Education and Fertility

before the Demographic Transition

Warwick Summer School in Economic Growth 2013

Sascha O. Becker

Francesco Cinnirella

Ludger Woessmann

The child quantity-quality (Q-Q) trade-off

- Galor and Moav (QJE 2002):
  - Stress importance of human capital in explaining the transition from stagnation to growth

- Vast majority of empirical studies of this trade-off mostly use modern data, from during or after the Demographic Transition
  - Angrist et al. 2002; Black et al. 2005; Hanushek (1992); Rosenzweig and Wolpin (1980).
  - Bleakley and Lange (REStat 2009) go back as much as 1910
  - Fernihough (2011) uses 1911 Irish Census data

- Becker, Cinnirella, Woessmann (JOEG 2010 and Cliometrica 2012) look at the QQ trade-off using data from before the demographic transition
  - Further work from before DT: Klemp and Weisdorf (2012) using family reconstitution data from historical England

Contribution of Becker, Cinnirella, Woessmann (JOEG 2010)

- We provide empirical evidence about the child quantity-quality (Q-Q) trade-off in Prussia *before* the fertility transition, using data from 1849.
- We pay particular attention to the simultaneity bias between education and fertility by using an instrumental variables approach.
- We investigate the long-run impact of educational differences that existed in 1849 on the speed/strength of the demographic transition at the turn of the 19th/20th century.
- County level data from 19th century Prussia
  - Population, Schooling, and Factory Censuses 1849 (year t)
  - Population Census 1816 (year $t-1$)
  - Population Censuses from 1880-1905

Theory

- Theory emphasizes role of prices and of preferences for education:
  - cost of raising children
  - cost of education
  - preference for education
- Suppose parents maximize a log-linear utility function as in Galor and Moav (2002):

$$u = (1-\gamma)\ln c + \gamma\,(\ln n + \beta \ln h) \quad \text{where} \quad 0 < \gamma < 1 \quad \text{and} \quad \beta < 1 \qquad (1)$$

- Spend tau_q of their time budget (and an according share of their potential income) on raising children.
- Spend fraction tau_e of parents' time for each unit of education e of each child.
- Raising one child of education (quality) e thus costs (tau_q+tau_e*e) units of time.

Theory

- Budget constraint: $yn(\tau^q + \tau^e e) + c \leq y$
- Optimization yields: $n = \gamma/(\tau^q + \tau^e e)$ (3)
- … and $e = e\left(\beta, \tau^q, \tau^e\right)$ where $e'(\beta) > 0$.
- Equation 3 shows a trade-off between the number n of children and their quality (education e).
- That trade-off is driven by the cost of raising children τ q, the cost of education τ e, and by the preference for education β .

From theory to IV strategy

- The theory motivates our IV strategy:
- 1) as instruments for education, we use
  - landownership inequality: due to the opposition of the landed nobility to education, corresponds to a rise in the cost of education (Galor et al 2009)
  - distance to Wittenberg: Protestant urge to read the Bible led to education efforts: "preference shock" for education (Becker and Woessmann 2009)
- 2) as instrument for fertility:
  - adult sex ratio as proxy of marriage market tightness affecting marriage rates and fertility (Angrist 2002; Abramitzky et al. 2010)

Descriptive statistics

Table 1 Summary statistics

	Mean	Std. dev.	Min	Max
Census 1849				
Child–woman ratio	0.64	0.08	0.35	0.84
School enrolment rate	0.80	0.12	0.33	0.99
Share in industry	0.03	0.03	0.01	0.32
Share in agriculture	0.43	0.17	0.00	0.85
Share urban	0.24	0.19	0.00	1.00
Population density (1000 people per km^2)	0.20	1.12	0.02	14.98
Share married women	0.70	0.06	0.43	0.85
Share Protestants	0.60	0.39	0.00	1.00
Poland	0.42	0.49	0.00	1.00
Life expectancy at age 0	35.48	7.53	12.19	49.48
Life expectancy at age 5	45.84	6.92	20.05	56.62
Schools per 100 children (6–14)	0.82	0.27	0.27	1.72
Temporary male migration	0.00	0.03	−0.04	0.52
Marital fertility rate	0.70	0.06	0.43	0.85
Landownership inequality	0.01	0.01	0.00	0.08
Distance to Wittenberg (in 100 km)	3.33	1.64	0.00	7.31
Sex ratio adults 15–45	0.99	0.08	0.82	1.39
Census 1816				
Child–woman ratio	0.67	0.12	0.38	1.72
School enrolment rate	0.58	0.20	0.03	0.95
Sex ratio children 0–7	1.01	0.06	0.48	1.13
Demographic data 1880–1905				
Crude birth rate (1880)	34.78	4.34	24.57	50.75
Crude birth rate 1880–1905 (% change)	−0.10	0.10	−0.46	0.20
Marital fertility rate (1890)	27.03	3.66	17.81	34.36
Marital fertility rate 1890–1905 (% change)	−0.08	0.10	−0.40	0.21
Net migration per 1000 inhabitants (1880)	−1.75	3.79	−32.22	2.37

The empirical model

$$fertility_i = \alpha \cdot education_i + \mathbf{X}_{i1}\delta_1 + e_{i1} \quad (1)$$

$$education_i = \beta \cdot fertility_i + \mathbf{X}_{i2}\delta_2 + e_{i2} \quad (2)$$

- Education measure:
  - Enrolment rates in public primary schools
  - Defined as the number of children enrolled in school divided by the number of children aged 6–14
- Fertility measure:
  - Child-woman ratio
  - Defined as the number of children aged 0–5 per woman of child-bearing age (15–45)

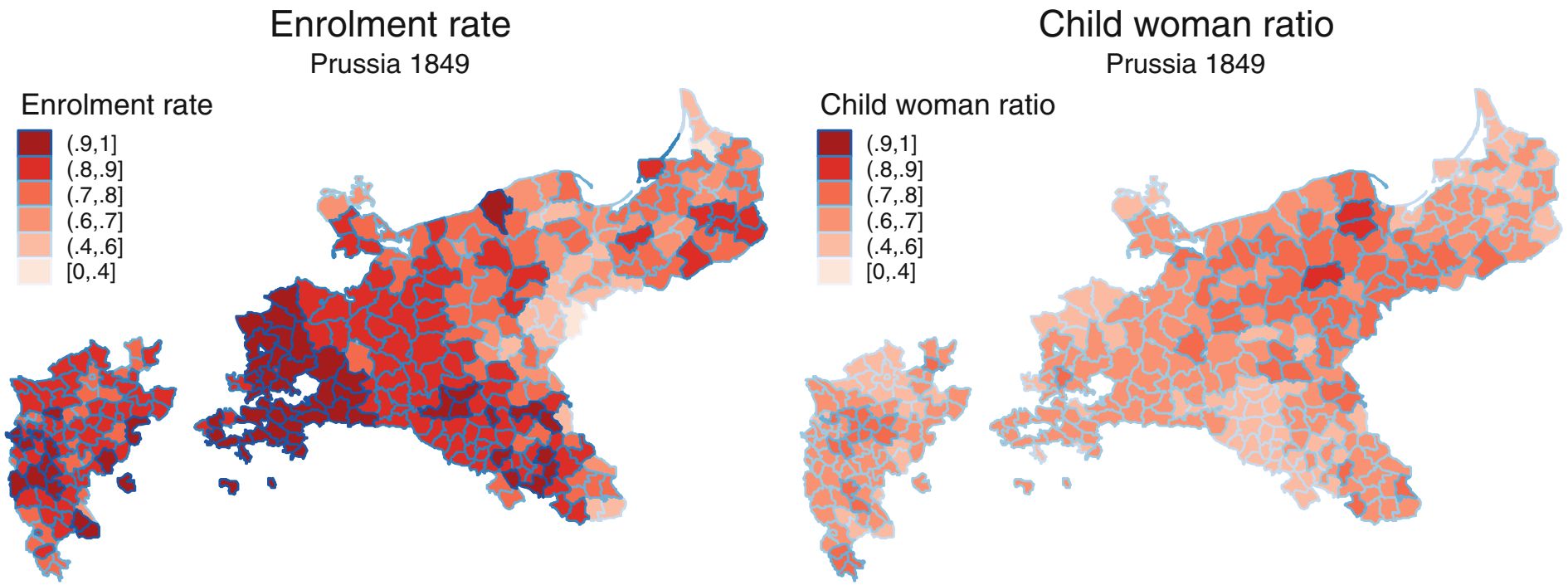


Fig. 1 The geographic distribution of primary school enrolment and fertility. *Source*: County-level data from the Prussian Census 1849; see main text and Appendix for details

The effect of education on fertility: OLS

Table 2 The association between education and fertility

Dependent variable	Child–woman ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
School enrolment	−0.080** (0.040)	−0.075** (0.037)	−0.159*** (0.036)	−0.148*** (0.033)	−0.199*** (0.036)	−0.174*** (0.037)
Share in industry		0.431*** (0.112)	0.420*** (0.101)	0.394*** (0.106)	0.333*** (0.104)	0.341*** (0.101)
Share in agriculture		0.091*** (0.033)	0.097*** (0.033)	0.106*** (0.032)	0.114*** (0.031)	0.116*** (0.030)
Share urban		−0.069** (0.034)	−0.025 (0.029)	0.017 (0.030)	0.003 (0.029)	−0.024 (0.031)
Population density		−0.010** (0.004)	−0.002 (0.004)	−0.004 (0.003)	−0.004 (0.004)	−0.004 (0.003)
Share married women			0.561*** (0.085)	0.676*** (0.093)	0.677*** (0.088)	0.658*** (0.084)
Share Protestants				−0.045*** (0.009)	−0.043*** (0.009)	−0.038*** (0.010)
Poland					−0.031*** (0.009)	−0.045*** (0.010)
Life expectancy at age 0						−0.002*** (0.001)
Constant	0.702*** (0.033)	0.665*** (0.040)	0.325*** (0.060)	0.249*** (0.063)	0.303*** (0.066)	0.367*** (0.069)
Observations	334	334	334	334	334	334
R^2	0.015	0.170	0.297	0.342	0.372	0.388

OLS regressions. Dependent variable: child–woman ratio. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Child–woman ratio is the number of children aged 0–5 (0–7 in 1816) over the number of women aged 15–45. School enrolment rate is the share of children aged 6–14 enrolled in public primary schools
Source: County-level data from the Prussian Census 1849; see main text and Appendix for details

Instrumental variable approach (1)

- Instrument for **education in 1849**:
  - IV1: landownership inequality (Galor, Moav, Vollrath RES 2009)
    - Inequality in the distribution of landownership negatively affects the implementation of human capital promoting institutions

    → Because landowners would not benefit from the accumulation of human capital given the low complementarity between land and human capital
    - Our measure: ratio of the largest landholdings (greater than 600 *Morgen*) over the total number of landholdings
  - IV2: distance to Wittenberg (Becker and Woessmann QJE 2009)
    - Protestant reformers favored education (prerequisite for reading the Bible)
    - Exploit concentric spread of Protestantism around the centre of the Reformation, Wittenberg

The effect of education on fertility: IV

Table 4 The effect of education on fertility

Dependent variable	IV first stage School enrolment			IV second stage Child–woman ratio		
	(1)	(2)	(3)	(4)	(5)	(6)
School enrolment				−0.557*** (0.172)	−0.570*** (0.155)	−0.564*** (0.105)
Landownership inequality	−1.974*** (0.378)		−2.082*** (0.358)			
Distance to Wittenberg		−0.025*** (0.004)	−0.027*** (0.004)			
Share in industry	0.233 (0.209)	0.439** (0.206)	0.308 (0.198)	0.478*** (0.113)	0.483*** (0.115)	0.481*** (0.105)
Share in agriculture	−0.054 (0.043)	−0.060 (0.042)	0.002 (0.041)	0.067* (0.039)	0.065* (0.039)	0.066* (0.037)
Share urban	−0.077* (0.040)	−0.189*** (0.042)	−0.155*** (0.040)	−0.077** (0.034)	−0.079** (0.033)	−0.078** (0.030)
Population density	0.013** (0.005)	0.016*** (0.005)	0.015*** (0.005)	0.003 (0.005)	0.004 (0.005)	0.003 (0.004)
Share married women	0.660*** (0.102)	0.251** (0.119)	0.281** (0.113)	0.779*** (0.145)	0.787*** (0.152)	0.783*** (0.128)
Poland	−0.071*** (0.012)	−0.060*** (0.012)	−0.043*** (0.012)	−0.062*** (0.018)	−0.063*** (0.015)	−0.063*** (0.013)
Constant	0.427*** (0.080)	0.790*** (0.097)	0.763*** (0.093)	0.540*** (0.106)	0.546*** (0.089)	0.543*** (0.078)
Observations	334	334	334	334	334	334
R^2	0.360	0.370	0.430			
Partial F-statistic 1st stage				18.007	34.233	27.985
Sargan–Hansen p-value						0.958

2SLS regressions. Second-stage estimates in columns (4), (5), and (6) correspond to first-stage estimates displayed in columns (1), (2), and (3), respectively. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Source: County-level data from the Prussian Census 1849; see main text and Appendix for details

Increase in the enrolment rate by 10% points causes a decline in the child–woman ratio by about 5 children per 100 women in child-bearing age.

Instrumental variable approach (2)

- Instrument for **fertility in 1849**:
  - IV: sex ratio in 1849 = $\text{males}_{15\text{-}45}/\text{females}_{15\text{-}45}$
    - Measure of marriage market tightness, affecting marriage rates and fertility (see Angrist 2002)
  - (at some point we also use IV2: fertility behavior of the previous generation (1816))
    - Fertility behavior has a significant hereditary component (see Rodgers et al. 2001)
    - Exclusion restriction: even if past fertility behavior influenced past educational choices, the latter is however accounted for in equation (2) as long as we control for enrolment in 1816.

The effect of fertility on education

Table 6 The effect of fertility on education

Dependent variable	IV first stage Child–woman ratio			IV second stage School enrolment		
	(1)	(2)	(3)	(4)	(5)	(6)
Child–woman ratio				−1.101*** (0.351)	−1.470*** (0.532)	−1.216*** (0.333)
Sex ratio adults 15–45 (1849)	0.276*** (0.063)		0.264*** (0.061)			
Sex ratio children 0–7 (1816)		0.230** (0.089)	0.210** (0.083)			
Share in industry	0.248** (0.113)	0.285** (0.122)	0.225** (0.112)	0.766*** (0.216)	0.882*** (0.271)	0.802*** (0.218)
Share in agriculture	0.100*** (0.034)	0.104*** (0.035)	0.090*** (0.033)	−0.005 (0.059)	0.038 (0.076)	0.008 (0.058)
Share urban	−0.096*** (0.031)	−0.057* (0.032)	−0.103*** (0.031)	−0.261*** (0.057)	−0.279*** (0.065)	−0.267*** (0.058)
Share Protestants	−0.006 (0.012)	−0.024** (0.011)	−0.010 (0.012)	0.029 (0.026)	0.021 (0.030)	0.027 (0.027)
Population density	−0.015*** (0.005)	−0.012*** (0.004)	−0.015*** (0.005)	−0.003 (0.009)	−0.007 (0.012)	−0.004 (0.009)
Poland	−0.010 (0.011)	−0.023** (0.010)	−0.014 (0.010)	−0.113*** (0.021)	−0.121*** (0.025)	−0.116*** (0.021)
Constant	0.350*** (0.067)	0.392*** (0.089)	0.160 (0.106)	1.578*** (0.227)	1.804*** (0.335)	1.648*** (0.217)
Observations	334	334	334	334	334	334
R^2	0.240	0.210	0.263			
Partial F-statistic 1st stage				19.265	6.667	11.758
Sargan–Hansen p-value						0.449

2SLS regressions. Second-stage estimates in columns (4), (5), and (6) correspond to first-stage estimates displayed in columns (1), (2), and (3), respectively. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Standard errors are clustered at the level of the 280 units of observation in the 1816 data due to a change of borders after 1816

Source: County-level data from the Prussian Censuses 1849 and——for the sex ratio of children 0–7—from the 1816 Census; see main text and Appendix for details

Based on column (6): increase of the child–woman ratio by 1 child per 10 women is associated with a decrease of the enrolment rate by about 12% points.

The Q-Q and the demographic transition

- We have shown that, in Prussia 1849, households were *already* trading quantity for quality and vice versa.
- This trade-off is statistically and *economically* significant.

- We also estimate the predicting power of education in time *t* (1849) for the fertility transition in *t+1* (%change 1890-1905).
- 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.
- This view has been strongly criticized and more recent studies have proved the significant role played by economic factors in triggering the fertility transition (Bleakley and Lange 2009; Brown and Guinnane 2007; Galloway et al. 1994).

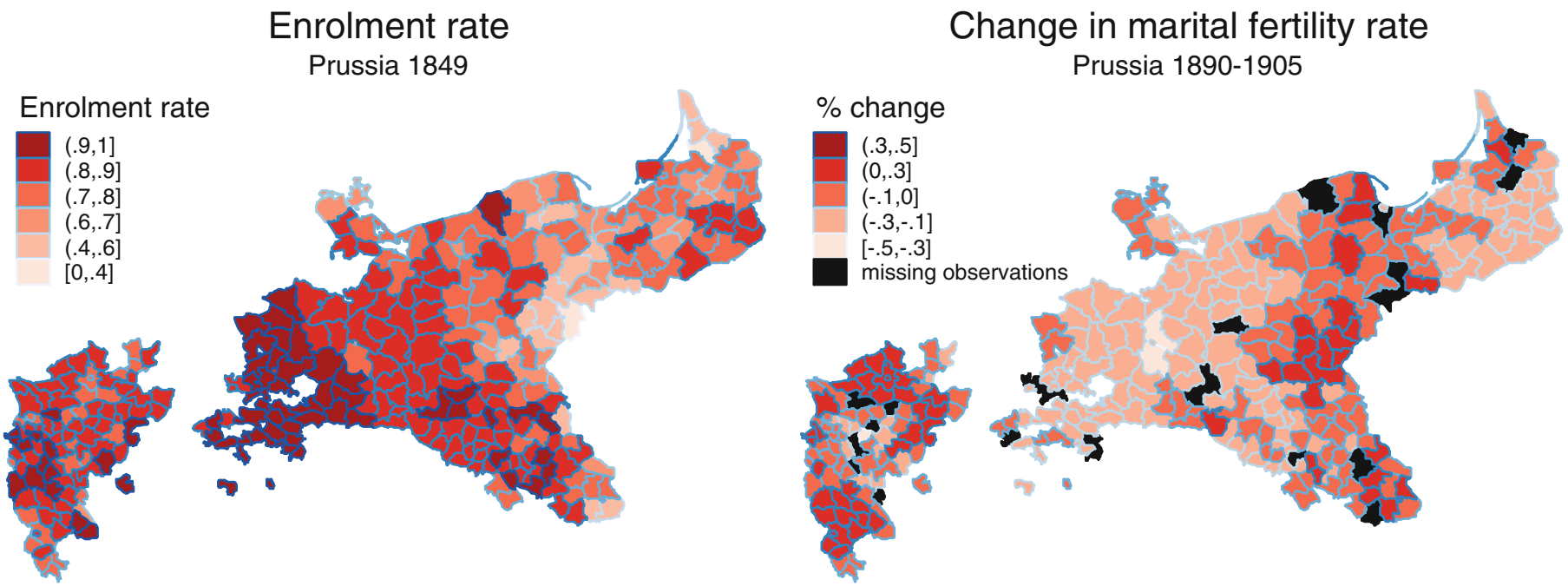


Fig. 2 The geographic distribution of education in 1849 and the fertility transition in 1890–1905. *Source*: County-level data from the Prussian Census 1849 and vital statistics for different years; see main text and Appendix for details

The long-run effect of education on the fertility transition

Table 8 The long-run effect of education on the fertility transition: crude birth rates

Dependent variable	Crude birth rate 1880–1905 (% change)					
	(1)	(2)	(3)	(4)	(5)	(6)
School enrolment	−0.132*** (0.043)	−0.079* (0.047)	−0.048 (0.047)	−0.069 (0.049)	−0.042 (0.049)	−0.094* (0.048)
Child–woman ratio	−0.227*** (0.078)	−0.299*** (0.070)	−0.315*** (0.069)	−0.290*** (0.069)	−0.345*** (0.070)	−0.145 (0.089)
Share in industry	0.110 (0.165)	0.010 (0.169)	−0.068 (0.176)	−0.081 (0.172)	−0.070 (0.170)	0.063 (0.151)
Share in agriculture	−0.008 (0.040)	0.021 (0.037)	0.061 (0.041)	0.057 (0.040)	0.042 (0.040)	0.024 (0.039)
Share urban	−0.330*** (0.036)	−0.254*** (0.036)	−0.270*** (0.037)	−0.242*** (0.040)	−0.240*** (0.040)	−0.254*** (0.038)
Population density	0.017*** (0.004)	0.007* (0.004)	0.008* (0.004)	0.008* (0.005)	0.007 (0.005)	0.008* (0.004)
Share Protestants		−0.118*** (0.013)	−0.102*** (0.014)	−0.106*** (0.014)	−0.105*** (0.014)	−0.111*** (0.014)
Poland		−0.016 (0.011)	−0.021* (0.011)	−0.008 (0.013)	−0.001 (0.013)	0.000 (0.013)
Schools per 100 children			−0.067*** (0.023)	−0.066*** (0.023)	−0.075*** (0.023)	−0.064*** (0.021)
Life expectancy at age 0				0.002** (0.001)	0.002*** (0.001)	0.001 (0.001)
Net migration per 1000 inhabitants (1880)					−0.004*** (0.001)	−0.004*** (0.001)
Crude birth rate (1880)					−0.006*** (0.002)	
Constant	0.223*** (0.065)	0.278*** (0.069)	0.300*** (0.068)	0.232*** (0.072)	0.229*** (0.073)	0.400*** (0.082)
Observations	309	309	309	309	309	309
R^2	0.243	0.426	0.443	0.451	0.470	0.498

OLS regressions. Dependent variable: crude-birth rate 1880–1905 (% change). All right-hand side variables refer to 1849, except where other year is indicated in parentheses. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Crude birth rate is defined as the number of legitimate births (in 1000 s) over the total population
Source: County-level data from the Prussian Census 1849 and demographic data for different years; see main text and Appendix for details

Summary

- We show that, as postulated by unified growth theory, the trade-off between quantity and quality of children was already in place in the first half of the 19th century in Prussia, before the demographic transition.
- IV strategy naturally follows from UGT model
- We find evidence for a causal link from educational choices to fertility, and vice versa.
- Finally, we provide some evidence that accumulation of human capital might have played a significant role for the fertility transition at the end of the 19th century.

Contribution of Becker, Cinnirella, Woessmann (Cliometrica 2012)

- We provide empirical evidence about the child quantity-quality (Q-Q) trade-off in Prussia even further *before* the fertility transition, using data from 1816.
- … several decades before the DT, prior to the Industrial Revolution, when the technology-driven demand for education was still low.
- We pay particular attention to the simultaneity bias between education and fertility by using an instrumental variables approach.
- Our results reveal that a significant negative association existed between the educational enrollment rate and the child–woman ratio in 1816.

Comparing results for 1849 and 1816

- Estimates in 1849 exceed our estimate in 1816 by more than a half.
- This increase in the estimated effect between 1816 and 1849 might suggest that, *ceteris paribus* (e.g. assuming cost of education constant), preferences for offspring quality increased over time.
- Such an interpretation would be consistent with the evolutionary model of Galor and Moav (2002) who argue that the impact of the increase in the demand for human capital on the decline in the number of surviving offspring may have been magnified by cultural evolution in the attitude toward child quality (Galor and Moav 2005, p. 501).
- Alternative interpretations:
  - Smaller coefficient in 1816 could also be due to larger measurement error in the 1816 enrollment data.
  - Increase in the opportunity cost of raising a child would also result in a stronger effect for 1849.
  - Thus, the consistence of the intertemporal comparison with evolutionary models should only be taken as suggestive, rather than definitive.

Becker, Cinnirella, Woessmann (EREH 2013) "Does women's education affect fertility? Evidence from pre-demographic transition Prussia"

- Idea: child quantity–quality trade-off – and many other factors such as women's employment opportunities, relative wages etc. – have been studied as factors underlying historical fertility limitation
- … but the role of women's education has received little attention
- 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.
- Result: Despite controlling for several demand and supply factors, find a negative residual effect of women's education on fertility.

Previous literature

- Much attention has been devoted to
  - the impact of employment opportunities for women outside agriculture (Crafts, 1989; Galloway et al. 1994)
  - the effect of female relative wage (Dribe 2009; Schultz 1985)
  - the child Q-Q trade-off (Becker, Cinnirella and Woessmann 2010, 2012; Fernihough 2011; Klemp and Weisdorf 2012 etc.)
- Yet, the role of parental education (women's education) has received little empirical attention.

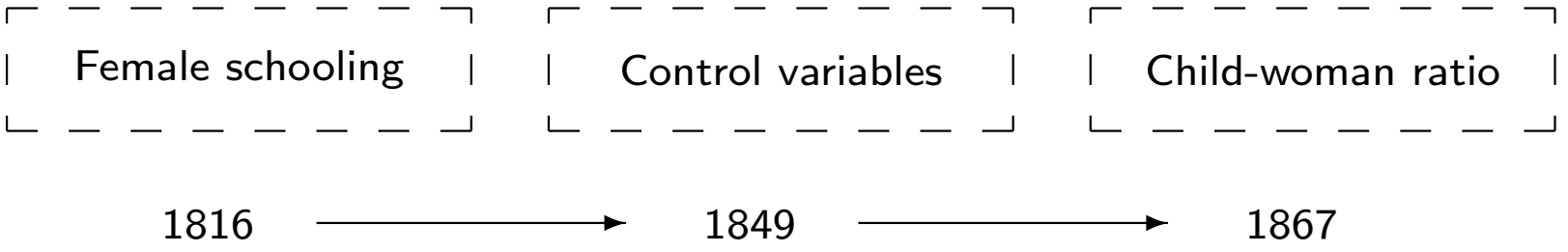
The Easterlin synthesis

- Demand for children: the number of surviving children the parents would want if fertility regulation were costless.
  - Driving factors: Income, relative cost of children, tastes w.r.t. 'child quality'.
- Supply of children: the number of surviving children a couple would have if they made no deliberate attempt to limit family size.
  - It reflects both a couple's natural fertility and the chances of child survival.
- The costs of fertility regulation: It refers to couple's attitudes toward and access to fertility control methods and supplies.

Estimation strategy

$$fertility_i = \alpha_i + \beta\, edu_i + \mathbf{X}_i\, \lambda + \mathbf{Z}_i\, \gamma + \epsilon_i$$

- Where
  - fertility is the child-woman ratio in 1867 for county i;
  - edu is the share of girls (6-14) enrolled in primary school in 1816;
  - X is a vector of demand variables in 1849;
  - Z is a vector of supply factors in 1849;



Dependent variable

- Our measure for fertility is the
- Child-woman ratio(1867)=Kids[10–19]/Women[40–69]
  - The numerator includes, among others, those children who were born/conceived in 1849, year for which we observe demand/supply factors.
  - The denominator includes the cohort of girls who enrolled in primary school in 1816.
  - Note that women between age 40-69 in 1867 were between 22-51 in 1849 and between 0-18 in 1816.

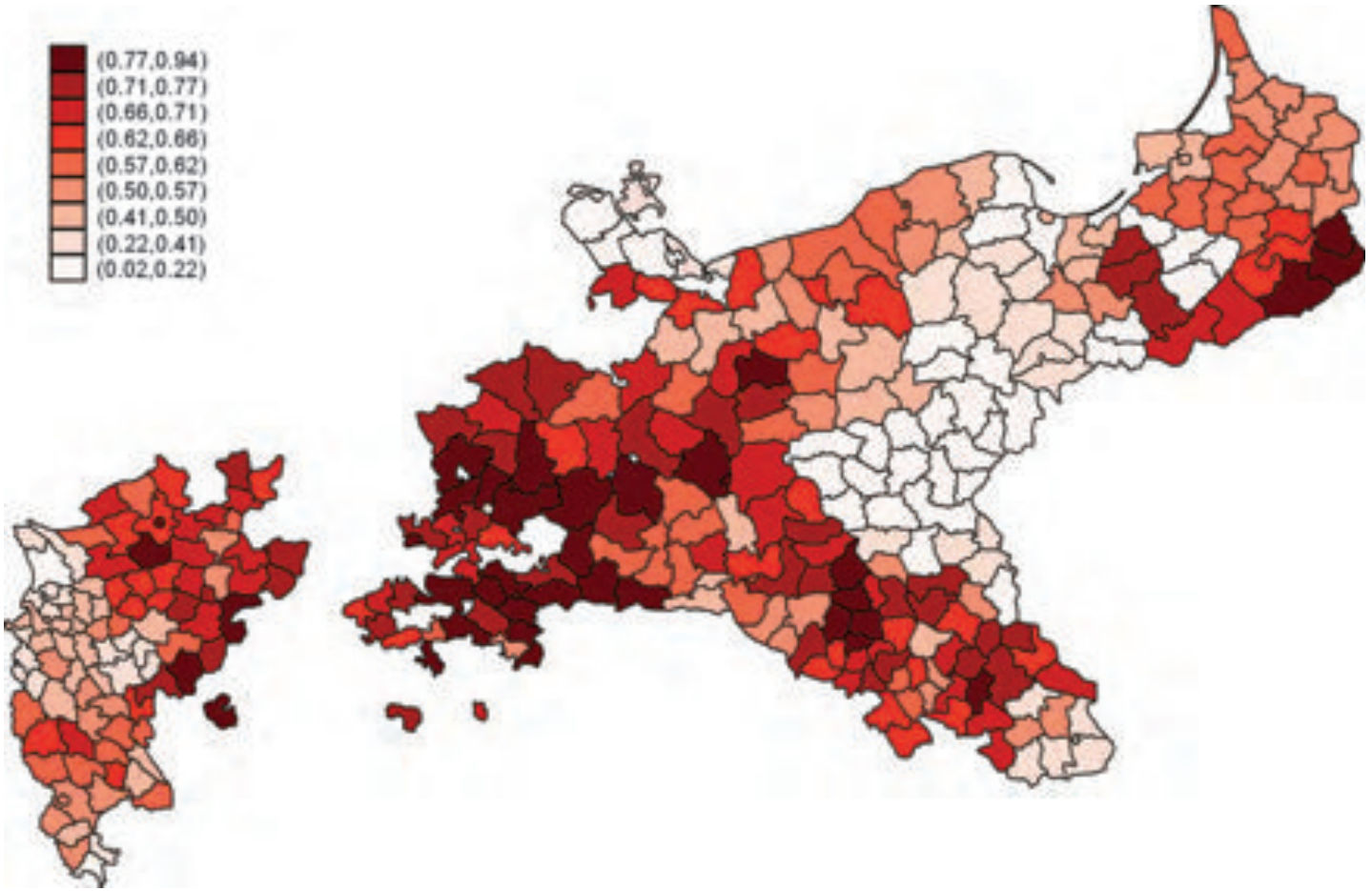


Figure 1. *The female enrollment rate in 1816.* Note: *Ratio of girls enrolled in primary and middle schools over the number of girls aged 6–14. Depiction in county borders of 1849.* Source: *Data for 334 counties from the Prussian Statistical Office; for details, see Supplementary material online, Appendix A.*

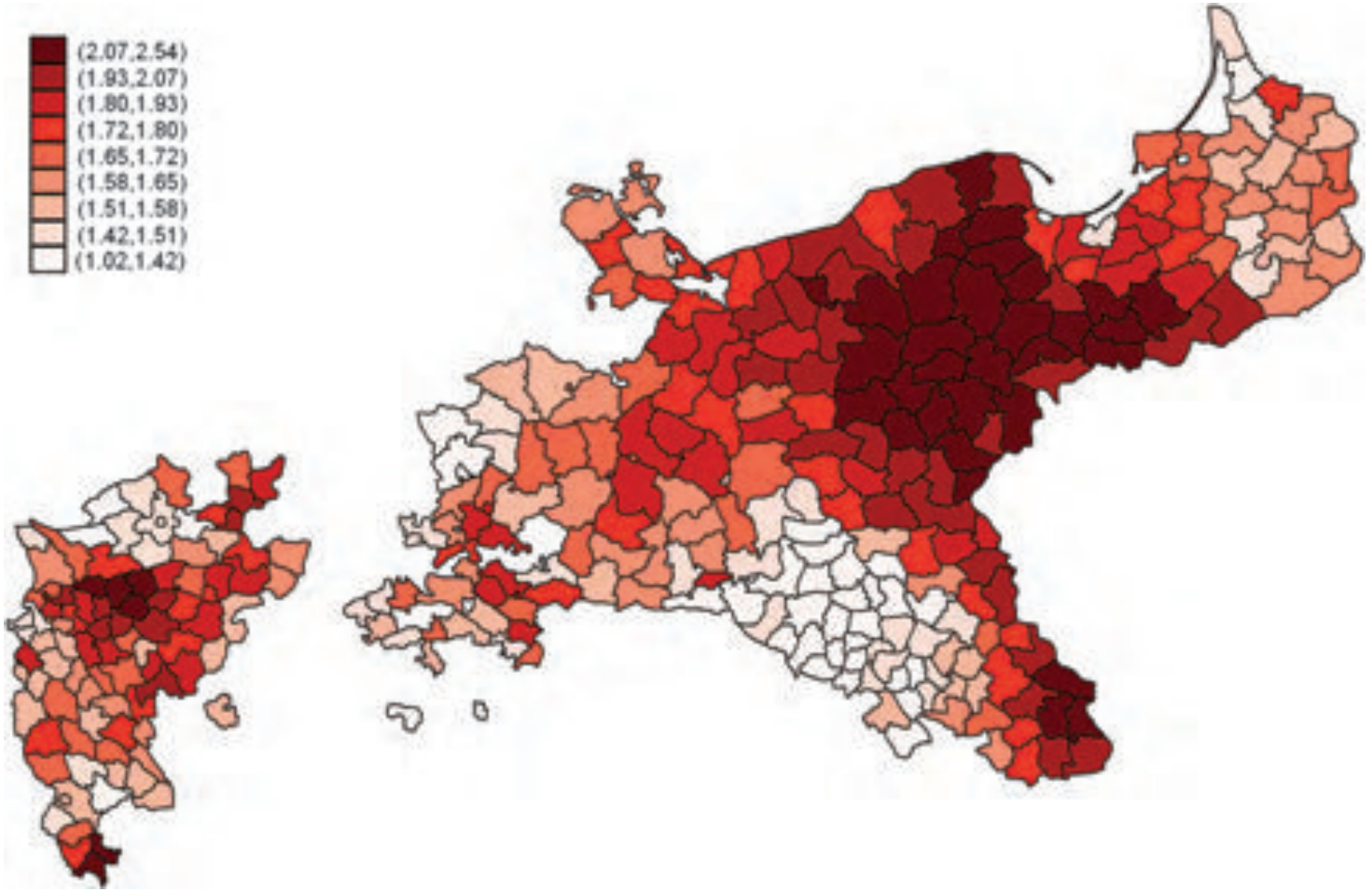


Figure 2. *The child–woman ratio in 1867.* Note: *Number of children 10–19 over women aged 40–69. Depiction in county borders of 1849.* Source: *Data for 334 counties from the Prussian Statistical Office; for details, see Supplementary material online, Appendix A.*

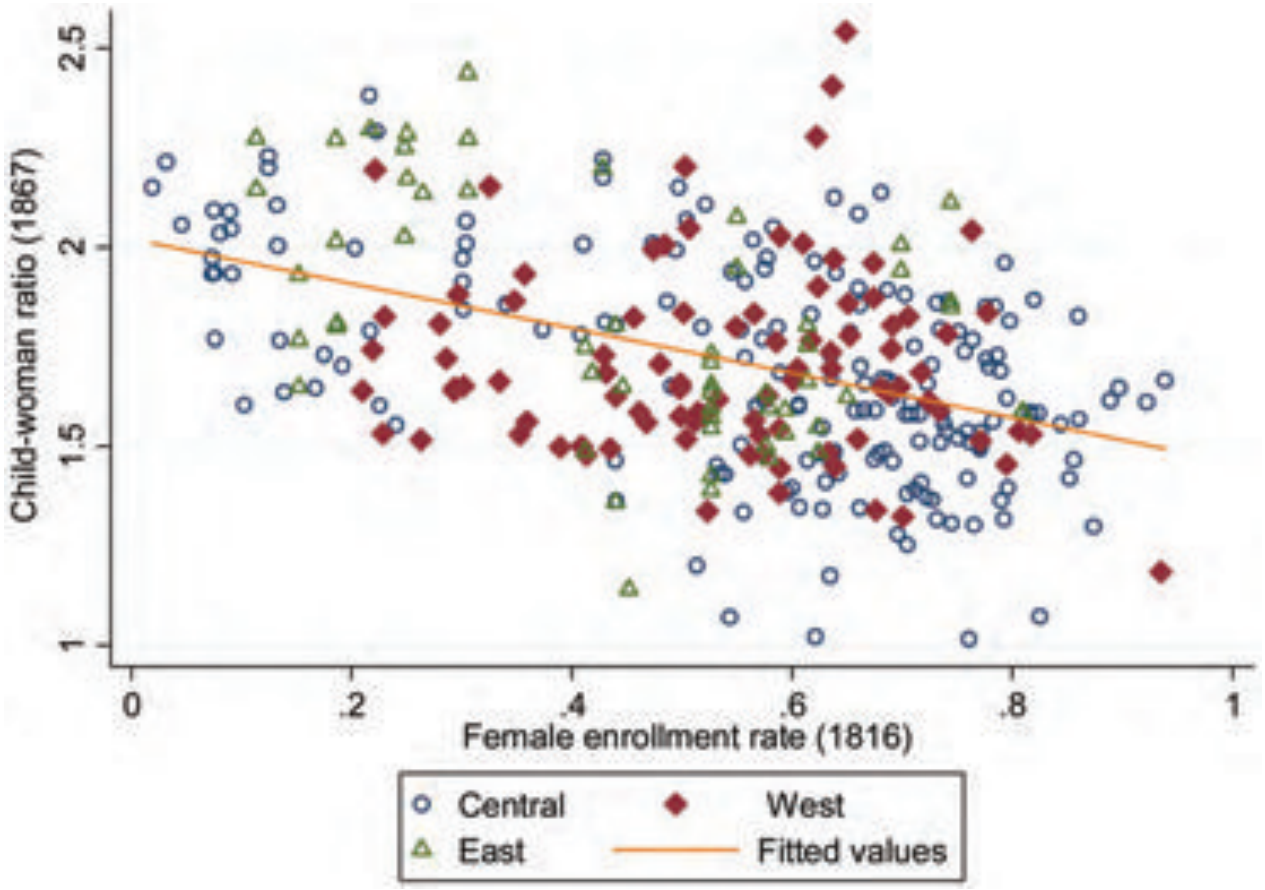


Figure 3. *The relationship between mothers' education and fertility.* Note: *The female enrollment rate is the ratio of girls enrolled in primary and middle schools over the number of girls aged 6–14. The child–woman ratio is defined as the number of children 10–19 over women aged 40–69.* Source: *Data for 334 counties from the Prussian Statistical Office; for details, see Supplementary material online, Appendix A.*

Table 1. *Summary statistics*

Variable	Mean	Std. Dev.	Min.	Max.
Child–woman ratio (1867)	1.714	0.268	1.016	2.540
Female enrollment rate (1816)	0.545	0.210	0.020	0.939
Employed in textile factories (1849)	0.149	0.209	0.013	1.747
Age at marriage (1849)	0.226	0.061	0.090	0.464
Enrollment rate (1864)	0.753	0.104	0.438	1.201
Child mortality (1849)	7.50	2.35	3.36	14.91
Maternal mortality ratio (1849)	0.829	0.345	0	2.050
Urban share (1849)	0.246	0.186	0	1
Share in industry (1849)	0.030	0.029	0.006	0.322
Share Protestants (1849)	0.605	0.394	0.002	0.999
Share married women (1849)	0.701	0.058	0.431	0.854
Population density (1849)	0.200	1.121	0.020	14.978
Share population born in county (1880)	0.781	0.099	0.421	0.948
Net international migration per 1000 inhabitants (1880)	−1.682	3.669	−32.219	2.374
Net international migration per 1000 inhabitants (1862)	−0.641	1.632	−13.322	1.669
Cattle per woman (1849)	0.676	0.208	0.006	1.454
Women in industry per capita (1867)	0.007	0.009	0	0.063
Landownership concentration (1816)	0.017	0.020	0	0.148
Child–woman ratio (1816)	0.894	0.156	0.505	2.292
Polish annexations	0.147	0.354	0	1
Railway density	0.004	0.009	0	0.080
Road density	0.098	0.073	0	0.454
Wholesalers per 1000 inhabitants	0.171	0.393	0	2.722

Note: The child–woman ratio is the number of children aged 10–19 over the number of women aged 40–69. The female enrollment 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; for details, see Supplementary material online, Appendix A.

Table 2. *Mothers' education and fertility—basic results*

Dep. var.: Child–woman ratio (1867)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Female enrollment rate (1816)	−0.561*** (0.057)	−0.620*** (0.062)	−0.597*** (0.061)	−0.539*** (0.058)	−0.342*** (0.067)	−0.348*** (0.068)	−0.344*** (0.069)
Employed in textile factories (1849)			−0.281*** (0.101)	−0.197*** (0.089)	−0.176*** (0.086)	−0.170*** (0.078)	−0.158*** (0.079)
Age at marriage (1849)				−1.832*** (0.207)	−1.687*** (0.220)	−1.638*** (0.216)	−1.610*** (0.214)
Enrollment rate (1864)					−0.730*** (0.152)	−0.858*** (0.180)	−0.797*** (0.179)
Child mortality rate (1849)						−1.496*** (0.589)	−1.726*** (0.606)
Maternal mortality ratio (1849)							0.077*** (0.041)
Urban share (1849)		−0.079 (0.085)	−0.025 (0.090)	0.056 (0.079)	0.131 (0.087)	0.182* (0.092)	0.200** (0.097)
Share in industry (1849)		0.642 (0.425)	1.145*** (0.393)	0.749* (0.383)	1.043*** (0.369)	0.925** (0.367)	0.961** (0.381)
Share Protestants (1849)		0.044 (0.035)	0.021 (0.036)	−0.087** (0.035)	−0.116*** (0.037)	−0.118*** (0.038)	−0.116*** (0.038)
Share married women (1849)		0.273 (0.324)	0.344 (0.323)	−0.111 (0.265)	0.296 (0.309)	0.359 (0.313)	0.362 (0.314)
Constant	2.020*** (0.035)	1.835*** (0.225)	1.800*** (0.225)	2.546*** (0.207)	2.658*** (0.226)	2.805*** (0.235)	2.694*** (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. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. See table 1 for definition of variables.
Source: Data for 334 counties from the Prussian Statistical Office; for details, see Supplementary material online, Appendix A.

Table 3. *Instrumental-variable results*

Dependent variable:	(1) Child–woman ratio (1867) (OLS)	(2) Female enrollment rate (1816) (first stage)	(3) Child–woman ratio (1867) (second stage)	(4) Child–woman ratio (1867) (OLS)	(5) Female enrollment rate (1816) (first stage)	(6) Child–woman ratio (1867) (second stage)	(7) Child–woman ratio (1867) (second stage)
Female enrollment rate (1816)	−0.344*** (0.069)		−0.859*** (0.374)	−0.325*** (0.082)		−0.850** (0.377)	−0.831** (0.374)
Landownership inequality (1816–49)		−2.594*** (0.554)			−2.583*** (0.561)		
Child–woman ratio (1816)				0.285 (0.272)	−0.108 (0.104)	0.225 (0.224)	0.172 (0.231)
Age at marriage (1849)	−1.610*** (0.214)	0.044 (0.171)	−1.565*** (0.220)	−1.394*** (0.228)	−0.038 (0.178)	−1.394*** (0.225)	−1.482*** (0.242)
Employed in textile factories (1849)	−0.158** (0.079)	−0.022 (0.036)	−0.154** (0.075)	−0.143* (0.079)	−0.028 (0.036)	−0.142* (0.074)	−0.148** (0.073)
Enrollment rate (1864)	−0.797*** (0.179)	0.902*** (0.110)	−0.286 (0.417)	−0.678*** (0.167)	0.851*** (0.116)	−0.186 (0.390)	−0.262 (0.385)
Crop yields per hectare, first principal component (1886)							0.017** (0.008)
Crop yields per hectare, second principal component (1886)							−0.014 (0.016)
Share of agricultural establishments using machines (1882)							−0.422 (0.379)
Constant	2.694*** (0.234)	0.266* (0.146)	2.788*** (0.243)	2.307*** (0.376)	0.411** (0.195)	2.483*** (0.362)	2.733*** (0.379)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	334	334	334	334	334	334	326
R^2	0.450	0.479	0.357	0.466	0.482	0.370	0.399
F-Statistic first stage			21.936			21.180	28.538

Note: OLS and two-stage least squares regressions. Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. See table 1 for definition of variables. See text for details on landownership concentration. Further 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; for details, see Supplementary material online, Appendix A.

Table 4. *Panel estimation results*

Dep. var.: Child–woman ratio	First phase (1816–1849)	Second phase (1849–1875)	Pooled	County fixed effects		
	(1)	(2)	(3)	(4)	(5)	(6)
Female enrollment rate of parental generation	−0.208*** (0.046)	−0.212*** (0.043)	−0.209*** (0.032)	−0.216*** (0.042)	−0.198*** (0.042)	−0.157*** (0.033)
Children's enrollment rate					0.189** (0.075)	0.190*** (0.059)
Lagged child–woman ratio						−0.479*** (0.033)
Time fixed effects			Yes	Yes	Yes	Yes
County fixed effects			No	Yes	Yes	Yes
Observations	334	334	668	668	668	668
Counties	334	334	334	334	334	334
R^2 (within)				0.953	0.953	0.972
R^2 (overall)	0.057	0.068	0.807	0.807	0.807	0.636

Note: Panel estimation with two time periods. Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. The first time period relates child–woman ratios in 1849 to female enrollment rates in 1816, the second time period relates child–woman ratios in 1875 to female enrollment rates in 1849. See text for details on data definitions.

Source: Data for 334 counties from the Prussian Statistical Office; for details, see Supplementary material online, Appendix A.

Quantification

- Back of the envelope calculation:
  - Relate results to the subsequent fertility transition in Prussia
- Using the panel dimension estimates in column (6):
  - Increase in the female enrollment rate by 10 percentage points decreases the child–woman ratio by roughly 0.016.
  - Population data for the period 1875–1910 show that the child–woman ratio declined by roughly 0.09.
  - Enrollment data suggest that roughly over the prior 30 years, average enrollment increased by 13.5 percentage points in Prussia (from 80.1 percent in 1849 to 93.6 percent in 1882).
  - Assuming that our estimated effect remained constant throughout the century, this simple pattern suggests that the increase in educational enrollment in the parental generation might account for a decline in the child–woman ratio of 0.022,
  - …or roughly one quarter of the actual total decline in the child–woman ratio during the fertility transition period 1875–1910