed at studying the fertility patterns of most Western European countries (Coale and Watkins, 1986). The EFP concluded that the spread of new moral and cultural norms together with birth control technology were responsible for the fertility decline in Europe.[2] In particular, Knodel (1979) using family reconstitution data studies the transition from natural fertility to family limitation in a sample of 12 German villages. Knodel finds a strong heterogeneity in the timing of the emergence of family limitation but he cannot identify the factors that could explain such diversity.

Regarding the causes of the demographic transition, Knodel (1974) and the European Fertility Project in general attributed much importance to the processes of innovation and diffusion of knowledge about contraception, downplaying the role of socio-economic factors. This view has been firmly criticized and, more recently, several studies have shown the importance of socio-economic factors as determinants of the fertility decline.

A few studies show that employment opportunities for women and cultural factors might have shaped the demographic transition at the end of the nineteenth century (Crafts, 1989; Galloway, Hammel, and Lee, 1994). Analyzing county data for Prussia starting from the last quarter of the nineteenth century, Galloway, Hammel, and Lee (1994) also include an educational variable constructed as the number of teachers per 100 individuals aged 6-13, which has a negative effect on the marital fertility rate.

Brown and Guinnane (2002) study the fertility transition in Bavaria, a German region characterized by strong Catholicism and a relatively rural economy. They use census data for the period 1880-1910 and find that Catholicism had a large and growing impact on fertility, stressing the importance of social norms in fertility regulation. They find also differential fertility by occupation and a significant effect of wages, which speaks in favor of an "adjustment" interpretation of the demographic transition. Important with respect to our analysis, Brown and Guinnane do not include measures of education (or schooling) because of lack of such information. More in general, all these studies do not include a direct measure (or a proxy) for mothers' education.

In a recent paper, Dribe (2009) analyzes the factors that characterized the fertility transition in Sweden. Using county-level data for the period 1880-1930,

[2] See Brown and Guinnane (2007) for a critique of the empirical approach and the conclusions of the European Fertility Project.

Dribe finds that lower child mortality, higher urbanization, and stronger "educational orientation" were associated with lower marital fertility. Similar to Galloway, Hammel, and Lee (1994), Dribe measures educational orientation through the ratio of the number of teachers over 100 children aged 7-14. This variable serves as an indicator of the importance of child quality and therefore to control for the child quantity-quality trade-off. Interestingly, Dribe finds that only variation in the levels of education and not variation over time is relevant for explaining fertility decline (Dribe, 2009, p. 83).

Recent theoretical (Galor and Weil, 2000) and empirical work (Becker, Cinnirella, and Woessmann, 2010, 2011) analyzes the relationship between the quantity-quality trade-off of children and fertility restraint for the period before and during the demographic transition. In other theoretical models, human capital is a crucial ingredient not through its association with technology, but rather with life expectancy (see for instance Cervellati and Sunde (2005)).

In this paper, we show that mothers' formal education played an important role in fertility restraint, independently from intervening factors such as age at marriage, employment opportunities for women outside agriculture, and parental preferences for educated children. Possible mechanisms underlying the effect of women's education on fertility are its role for knowledge about the means of fertility control (Easterlin and Crimmins, 1985), for the relative female wage, and for preference shifts towards a larger variety of newly available consumption goods (Guzman and Weisdorf, 2010). We will return to these mechanisms in greater details in the discussion of our results in Section 8.

3. Demographic patterns in Prussia

In the framework of the European Fertility Project (EFP), Knodel (1974) studied the demographic transition in Germany. Using the definition of a 10 percent decline of the index of marital fertility rate, Knodel identifies the onset of the fertility transition in Germany in 1895.

Figure 1 shows the trends of the crude birth rate, mortality rate, and marriage rate for Prussia in the nineteenth century. The figure shows relatively stable trends for the first three quarters of the century. In fact, after decreasing in the 1820s, the crude birth rate fluctuates around 40 births per 1000 people. Similarly, the mortality rate fluctuates between 25 and 30 deaths per 1000 people. Mortality peaks in 1831, when Prussia was hit by a cholera epidemic, in 1848, in conjunction with the political unrest, and in 1866 during the Austrian-Prussian war. With the exception of 1866, the birth rate mirrors the swings of the mortality rates. Only around the last two decades of the nineteenth century, birth and mortality rates point to a secular decline. At the bottom of Figure 1, we also show the trend in marriage rates, which remained fairly constant oscillating at around 9 marriages per 1000 people.

The birth rate levels shown in Figure 1 are consistent with the European marriage pattern characterized by high fertility within marriage but relatively low levels of birth rates.[3] Other characteristics of the European marriage pattern were a late average age at first marriage and a relatively high share of unmarried women. Knodel studies family reconstitution from 12 German villages and reports for the period 1750-1899 an average age at first marriage that fluctuates around 26.9 for women and 29.4 for men (Knodel, 1979, Table 1, p. 496). Our data show that, in 1849, a considerable share of women married after age 30 and that this positively correlates with the (stock) share of unmarried women.

4. Prussian county data on education and fertility

A major criticism of the European Fertility Project is the choice of relatively large units of analysis. In the case of Germany, the EFP used 30 *Regierungsbezirke,* which are large administrative districts with roughly half a million inhabitants and comprising more than 10 counties (*Kreise*), on average. Similarly to the study of Galloway, Hammel, and Lee (1994) and Galloway, Lee, and Hammel (1998) but going much further back in time, in our study we use more disaggregated data, namely at the level of the 334 counties (*Kreis*) for the period before the onset of the Prussian demographic transition. Our main data stem from the Prussian censuses in 1816, 1849, and 1867 and are reported by the Prussian Statistical Office (see appendix for details).

[3] The biological maximum is considered to be around 60 births per thousand.

The 1816 Prussian census contains information on the number of children enrolled in primary school by county. Our main variable of interest—the female enrolment rate—is constructed as the number of girls enrolled in primary school in 1816 over the total number of girls aged 6-14. Its geographical pattern is shown in Figure 2. We shall then consider female enrolment rates in 1816 as a proxy for the level of education of future mothers.

As our measure of fertility, we would ideally like to have the number of children of the women who were enrolled in primary schools in 1816. Unfortunately, we cannot observe fertility for exactly these cohorts. But we have detailed population censuses that allow us to link the number of children in 1867 with female education levels in 1816.[4] Thus, as fertility measure we use the child-woman ratio constructed as the number of children aged 10-19 over the number of women aged 40-69 in 1867, depicted in Figure 3.[5] We use the number of children aged 10-19 because this age group contains, amongst others, those children who were born in 1849—the year for which we observe most of the demand and supply factors entering our regressions, discussed in greater detail in the next section. Most importantly, cross-county differences in this age group are expected to mirror differences in fertility and, in particular, in family size. The number of women aged 40-69 in 1867—the denominator of our child-woman ratio—is expected to capture the female cohorts who were in school in 1816. In fact, women between ages 40-69 in 1867 were aged 22-51 in 1849 and aged 0-18 in 1816.

In sum, variation across counties of the child-woman ratio in 1867 is expected to capture variation in fertility of mothers (i) with an educational level proxied by the female enrolment rates in primary school in 1816, and (ii) whose demand and supply factors are captured by our set of control variables for 1849. Figure 4

[4] Since we also have the female enrolment rates in 1849, we can proxy the female enrolment rates in 1832 by interpolating the rates in 1816 and 1849. In this way, those enrolled in primary school in 1832 (aged 6-14) would be 23-31 in 1849 and 41-49 in 1867. All results provided in the following analysis hold when using the 1832 approximation.

[5] We use data from 1867 and not earlier because that is the first year in which the population census uses detailed age categories.

shows the relationship between our two variables of interest: female enrolment rate in 1816 and the child-woman ration in 1867.[6]

Since the denominator of the child-woman ratio contains women of a relatively old age given the period considered here, female mortality is a crucial issue. According to our data, average female life expectancy at age 25 in 1849 was 58.7 (standard deviation 4.4). In general, there is a positive relationship between life expectancy and education. In our case, the correlation coefficient between female primary school enrolment rate in 1816 and life expectancy at age 25 in 1849 is 0.35. That is, women with a formal education were more likely to live longer, which means that they are over-represented in our child-woman ratio in 1867. Assuming a negative relationship between female education and fertility, that would bias our estimates toward more negative estimates. Additionally, women giving birth to more children were more likely to die in childbirth, which would also affect our dependent variable. The 1849 census contains information on the number of women who died at child birth, which allows us to construct a maternal mortality ratio.[7] Our data show that around 0.8 mothers died for every 100 live births.[8] We can show that controlling for female life expectancy at age 25 and for the maternal mortality ratio does not affect our findings. In addition, we also provide evidence that our results do not change in alternative specifications of the dependent variable that aim to alleviate the issue of female mortality.

Prussian census data do not provide detailed information on age at marriage. Yet, the 1849 census reports the (flow) number of marriages in 1849 by three age categories: women younger than 30, between 30 and 45, and older than 45.[9] Our

[6] Another important assumption here is that between 1849 and 1857, counties did not change systematically their age at marriage pattern. In fact, the children aged 10-19 we observe in 1867 are also the product of marriages, not observed, that occurred between 1850 and 1857. Systematic changes in the pattern of age at marriage across counties during this period would affect our coefficient estimate. However, there is no evidence of systematic changes in age at marriage in such a short period of time.

[7] The maternal mortality ratio is defined as the ratio of the number of maternal deaths per 100 live births.

[8] To provide an order of magnitude, according to the United Nations Population Fund (UNFPA), in 2005 the maternal mortality ratio for developing countries was 450 per 100,000 live births.

[9] The same categorization is available also for men.

measure for age at marriage is constructed as the share of women who married when older than 30. The variable is thus bounded between zero and one. A value of the variable close to one (zero) indicates a tendency to marry later (earlier).[10] According to our data, on average, around 23 percent of the marriages in 1849 involved a woman above the age of 30. Table 1, which presents descriptive statistics for all our variables, shows that this variable presents considerable variation with levels ranging from about 0.09 to 0.46.

We also have a variable for the share of married women in 1849 computed as the ratio of women in wedlock over the total number of women aged 15-45. According to this variable, about 70 percent of the women lived in a marriage (s.d. 0.06), with the variable ranging from a minimum of 0.43 to a maximum of 0.85. This variable shall be used as a proxy for the nuptiality rate. It is interesting to note that there is a negative correlation between age at marriage and the stock share of married women ($\rho = -0.38$). This suggests that in those counties where the average age at marriage was higher the celibacy rate was also relatively high.

5. A supply-demand framework to study fertility

Easterlin and Crimmins (1985) suggest that the number of children born in a family is determined by three sets of factors: the demand for children, the supply of children, and the cost of fertility regulation. We shall also use this theoretical framework when choosing the covariates of our regression analysis and for the interpretation of the results. The merit of such a supply-demand approach is to overcome the dichotomy between economic (adjustment) and cultural (innovation) factors that characterizes the literature on the demographic transition (Friedlander, Okun, and Segal, 1999).

The demand for children depends on family income and the relative cost of children. If we consider children as normal goods, we expect to find a positive

[10] Remarriage might be an issue here, as we only observe the number of marriages at one point in time (in 1849) and do not know whether it is a first marriage. In fact, we know that remarriage rates were not a trivial number. Knodel (1974) reports a share of remarriages between 15 and 25 percent of all the marriages and that men were more likely to remarry than women. However, as long as remarriage rates do not differ systematically across counties, that should not affect our analysis.

effect of income on fertility. We do not have a direct measure for income, but we can control for the industrialization level (and urbanization), which is generally a good proxy for the income level. In particular, we use the share of the population employed in manufacturing.

Recently, unified growth theory[11] extensively uses the concept of the quantity-quality trade-off of children to model the demographic transition and consequently the transition from stagnation to growth.[12] The theory argues that, as returns to education increased due to technological developments, families shifted their preferences toward higher quality of children, which eventually affected negatively the demand for children. We take into account parental tastes for the education of their children, and therefore the child quantity-quality trade-off, by controlling for the level of education in 1864.

It has been shown that employment opportunities for women outside agriculture—the opportunity cost of a child—significantly influence fertility levels. Assuming that the time devoted to child rearing cannot be spent in the labor market, better employment opportunities for women should be negatively related to fertility. We include two variables to proxy for employment opportunities for women outside agriculture: (i) the ratio of individuals employed in textile factories over the number of women (15-60) and (ii) the share of individuals employed as craftsmen in the textile sector in 1849.[13]

Easterlin and Crimmins (1985) define the supply of children as the number of surviving children a couple would get if they made no conscious efforts to limit the size of the family. It therefore reflects natural fertility and child survival rates. To take into account these factors, in our regression analysis we control for age at marriage and child mortality (0-5). We expect age at marriage to be negatively correlated with fertility, as later age at marriage implies a shorter duration of marriage. In addition, lower child mortality is expected to be negatively correlated with total fertility as lower child mortality allowed families to be more effective in

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[11] See Galor (2005) for an exhaustive review of the theory.

[12] See Becker and Lewis (1973) and Becker and Tomes (1976) for the seminal contributions on the quantity-quality trade-off of children.

[13] Unfortunately, the 1849 census does not provide gender-specific employment figures.

reaching the desired number of children and reduced any hoarding effect (Doepke, 2005). Finally, we also control for religion in order to account for cultural differences that may have contributed to the spread of new attitudes towards fertility control procedures.[14]

6. Regression analysis

We start our empirical analysis by estimating the relationship between women's formal education and fertility by standard ordinary least squares (OLS) controlling for variables such as women's age at marriage, employment opportunities outside agriculture, and preference for child quality. More formally:

$$fertility_{i,1867} = a_i + \beta\, edu_{i,1816} + \mathbf{X}_{i,1849}\,\lambda + \mathbf{Z}_{i,1849}\gamma + \varepsilon_i \qquad (1)$$

where *fertility* is the ratio of youths aged 10-19 over the number of women 40-69 in 1867, *edu* is the share of girls (6-14) enrolled in primary school in 1816, β the parameter of interest, **X** and **Z** respectively a vector of demand and supply variables for 1849, and the subscript i=1, 2, …, 334 indicates the county (*Kreis*).

Standard economic models and empirical evidence suggest that mothers with higher level of education get married later, have higher employment opportunities, have a higher relative wage, have a relatively stronger preference for child quality, and have higher consumption aspirations. All these factors, in turn, are expected to lower the demand for children. We therefore expect the effect of women's formal education on fertility to be reduced substantially by these intervening factors.

6.1 Women's education and fertility

Table 2 reports the OLS estimates of equation (1). We present various specifications that sequentially introduce more control variables in order to study how the effect of women's education changes when adding further intervening factors. Note that the model includes also enrolment rates in 1864 to account for the revealed preference of parents for their children's education, i.e. the quantity-quality trade-off of children. In addition, we also control for the maternal mortality

[14] See Coale and Watkins (1986) on the conclusions of the Princeton Fertility Project.

ratio in 1849 to correct for differentials in female mortality that could affect the denominator of our dependent variable.[15]

Column 1 shows the strong negative correlation of women's formal education with fertility. An increase in the female enrolment rate in 1816 by 10 percentage points is associated with a decrease of around 6 children per 100 women in 1867. This effect is very large, as it implies that a one standard deviation increase in the enrolment rate is associated with a decrease of the child-woman ratio of about 0.44 standard deviations. This strong correlation is corroborated by the high level of explained variance already in the bivariate specification of column 1, which implies that female schooling levels in 1816 explain around 20 percent of the cross-county variation in the child-woman ratio in 1867.

The coefficient remains significant and of similar magnitude when controlling for urbanization, industrialization, religion, and the marriage rate (column 2). Column 3 shows that employment opportunities for women outside agriculture have a strong negative effect on fertility. In particular, employment levels of craftsmen in the textile sector are strongly negatively correlated with fertility. The possibility to earn a (higher) wage increases the opportunity cost of children and therefore depresses the demand for children. Our result is in line with the study of Schultz (1985) who, using county-level data for Sweden, reports a negative effect of higher female relative wages on fertility.[16] Yet, the effect of women's education maintains its magnitude and significance in the specification of column 3.

Similarly, women's age at marriage has a significant negative effect on fertility (column 4). The remarkable increase of the explained variance in this specification

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[15] Given the relatively strong correlation with maternal mortality, the coefficient for female life expectancy at age 25 is never statistically significant, which is why we control only for maternal mortality.

[16] Employment opportunities in the textile sector might also capture child employment opportunities, which would have a positive effect on fertility. We are not aware of any estimate of child labor in Prussia for the period under consideration. However, the Prussian Child Labor Law was passed in 1839, setting a minimum age of nine for children working in factories. The minimum age was increased to twelve years in 1853. Therefore, the period under investigation is likely characterized by declining rates of child labor. This is also witnessed by the increasing enrolment rates in primary school that reached the average value of 80 percent in 1849. This would support the argument of an increasing relative cost of children.

stresses the importance of age at marriage in explaining fertility variation. This does not have to mean that age at marriage was deliberately used to limit fertility. Generally, the theory assumes that age at marriage is exogenous to the decision on deliberate fertility control (Easterlin and Crimmins, 1985). Yet, to the extent that education and age at marriage are correlated, it is important to control for women's age at marriage to isolate the effect of women's education on fertility. Still, controlling for age at marriage the coefficient for women's education remains large and highly significant.

Educated mothers are likely to have stronger preference for the education of their children. Therefore, the estimated effect of women's education might simply reflect such a preference for quality to the detriment of quantity. There is also evidence showing that investment in children in the form of education was complementary to investment in better nutrition (Weir, 1993; Hatton and Martin, 2009). To account for the child quantity-quality trade-off, column 5 controls for the primary school enrolment rates in 1864. Enrolment levels in 1864 indeed have a significant negative impact on realized fertility. Most important, controlling for the quantity-quality trade-off reduces the effect of female education by almost 30 percent.[17] This result is consistent with the hypothesis that mothers with a formal education tend to have a higher preference for child quality.

There is a large theoretical and empirical literature stressing the importance of child mortality in explaining fertility restraint (Crafts, 1989; Boyer1989).[18] Column 6 therefore introduces a control for child mortality (age 0-5) in 1849. Unexpectedly, the sign of the coefficient is negative, which becomes even larger when controlling for maternal mortality in column 7.[19] This result is actually common to other studies (e.g., Brown and Guinnane, 2002; Galloway, Hammel, and Lee, 1994).

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[17] Similarly to other studies, we also used the number of school teachers per capita as an indicator for preferences for child quality. The results are qualitatively the same. Yet, we view the number of children attending school in 1864 as a superior measure for the child quantity-quality trade-off.

[18] By contrast, the European Fertility Project concluded that the infant mortality rate did not play a major role in the European fertility decline (van de Walle, 1986).

[19] The negative effect persists also when we use the infant mortality rate or mortality rates for different ages.

Finally, column 7 introduces a control for maternal mortality to account for differential mortality levels that might affect the number of women in the denominator of our dependent variable. Clearly, this variable is endogenous to the child-woman ratio, as a higher number of births increases the probability of dying at childbirth, which may explain the significant positive coefficient of this variable. However, even after controlling for maternal mortality, the effect of women's education remains unaltered.

In sum, we find that women's age at marriage, employment opportunities for women outside agriculture, and the quantity-quality trade-off of children have, respectively, a strong impact on realized fertility before the demographic transition in Prussia. Yet, even after controlling for these factors, we find that women's formal education has a significant negative residual effect on fertility. This effect is economically non-trivial: in the most encompassing specification of column 7, a one standard deviation increase in the female enrolment rate in 1816 is associated with a decrease of the child-woman ratio in 1867 of about 0.3 standard deviations.

6.2 Robustness checks

Table 3 presents a series of additional robustness checks. Column 1 introduces a control for population density. The coefficient of our variable of interest remains unaffected and the explanatory power of the model does not improve significantly.

As our analysis links information from three different censuses, systematic differences across counties in migration patterns may constitute a problem. In fact, migration generally concerned young, single males (Boyer and Williamson, 1989). Therefore, if parents considered children as assets for their old-age period, higher out-migration rates might be negatively correlated with fertility. By contrast, a positive balance of immigrants might negatively affect fertility as migrants tended to get married later.[20] Column 2 introduces a measure for net migration. Unfortunately, we only have detailed data on migration for the last two decades of the nineteenth century. Thus, we use net migration in 1880, constructed as the

[20] In fact, there is a slightly positive correlation between age at marriage and our variable for net migration in 1880 (ρ=0.12).

difference between immigrants and emigrants over the reference population (in 1000).[21] We find that counties with a higher net migration, and thus with relatively more immigrants than emigrants, tend to have lower fertility. Yet, our coefficient of interest remains unaffected in its magnitude and significance.

Recently, Alesina, Giuliano, and Nunn (2010) suggested that, consistent with the existing anthropological evidence, in societies with a traditional use of animal plough agriculture the division of labor is split along gender lines, with men working outside of the home in agriculture and industry, and women working within the home. The idea is that animal plough agriculture was heavier work, more suited for men, and that such cultures persisted over time. In column 3, we follow this line of thought and control for cattle per woman as a measure of the type of agriculture prevalent in an area. This control turns out not to be significant.

Figures 2 and 3 suggest that geographical clustering could be an issue as, for instance, there is higher fertility in the East. Cultural and institutional factors are likely to be behind such geographical stratification. Column 4 adds measures of latitude and longitude (in radians) in order to test whether the estimated association between women's education and fertility holds independently of broad geographic patterns. We find that higher latitude is associated with higher fertility, whereas higher longitude is associated with lower fertility. These geographical controls, especially latitude, have a large effect on fertility. Further, they significantly reduce the effect of female education, as a one-standard deviation increase in the female enrolment rate in 1816 is now associated with a decrease of the child-woman ratio in 1867 by about 0.2 standard deviations. However, though smaller, the negative effect of women's formal education on realized fertility is still highly statistically and economically significant.[22]

Finally, column 5 presents estimates using a different variable for employment opportunities for women outside agriculture. Contrary to 1849, for 1867 we

[21] We could also use net migration for the year 1862 but this variable is less precise as, contrary to 1880, it does not consider unofficial emigrants. However, estimates using net migration in 1862 are virtually identical.

[22] We further investigated the effect of geographical clustering by estimating models that explicitly take into account spatial autocorrelation. Our findings (not reported) are robust in spatial lag and spatial error models (see Anselin, 1988 and Anselin and Hudak, 1992).

observe the share of women employed in industry. Clearly, this is a better variable for employment opportunities for women outside agriculture, as it takes into consideration the actual industrial female labor force; on the other hand, this variable is observed only when the decision about fertility has already been taken. As expected, we find a strong negative effect of the female employment variables for 1867, but the coefficient for women's education is still highly significant.

In some studies, female literacy has been interpreted as a proxy for knowledge of contraception methods (Boyer and Williamson, 1989). Therefore, one could argue that the estimated effect of mothers' education on fertility is capturing, to some extent, the relationship between contraception and fertility. In order to test this hypothesis, we used changes in illegitimacy rates as a proxy for the use of contraceptive methods (Shorter, Knodel, and van de Walle, 1971). In fact, as argued by Boyer and Williamson (1989) and Crafts (1984), cross-sectional differences in illegitimacy rates mirror not only the use of contraceptives but also, for instance, the extent of non-marital sexual activity. Thus, we test whether controlling for changes in illegitimacy rates in the period 1849-1862 affects the estimated effect of women's education. We find that the coefficient for women's education remains unchanged both in its magnitude and significance.[23]

7. Instrumental-variable results

So far, our estimates have shown a robust association between women's education and fertility. However, our results do not necessarily show a causal relationship, as the existence of unobserved county-specific variables that are correlated with both women's education and fertility could bias the estimates. Therefore, we adopt an instrumental-variable (IV) approach which uses exogenous variation in enrolment rates to estimate its causal effect on realized fertility. In particular, we use landownership inequality in 1816 as an instrument for women's enrolment rates in primary schools.

The idea of using educational variation that derives from landownership inequality builds on Galor, Moav, and Vollrath (2009) who present a theoretical

[23] Estimates not reported here but available upon request.

model where inequality in the distribution of landownership negatively affects the implementation of human-capital-promoting institutions. This is due to the low complementarities between land and human capital. The authors provide empirical evidence for the United States in the twentieth century corroborating their prediction.[24] In the case of Prussia, there is substantial anecdotal evidence that noble landowners (Junker) opposed the construction of rural schools or did not monitor the enforcement of school attendance (Melton, 1988).

For their U.S. evidence, Galor, Moav, and Vollrath (2009) use the share of land held by large landowners. In Prussia, the 1816 census provides information on the number of land holdings grouped in three categories: 0-15, 15-300, or greater than 300 *Morgen*.[25] This allows us to construct an index of landownership inequality as the ratio of the largest land holdings over the total number of holdings.[26]

The exclusion restriction for the validity of the IV estimates is that landownership inequality in 1816 is not *directly* related to later fertility outcomes. Bengtsson and Dribe (2006) show that total marital fertility, as well as age-specific marital fertility, is very similar across socioeconomic groups with different landownership patterns in pre-transition Sweden. By contrast, Brown and Guinnane (2002) find that in rural Bavaria farm size is negatively correlated with marital fertility. However, it is important to note that both studies analyze the effect of farm size and do not investigate the role of *inequality* in the distribution of land, which is the relevant measure of our identification strategy. In our case, though the landed nobility had discretional power regarding the marriages of laborers, it seems unlikely that, once the concession to marry was granted, the landowner could influence the level of marital fertility. Therefore, to the extent that we control for the age at marriage and for the share of married couples, the

[24] Easterly (2007) also provides cross-country evidence on the adverse effect of inequality on human capital formation and economic development.

[25] One *Morgen* is equal to about 0.25 hectares. For counties whose information on landownership in 1816 cannot be directly matched with the 1849 borders due to administrative reforms of the county structure (see data appendix), we use information on landownership inequality in 1849. If, alternatively, we adjust all our variables to the county borders in force in 1816, qualitative results on the ensuing 267-observation sample are qualitatively the same (available on request).

[26] Becker, Cinnirella, and Woessmann (2010) use variation in landownership inequality in 1849 in order to identify exogenous variation in enrolment rates in 1849.

exclusion restriction should hold. Furthermore, even if we suppose that landownership inequality in 1816 had a direct effect on fertility, that would affect fertility in 1816, which is a variable we include in our regression. In fact, our IV regressions include the child-woman ratio in 1816 constructed as the ratio of children aged 0-7 over the number of women aged 15-45 in 1816.

Table 4 starts with OLS estimates of this specification, which are very similar to our previous results. Columns 2 and 3 then report the first and second stage, respectively, of our IV regression. The first-stage results reveal a significant negative relationship between landownership inequality and the female enrolment rates in 1816. The *F*-statistic of the excluded instrument in the first stage is reassuringly high, at 21.2. The second-stage estimates confirm the significantly negative effect of women's education on their fertility from the OLS regressions, with a point estimate that is notably larger.

Table 5 presents alternative estimates to show that our findings are not driven by selective mortality, which would affect the dependent variable. In column 1, instead of having the number of women aged 40-69 in 1867 as the denominator of the dependent variable, we use the number of households in 1867. The idea is that the household might continue to exist even if the mother died, so that female mortality does not bias our dependent variable. A drawback of this alternative measure is that we cannot refer to a precise female age group. Column 2 uses as the dependent variable the ratio of children aged 0-14 over the number of women aged 17-45 in 1849, again meant to capture the girls enrolled in 1816. Given the younger age group observed in 1849 in the denominator, the issue of women mortality is less severe than in the standard specification. In both cases, the coefficient for female enrolment in 1816 is highly significant and of similar size.

8. Discussion

Our estimates imply that women's education has a significant negative effect on realized fertility, independently of the fact that more educated women tend to get married later, have more employment opportunities outside agriculture, and have a stronger preference for the education of their children. Instrumental-variable estimates suggest that this effect is causal. This result is important in its own right, as it sheds light on a determinant of fertility decline, namely women's education, that has been largely neglected in the historical literature.

This finding opens up the question about the mechanism that is driving the negative relationship between women's education and fertility. Easterlin and Crimmins (1985) discuss the various effects that formal education might have on fertility control. On the one hand, formal education improves health conditions, so that it can have a positive effect on fertility by enhancing the potential supply of children. On the other hand, education lowers the costs of fertility regulation by providing more information about the means of fertility control. Following Crafts (1984) and Boyer and Williamson (1989), we used variation over time in illegitimacy rates as a proxy for the use of contraceptive methods. The effect of women's education remained highly significant, both economically and statistically. Though far from conclusive, this suggests that female education is not (only) capturing better access to information about contraception.[27] Furthermore, estimates of spatial lag models that explicitly take into account spatial autocorrelation seem to rule out any local spillover explanation, as the negative relationship between mothers' education and fertility holds also when controlling for the level of fertility of neighboring counties.[28]

A more plausible explanation for our residual effect of women's education regards the female relative wage. It is hypothesized that an increasing female wage relative to that of men increased the opportunity cost of children and therefore reduced fertility. Such a trend in the relative wage of females might have been induced by increasing levels of women's education. In fact, Dribe (2009) finds for Sweden that increasing female relative wages were associated with declining fertility among women over 35. This result is consistent with Schultz (1985) who finds that a quarter of the decline in the Swedish total fertility rate from 1850 to 1910 can be explained by the 10 percent rise in the female to male wage ratio. In our regression analysis, we do not have a direct measure for the female relative

[27] In addition, there is some evidence according to which methods of fertility control were known and available at a reasonable cost; see for example Bengtsson and Dribe (2006) on the case of Sweden.

[28] Estimates of the spatial lag model are available upon request.

wage, but only control for employment opportunities outside agriculture. Yet, we have the number of manual workers by gender, which allows us to construct the ratio of female over male manual workers for 1849. A larger number of female handworkers could proxy for a higher female relative wage. Indeed, the coefficient on this ratio in the instrumental-variable specification is negative, though insignificant, which is consistent with the negative effect on fertility of a higher female relative wage.[29] The effect of women's education, however, is virtually unaffected. Therefore, although we cannot directly reject the hypothesis that our estimated effect of women's education captures to some extent the effect of a higher female relative wage, our IV strategy and the additional control variables mitigate the concern of an omitted-variables problem.[30]

Another possible explanation, which has received little attention in the literature, is the availability of new consumption goods. Standard economic theory assumes that children are normal goods and that consumption goods and children are gross substitutes. In a recent paper, Guzman and Weisdorf (2010) formally show how an increase in consumption goods variety may depress the demand for children. Under certain assumptions, the introduction of new consumer goods to markets can have the effect of turning tastes away from children, toward consumption of previously unavailable items. In our case, formal education may operate by shifting preferences from children to consumption goods as educated women develop higher (or different) consumption aspirations (de Vries, 2008; Leibenstein, 1975; Easterlin and Crimmins, 1985).[31] Knodel (1974, p. 127), analyzing the decline of fertility in Germany, argues that "improvements in the standard of living were supposed to instill mobility aspirations as well as desires for even greater material wealth and the limitation of family size was seen as one way to realize these goals". Clearly, an empirical test of this "change of

[29] Estimates not presented here but available upon request.

[30] We also included the land-labor ratio to additionally control for the economic structure of the county. The effect of women's education remained unaffected.

[31] Ogilvie (2010) argues that before 1800, the industrious and consumer revolutions were held back in continental Europe largely due to the influence of guilds. The Stein-Hardenberg Reforms in the first decade of the nineteenth century abolished, amongst others, guild restrictions and thus removed important obstacles for the consumer revolution.

preferences" hypothesis is hard to implement with county-level data. Data on consumption patterns at a disaggregated level are very scarce and therefore a thorough test of this hypothesis is at the moment not possible. Nevertheless, the study of the relationship between higher levels of education and consumption patterns deserves further research.

9. Conclusion

A growing theoretical and empirical literature views the industrial revolution and the demographic transition in a unified framework. In particular, scholars try to understand the interrelationships between factors that characterized the industrial revolution and those that triggered the demographic transition.

In this paper, we contribute to this literature by shedding light on the relationship between women's formal education, measured in terms of school enrolment rates, and their fertility. Linking county-level data from three different censuses, we show that increases in women's education played a substantial role in reducing fertility already before the demographic transition in Prussia. Least-squares estimates show that an increase of girls' enrolment rates by one standard deviation is associated with a decrease in realized fertility between 0.2 and 0.3 standard deviations. This effect is net of factors such as later age at marriage and better employment opportunities for women outside agriculture.

Previous research has shown to what extent the quantity-quality trade-off of children affected fertility levels in Prussia. In line with those results, our estimates suggest that mothers with a formal education have stronger preferences for the education of their children. In fact, once we control for the child quantity-quality trade-off, the effect of women's education on their fertility is reduced by almost 30 percent. However, even after controlling for classical fertility demand and supply factors, we find a robust residual effect of women's education on their fertility.

In order to discard possible biases coming from unobserved heterogeneity, we adopt an instrumental-variable approach. We use exogenous variation in enrolment rates driven by landownership inequality in 1816. Inequality in the distribution of land negatively affects the implementation of human-capital-promoting institutions given the low complementarities between agriculture and education. The instrumental-variable estimates suggest that female education has indeed a causal negative effect on fertility.

This result is important in its own right as it quantifies the role of women's education in reducing fertility, a factor that has so far been widely neglected in the analysis of historical fertility patterns. It also provides another link through which the industrial revolution, by increasing the demand for educated labor, may have subsequently triggered the demographic transition. In addition, our finding opens up an intriguing question, namely on the mechanism that is at work behind the inverse relationship between women's education and realized fertility.

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Appendix: County-level data for Prussia in the nineteenth century

1816 is the earliest year for which the Prussian Statistical Office, founded in 1805, collected detailed data at the county and municipality level. The county data provide information on the number of public elementary schools (*Öffentliche Elementarschulen*), the only school type equally available in rural areas and towns at the time, and the number of students therein. In addition, the town data report on the number of schools and students in the following school types available only in towns: private elementary schools (*Privat-Elementarschulen*), public middle schools for boys and girls (*Öffentliche Bürger- oder Mittelschulen für Söhne und Töchter*), and private middle schools (*Private Bürger- oder Mittelschulen für Söhne und Töchter*). To capture all children at recommended school age, county and town enrolment data are aggregated to compute total primary enrolment.[32] The source of the 1816 Population Census data is Alexander A. Mützell, *Neues Topographisch-Statistich-Geographisches Wörterbuch des Preussischen Staats*, Vol. 6, Halle: Karl August Kümmel, 1825.[33]

The source of the 1849 census data is the Prussian Statistical Office, which published the data in the period 1851-1855 under the title "*Tabellen und amtliche Nachrichten über den Preussischen Staat für das Jahr 1849*". The census of 1849 contains seven volumes. We use Vol. 1 for population data, Vol. 2 for education and

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[32] The 1816 census data are structured into 289 counties; an administrative reform subsequently split some counties in the Eastern part of Prussia into smaller units. We converted the data to match the 334 counties of the borders in 1849/1867 based on population data from the 1821 census. Regression results that cluster standard errors at the level of 280 independent units of observation in 1816 (accounting for the fact that some counties had to be combined first before they could be subdivided again into the new structure) are practically identical to those presented here.

[33] The 1816 school enrolment data were missing for the eleven counties of the district of Cologne. We imputed the data based on school enrolment data available in 1829 for all 59 counties of the Rhine Province. Given a correlation of 0.59 of the 1829 data with the 1816 data for the 48 counties with both datasets available, we regressed the 1816 data on the 1829 data and predicted the 1816 values for the eleven Cologne counties based on their 1829 values. Data on the age structure in 1816 were also missing for the eleven counties of the district of Cologne, which report population totals only. We used the share of the female age group 0-7 and 15-45 of the contiguous provinces (Arnsberg, Dusseldorf, Aachen, Koblenz) to impute the missing child-woman ratio of 1816 for the eleven Cologne counties.

mortality data, Vol. 5 for data on landownership, and Vol. 6a for factory data. All data are available for 334 counties.

The 1849 education data contain information on the number of schools and students for public elementary schools (*Öffentliche Elementarschulen*) and public middle schools for boys and girls (*Öffentliche Mittelschulen für Söhne und Töchter*). We combine enrolment in elementary and middle schools to obtain primary school enrolment, matching the fact that children at recommended school age (6-14 years) could either attend elementary schools or middle schools.

We construct measures of life expectancy at different ages by calculating age-specific mortality rates from population and mortality data, which are reported in age groups of varying size, usually encompassing five years.

The 1849 factory data contain information on the number of factories and workers for the Prussian counties. 119 types of factories are distinguished by the products fabricated. Our variable for industrialization in 1849 refers to the share of population working in textile, metal, and other factories. The textile sector includes factories for spinning, weaving, dyeing, and apparel. The metal sector includes processing of metals and production of metal products and machinery, as well as manufacture of stone and glass products. The other industrial sectors include such factories as those producing food, wood, paper, wax, and rubber.

The 1864 census reports education information on public elementary schools (*Öffentliche Elementarschulen*), private elementary schools (*Privat-Elementarschulen*), public middle schools for boys or girls (*Öffentliche Mittelschulen für Söhne oder Töchter*), and private middle schools for boys or girls (*Private Mittelschulen für Söhne oder Töchter*). To calculate enrolment rates, we divide the number of enrolled students by the number of children aged 6 -14 in 1864. The source of the 1864 census data is Preussische Statistik, Vol. 10.

In order to generate the child-woman ratio in 1867, we use the population census. In particular, we use data from Preussische Statistik, Vol. 16b. For the net migration rate in 1880, we use data contained in Preussische Statistik, Vol. 42.

Table 1: Summary statistics

Variable	*Mean*	*Std. Dev.*	*Min.*	*Max.*	*N*
Child-woman ratio (1867)	1.714	0.268	1.016	2.540	334
Female enrolment rate (1816)	0.545	0.210	0.020	0.939	334
Employed in textile factories (1849)	0.149	0.209	0.013	1.747	334
Age at marriage (1849)	0.226	0.061	0.090	0.464	334
Enrolment rate (1864)	0.753	0.104	0.438	1.201	334
Child mortality (1849)	7.50	2.35	3.36	14.91	334
Maternal mortality ratio (1849)	0.829	0.345	0	2.050	334
Urban share (1849)	0.246	0.186	0	1	334
Share in industry (1849)	0.030	0.029	0.006	0.322	334
Share Protestants (1849)	0.605	0.394	0.002	0.999	334
Share married women (1849)	0.701	0.058	0.431	0.854	334
Population density (1849)	0.200	1.121	0.020	14.978	334
Net migration per 1000 inhabitants (1880)	-1.682	3.669	-32.219	2.374	334
Cattle per woman (1849)	0.676	0.208	0.006	1.454	334
Women in industry per capita (1867)	0.007	0.009	0	0.063	334
Landownership inequality (1816)	0.017	0.020	0	0.148	334
Child-woman ratio (1816)	0.894	0.156	0.505	2.292	334
Enrolment rate (1849)	0.801	0.117	0.334	0.988	334

Note: Child-woman ratio is the number of children aged 10-19 over the number of women aged 40-69. Female enrolment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. Age at marriage is defined as the share of women who married at age older than 30. The maternal mortality ratio is defined as the number of maternal deaths per 100 live births.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

Table 2: Mothers' education and fertility—Basic results

Dep. var.: Child-woman ratio (1867)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Female enrolment rate (1816)	-0.561***	-0.620***	-0.597***	-0.539***	-0.342***	-0.348***	-0.344***
	(0.057)	(0.062)	(0.061)	(0.058)	(0.067)	(0.068)	(0.069)
Employed in textile factories (1849)			-0.281***	-0.197**	-0.176**	-0.170**	-0.158**
			(0.101)	(0.089)	(0.086)	(0.078)	(0.079)
Age at marriage (1849)				-1.832***	-1.687***	-1.638***	-1.610***
				(0.207)	(0.220)	(0.216)	(0.214)
Enrolment rate (1864)					-0.730***	-0.858***	-0.797***
					(0.152)	(0.180)	(0.179)
Child mortality rate (1849)						-1.496**	-1.726***
						(0.589)	(0.606)
Maternal mortality ratio (1849)							0.077*
							(0.041)
Urban share (1849)		-0.079	-0.025	0.056	0.131	0.182*	0.200**
		(0.085)	(0.090)	(0.079)	(0.087)	(0.092)	(0.097)
Share in industry (1849)		0.642	1.145***	0.749*	1.043***	0.925**	0.961**
		(0.425)	(0.393)	(0.383)	(0.369)	(0.367)	(0.381)
Share Protestants (1849)		0.044	0.021	-0.087**	-0.116***	-0.118***	-0.116***
		(0.035)	(0.036)	(0.035)	(0.037)	(0.038)	(0.038)
Share married women (1849)		0.273	0.344	-0.111	0.296	0.359	0.362
		(0.324)	(0.323)	(0.265)	(0.309)	(0.313)	(0.314)
Constant	2.020***	1.835***	1.800***	2.546***	2.658***	2.805***	2.694***
	(0.035)	(0.225)	(0.225)	(0.207)	(0.226)	(0.235)	(0.234)
Observations	334	334	334	334	334	334	334
R^2	0.193	0.209	0.251	0.379	0.428	0.442	0.450

Note: OLS regressions, Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Child-woman ratio is the number of children aged 10-19 over the number of women aged 40-69. Female enrolment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. Age at marriage is defined as the share of women who married at age older than 30.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

Table 3: Robustness specifications

Dep. var.: Child-woman ratio (1867)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Female enrolment rate (1816)	-0.343***	-0.315***	-0.313***	-0.248***	-0.259***
	(0.069)	(0.068)	(0.067)	(0.068)	(0.069)
Employed in textile factories (1849)	-0.160**	-0.148*	-0.147*	-0.145*	
	(0.079)	(0.079)	(0.080)	(0.079)	
Age at marriage (1849)	-1.615***	-1.552***	-1.558***	-1.921***	-1.916***
	(0.214)	(0.211)	(0.219)	(0.237)	(0.236)
Enrolment rate (1864)	-0.783***	-0.695***	-0.699***	-0.603***	-0.587***
	(0.180)	(0.182)	(0.182)	(0.224)	(0.220)
Population density (1849)	-0.009	-0.011	-0.011	-0.019**	-0.017**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Net migration per 1000 inhabitants (1880)		-0.012***	-0.012***	-0.009**	-0.009**
		(0.004)	(0.004)	(0.004)	(0.004)
Cattle per woman (1849)			0.009	-0.064	-0.051
			(0.070)	(0.069)	(0.071)
Latitude in rad x 100				3.507***	3.468***
				(0.859)	(0.867)
Longitude in rad x 100				-0.843***	-0.793***
				(0.303)	(0.300)
Women in industry per capita (1867)					-3.397**
					(1.456)
Constant	2.709***	2.620***	2.617***	-0.347	-0.317
	(0.236)	(0.228)	(0.224)	(0.854)	(0.858)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	334	334	334	334	334
R^2	0.451	0.472	0.472	0.509	0.509

Note: OLS regressions, Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Child-woman ratio is the number of children aged 10-19 over the number of women aged 40-69. Female enrolment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. Age at marriage is defined as the share of women who married at age older than 30. Net migration is computed as the difference between immigrants and emigrants over the reference population (*1000). Control variables: urban share, share in industry, share Protestants, share married women, child mortality rate, and maternal mortality ratio.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

Table 4: Instrumental-variable results

Dependent variable:	*(1)* *Child-woman ratio (1867)* *(OLS)*	*(2)* *Female enrolment rate (1816)* *(1st stage)*	*(3)* *Child-woman ratio (1867)* *(2nd stage)*
Female enrolment rate (1816)	-0.325***		-0.850**
	(0.082)		(0.377)
Landownership inequality (1816)		-2.583***	
		(0.561)	
Child-woman ratio (1816)	0.285	-0.108	0.225
	(0.272)	(0.104)	(0.224)
Employed in textile factories (1849)	-0.143*	-0.028	-0.142*
	(0.079)	(0.036)	(0.074)
Age at marriage (1849)	-1.394***	-0.038	-1.394***
	(0.228)	(0.178)	(0.225)
Enrolment rate (1864)	-0.678***	0.851***	-0.186
	(0.167)	(0.116)	(0.390)
Constant	2.307***	0.411**	2.483***
	(0.376)	(0.195)	(0.362)
Control variables	Yes	Yes	Yes
Observations	334	334	334
R^2	0.466	0.482	0.370
F-statistic 1st stage			21.180

Note: OLS and two-stage least squares regressions, Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Child-woman ratio is the number of children aged 10-19 over the number of women aged 40-69. Female enrolment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. Age at marriage is defined as the share of women who married at age older than 30. See text for details on landownership inequality. Control variables: urban share, share in industry, share Protestants, share married women, child mortality rate, and maternal mortality ratio.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

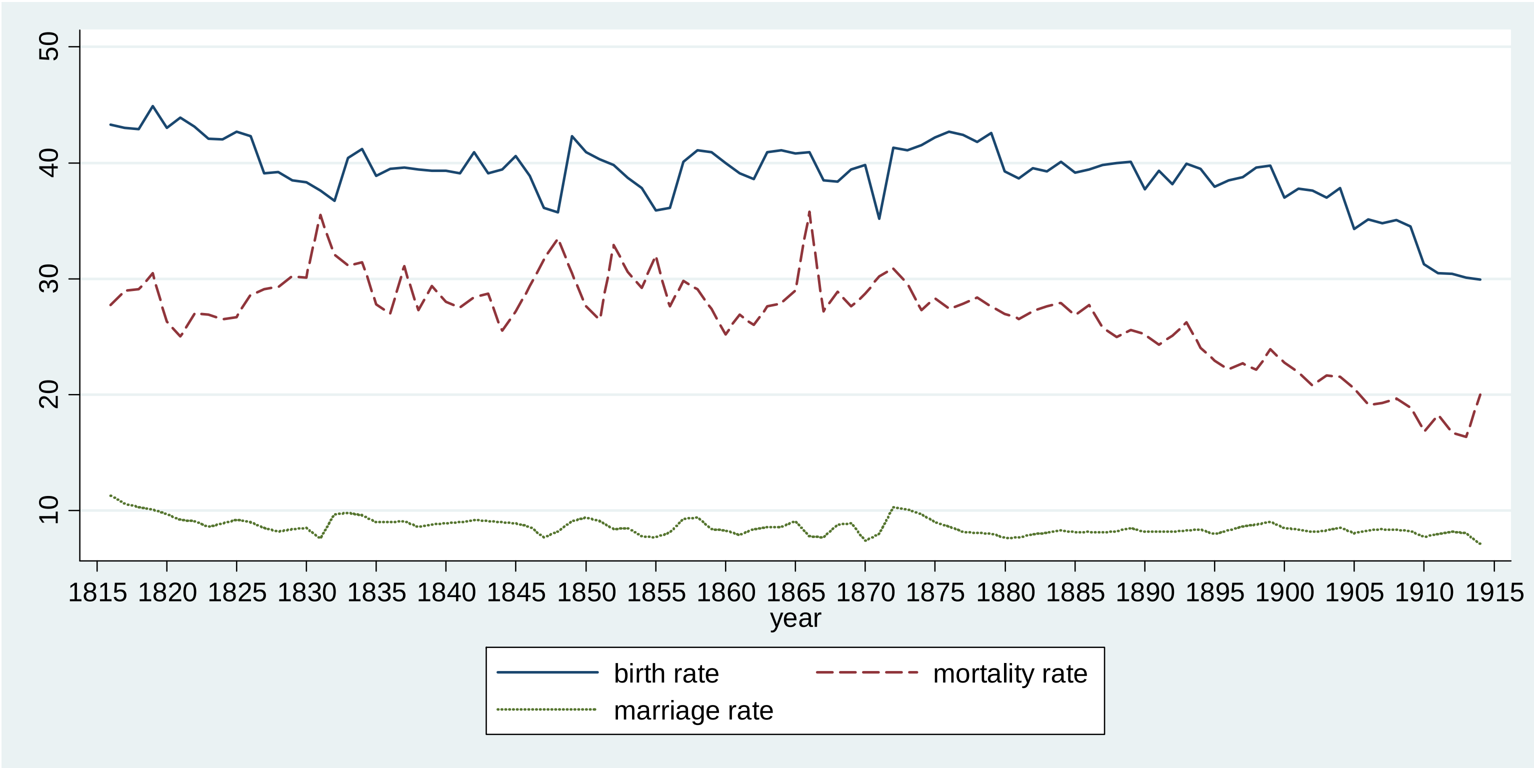
Table 5: Alternative specifications to address women's mortality

Dependent variable:	*(1)* *Ratio of children aged 10-19 over number of households (1867)*	*(2)* *Ratio of children aged 0-14 over women aged 17-45 (1849)*
Female enrolment rate (1816)	-0.444**	-0.415**
	(0.206)	(0.210)
Child-woman ratio (1816)	0.090	0.237*
	(0.063)	(0.122)
Employed in textile factories (1849)	-0.051*	-0.098**
	(0.028)	(0.042)
Age at marriage (1849)	-0.162	-0.782***
	(0.112)	(0.136)
Enrolment rate (1864)	0.174	
	(0.206)	
Enrolment rate (1849)		0.133
		(0.204)
Constant	1.366***	1.182***
	(0.142)	(0.234)
Control variables	Yes	Yes
Observations	334	334
R^2	0.078	0.587
F-statistic 1st stage	21.180	14.621

Note: Second stage of two-stage least squares regressions, with female enrolment rate instrumented by landownership inequality, Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Female enrolment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. Age at marriage is defined as the share of women who married at age older than 30. See text for details on landownership inequality. Control variables: urban share, share in industry, share Protestants, share married women, child mortality rate, and maternal mortality ratio.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

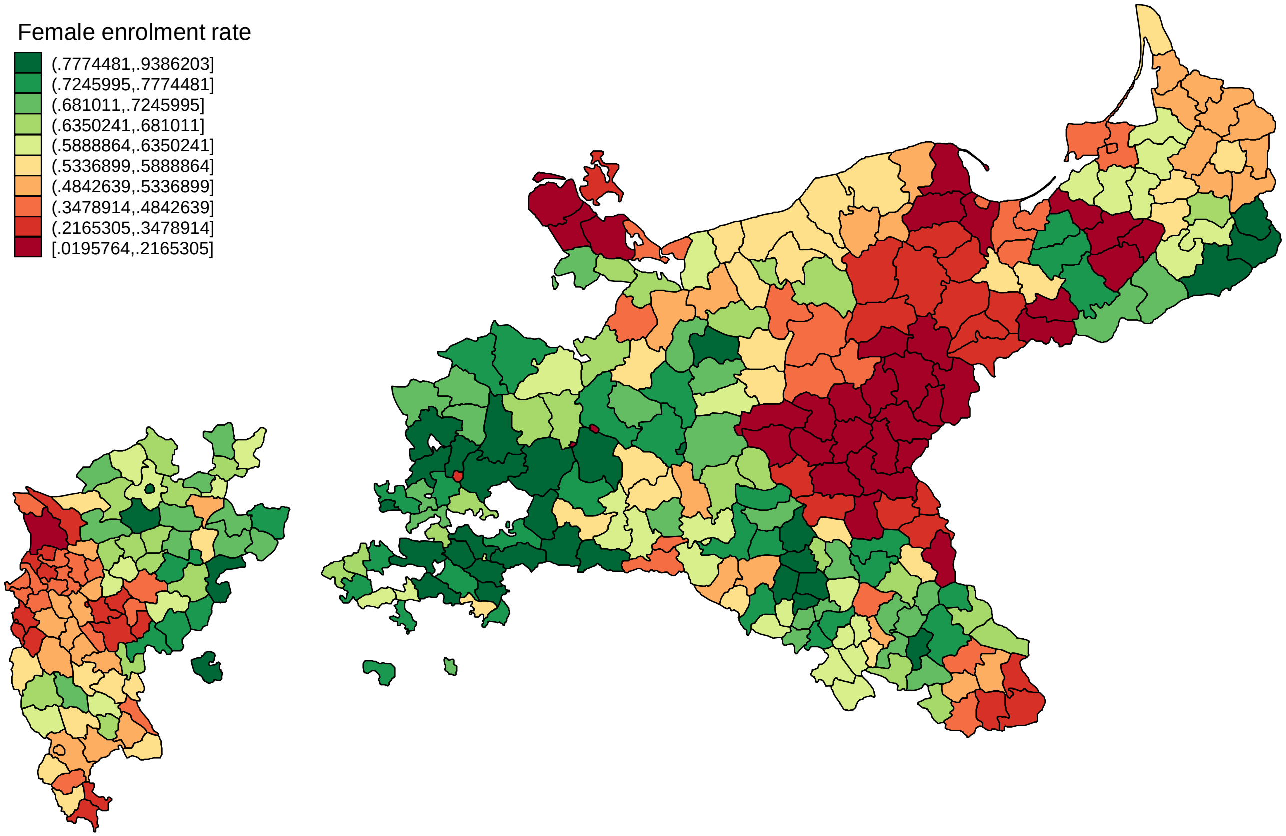
Figure 1: Demographic patterns in Prussia, 1815-1915



Note: Birth rate: crude births per 1000 people. Mortality rate: deaths per 1000 people. Marriage rate: marriages per 1000 people.

Source: Köllmann (1980); Galloway, Hammel, and Lee (1994).

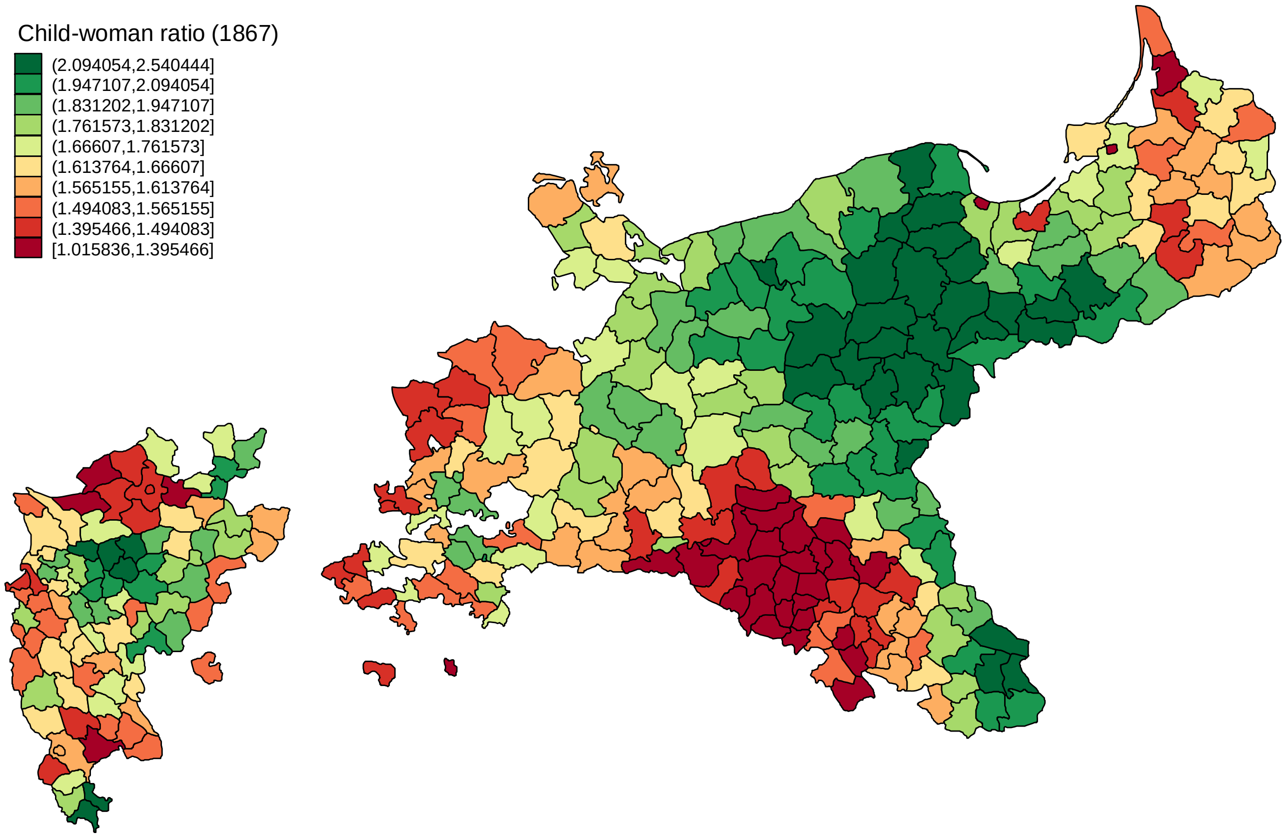
Figure 2: The female enrolment rate in 1816



Note: Ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. Depiction in county borders of 1849.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

Figure 3: The child-woman ratio in 1867



Note: Number of children 10-19 over women aged 40-69. Depiction in county borders of 1849.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.

Figure 4: The relationship between mothers' education and fertility

Note: Female enrolment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6-14. The child-woman ratio is defined as the number of children 10-19 over women aged 40-69.

Source: Data for 334 counties from the Prussian Statistical Office; see data appendix for details.