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Urban versus Rural: Fertility Decline in the Cities and Rural Districts of Prussia, 1875 to 1910

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'The new idea of the small family arose typically in the urban industrial society' (Notestein 1953)

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Abstract. Marital fertility in 54 Prussian cities and 407 Prussian *Kreise* (administrative areas) is analyzed using unusually rich and detailed socioeconomic and demographic data from eight quinquennial census between 1875 and 1910. Pooled cross-section time series methods are used to examine influences on marital fertility level and on marital fertility decline, focusing particularly on fertility differences according to level of urbanization. Increases in female labour force participation rate and income, the growth of financial services and communications, improvement in education, and reduction in infant mortality account for most of the marital fertility decline in 19th century Prussia. In 1875, rural and urban fertility were similar but by 1910, urban fertility was far lower than rural in part because the values of some of these variables changed more rapidly in the cities, and in part because some of these variables had stronger effects in urban settings.

Galloway, P., Lee, R. D. et Hammel, E. A., 1998. L'urbain opposé au rural: déclin de la fécondité dans les villes et les districts ruraux de Prusse de 1875 à 1910. Revue Européenne de Démographie **14**: 209–264.

Résumé. La fécondité des mariages de 54 villes prussiennes et de 407 "*Kreise*" (unités administratives) est analysée ici grâce à des données socio-économiques et démographiques, exceptionnellement riches et détaillées, fournies par huit recensements quinquennaux. Nous utilisons des méthodes agrégeant des séries chronologiques transversales, pour examiner les effets de ces variables sur l'intensité de la fécondité des mariages et sur son déclin, en s'attachant plus précisément aux différences de fécondité selon l'importance de l'urbanisation. L'accroissement de la participation féminine au marché du travail et celui du revenu, la croissance des services financiers et des communictions, les améliorations dans l'éducation et la réduction de la mortalité infantile expliquent la majeure partie du déclin de la fécondité en Prusse au XIX^{e} siècle. En 1875, les fécondités rurale et urbaine étaient similaires, mais à partir de 1910, la fécondité urbaine devient beaucoup plus faible que la fécondité rurale, en partie parce que certaines des variables citées changent plus rapidement dans les villes, et aussi parce que certaines de ces variables ont un plus fort effet en milieu urbain.

Key words: cities, Europe, fertility transition, Germany, historical demography, marital fertility, Prussia, urban, urban and rural areas

1. Introduction

It has generally been acknowledged that secular fertility decline in Europe either began in the cities or occurred at a greater pace in the cities than in the countryside (Notestein, 1953; Sharlin, 1986: 259; Lawton and Lee, 1989: 24; Perrenoud, 1990: 243). In this analysis, we will analyze fertility decline in the 54 largest cities of Prussia from 1875 to 1910 by applying pooled cross-section time series methods to a remarkably rich set of data. We will also examine differences in urban and rural fertility decline.

The Princeton European Fertility Project taught demographers a great deal about fertility transition, but also has been criticized for a lack of theory or, more usually, the inability to test existing theory adequately for a variety of reasons.[1] Some of these include overly large units of analysis, lack of useful socioeconomic measures, coarsely defined independent variables, insufficient sample size, and inadequate statistical methods. Because of these problems with most previous research, important elements of fertility transition theory have not been adequately tested for historical European regions, and certainly not for cities.

In the most comprehensive work to date on urban and rural differences in fertility decline Sharlin (1986: 259) found that urban populations were more likely to initiate family limitation. We find that between 1875 and 1910 marital fertility fell twice as fast in Prussian cities as in Prussia overall (Figure 1), and that the least urban *Kreise*[2] initiated the decline much later, on average. Furthermore, there were extraordinary differences in fertility level in Prussian cities, with I_g ranging from 0.545 to 0.927 in 1875, and 0.277 to 0.690 in 1910 (Appendix Table 1). Despite Sharlin's finding, relatively rapid urban fertility decline, and wide variation in fertility level found in cities, there has been surprisingly little research on urban fertility.[3]

For a number of important variables, the Prussians collected more detailed information for cities than for *Kreise*. As a consequence we are able to examine the role of manufacturing and the role of child labour in the analysis of fertility decline in cities, which was not possible in our work on *Kreise*. We can also examine in greater depth the role of female labour force participation in non-traditional occupations.

The city analysis is followed by an examination of the possibility that the process of fertility decline may have been different in urban and rural sectors. We will compare the results of our analysis of 54 cities with our study of 407 *Kreise*.[4] *Kreise* were on average only 30 percent urban. Using the *Kreis* data set, we will interact each of our independent variables with an urbanization variable to see if the regression estimates of the independent variables are affected by urbanization.

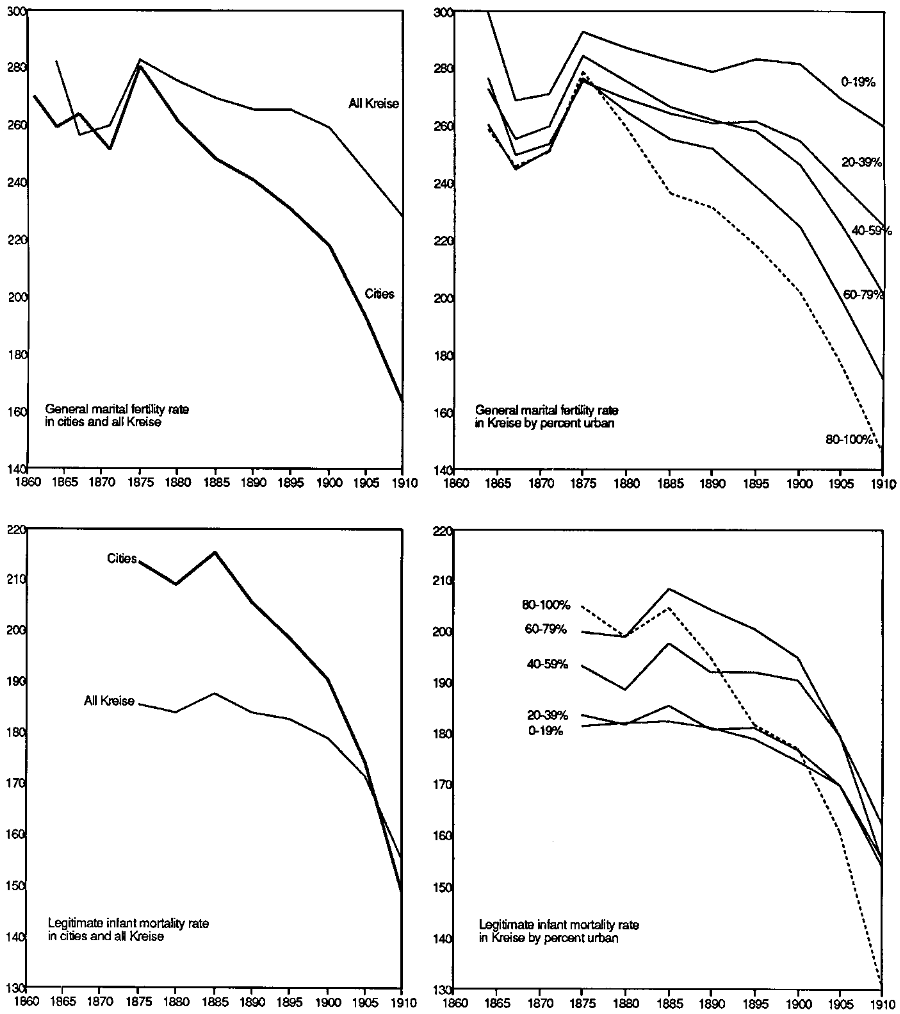

Figure 1. Average General Marital Fertility Rate (legitimite births × 1000/married female populations aged 15–49) and average legitimate infant mortality in cities, all Kreise, and Kreise by percent urban from 1875 to 1910. Percent ranges indicate average percent urban in Kreise from 1875 to 1910. Sources: Table 2 and Preussische Statistic (various volumes).

The Prussian data set is particularly suited to these kinds of analyses. The data set is superior to any previously available for studying the fertility decline in Europe in respect to quantity, refinement and consistency of definition, and availability over time of theoretically important variables. No other European data set provides as much demographic and socioeconomic detail for such a large number of people, some 40 million in 1910 or one-eighth of the population of Europe. Many of our variables are theoretically important to our understanding of fertility decline, yet they have been rarely, if ever, examined. These include female labour force participation rate, measures of income, banking and insurance services, development of post, telegraph, and railway systems, concentrations of church, health, education, mining and manufacturing workers, and legitimate infant mortality. The data set also includes religious and language variables.

We will analyze this data set using cross-section time series methods, an approach previously used in only two other studies of fertility decline in Europe: our associated analysis of 407 *Kreise* in Prussia (Galloway et al., 1994) and Richards' (1977) study of Germany using province level data.

We will begin with an overview of fertility transition theory, followed by a discussion of the variables used in our analysis within the context of fertility transition theory and the findings of previous research, explanation of the method, presentation of the results and implications for fertility policy in less-developed countries.

2. Overview of fertility transition theory

It will be convenient to follow Easterlin and Crimmins (1985) in distinguishing between influences on the demand for surviving children, the supply of surviving children, and the costs of regulation. First consider the supply of surviving children. This concept refers to biological and demographic influences on surviving children per family, influences that are not manipulated by couples to influence their fertility. Such influences may include breast-feeding practices, infant and child survival ratios, age at marriage, and spousal separation. Certainly any of these could consciously be used to alter the number of surviving children, but we believe that this was not typically the case.

Most theories of the demographic transition focus on the demand for children. Economic theory points to many influences of economic development on fertility (Becker, 1981; Willis, 1973). Rising incomes permit couples to afford more children, suggesting a positive income effect, other things equal. However, couples' demand for 'quality' of child rises strongly with income, making the price of children rise with income. Consequently the number desired may actually decline as income rises. New economic opportunities for women in the labour force compete with the demands of childrearing, and may therefore reduce the demand for surviving children as development proceeds. At the same time, if fertility declines for other reasons, women's time may be freed up for market work. The spread of compulsory education may undermine children's economic contributions to the household, raising the net price and reducing the demand for children.

Children also serve as both assets for old age support, and as insurance against risks in an uncertain world. Economic development reduces the need and the value of such child-services by providing more efficient market and public sector substitutes. For example, there was a rapid expansion of banking and insurance services during the period under consideration, and at the same time the welfare state was growing. Rapidly improving communications and transportation networks also reduced isolation and increased access to such services, which meant that parents did not have to rely for them on children. While we have couched these links in economic terms, similar ideas are expressed in classical transition theory (Notestein, 1953) and sociological analyses.

If the number of surviving children desired by a couple is less than the number they expect to achieve if they take no steps to prevent births, then they have a motive to act to reduce their fertility. If they do not know how to do this, or if they find available methods to be unacceptable for religious, social or personal reasons, then we say that the costs of regulation are high. In the Prussian context, where the main method of fertility limitation within marriage was *coitus interruptus* (Marcuse, 1917), monetary and travel time costs were unimportant, but generalized social and personal costs may have been central. For example, contraception was a serious sin for Catholics (Noonan, 1966: 421). Costs of regulation can fall as information spreads, as attitudes change, or as people observe other couples limiting their fertility. Varying costs of fertility regulation can independently influence fertility. Improving communications and transportation would hasten the diffusion of ideas, knowledge and attitudes, and thereby raise the probability of fertility regulation, other things being equal. Urban areas, with rapid communication, frequent contact, and relative anonymity, should have had lower regulation costs than rural areas.

We do not claim to be able to isolate empirically the role of the demand, supply and regulation cost variables; the categories are used only for organizational convenience.[5] Nor can we draw a clear distinction between the influence of structural and ideational factors in every case. Nonetheless, we will show that the weight of evidence strongly supports the view that structural socioeconomic change played an important role in the decline of fertility in Prussian cities.[6]

3. Time periods, units of analysis, and dependent variable

The population of Prussia in 1910 was some 40 million, exceeding that of every country in Europe except Russia (and, of course, Germany in which Prussia was the largest state). Prussia alone accounted for 12.5 percent of the population of all of Europe less Russia. Stretching from parts of modern-day Belgium to Russia, Prussia covered virtually the entire Northern European Plain, including the important grain producing districts of East Prussia and the greatest industrial region in Europe, the Ruhr. There were few countries which included such economically diverse regions. Many ethnic groups are found in Prussia, including Poles, Kassubians, Masurians, Danes, and Walloons. Only the Austro-Hungarian Empire exceeded Prussia in ethnic diversity. The period under consideration, 1875 to 1910, covers the period of transformation of a largely agrarian economy into the most powerful industrial state in Europe (Trebilcock, 1981: 41, 45).

The time periods used in the analysis are 1875, 1880, 1885, 1890, 1895, 1900, 1905, and 1910 which correspond to population census dates and to that period which has the richest and most detailed data. Data for census years 1867 and 1871 are not used because in those years there are few data concerning marital fertility, infant mortality data are nonexistent, and some of our independent variables concerning income, communications, banking, and insurance would have to be roughly estimated.

The unit of analysis in this study is the city, more specifically all 48 cities in Prussia in 1871 with a population exceeding 20,000, plus six more for which we could generate an 1875 age distribution, giving a total of 54 cities.[7] The 54 cities are well-distributed across Prussia except for one concentration of ten cities in the Ruhr, the industrial heart of Prussia (and Germany).

The cities are shown in Appendix Table 1 along with population for the years 1875 and 1910. There were dramatic differences in population growth, even allowing for increases in area. Between 1875 and 1910, Berlin increased its area by only seven percent, but more than doubled its population. The growth was even greater in Charlottenburg, a suburb of Berlin, where area increased by 12 percent, and population grew nearly twelvefold. In fact overall population in these 54 cities grew at a rate of 2.7 percent per annum, twice the 1.3 percent growth rate in Prussia overall. By 1910, 9.6 million persons lived in these 54 cities accounting for one-fourth of Prussia's entire population. Comparable figures for 1875 were 3.8 million, or only one-seventh of Prussia.

Our dependent variable is the general marital fertility rate (GMFR). GMFR is legitimate births multiplied by 1000 and divided by married females aged 15 to 49. A five year average of legitimate births centered around the census year is used. For example, to calculate GMFR for 1880, the average number of annual legitimate births from 1878 to 1882 is divided by the census number of married females aged 15 to 49. This result is then multiplied by 1000. We use GMFR as our dependent variable instead of I_g, in order to facilitate comparisons with our earlier analysis of areas covering all of Prussia.[8] Because GMFR already adjusts for proportions married, marriage patterns will not be used in our analysis.

Appendix Table 1 shows a wide range in I_g, varying from a high of 0.927 to a low of 0.277 over the entire 35 year period. In fact there was as much variability in I_g within these 54 Prussian cities as in all of Europe. The coefficient of variation of I_g in the 54 Prussian cities in 1910 was 0.22, exactly the same as the coefficient of variation of I_g in the 489 provinces of Europe in 1900 (Coale and Treadway, 1986: 44). The I_g's exceeding 0.900 are among the highest ever recorded.

The average GMFR in the 54 cities of Prussia compared to the average GMFR in all the *Kreise* of Prussia is shown in Figure 1.[9] Fertility rates are similar up to 1875. Calculations of GMFR for all of Prussia back to 1816 suggest little trend between 1816 and 1875 (Galloway et al., 1994: 141). Unfortunately we cannot calculate urban fertility before 1861, but we suspect it is similar to Prussia overall based on the 1861 to 1875 data. The upward bulge in fertility in 1875 may be compensation for a significant decline in fertility in 1871 because of the 1870–1871 Franco-Prussian War. The upsurge is probably associated with marriages of war veterans, remarriages of war widows, and perhaps a general euphoria following the Prussian victory.

After 1875 the picture changes considerably with urban fertility declining more than twice as rapidly as average fertility in Prussia overall. Average GMFR in the cities drops from 281 in 1875 to 164 in 1910 (see Appendix Table 1), or by 42 percent, while average GMFR in Prussia overall declined from 282 in 1875 to 228 in 1910, or some 19 percent (Galloway et al., 1994: 143).

Figure 1 also shows GMFR in *Kreise* by percent urban. There is clear divergence over time, with the most rural *Kreise* showing little fertility decline, and the more urban *Kreise* the fastest fertility decline. Generally the rate of fertility decline increases according to level of urbanization.[10]

The bottom panels of Figure 1 show infant mortality decline in the cities, in the 407 *Kreise*, and in *Kreise* by level of urbanization. Note that as *Kreis* fertility diverges over time, infant mortality tends to converge over time, especially in the urban groups 0–19%, 20–39%, 40–59%, and 60–79%. Infant mortality in urban group 80–100% is slightly higher than all the other groups in 1875, but by 1910 is very much lower.[11]

4. Independent variables

The availability of registration, population, occupation, and education census data for the variables used in our analysis is shown in Table 1.[12] The notes to Table 1 indicate those situations in which interpolation was necessary.[13] A detailed listing of the independent variables follows along with theoretical expectations and findings of relevant previous research. Means for the cities and *Kreise* variables may be found in Table 2.

4.1. CATHOLIC (CATHOLIC POPULATION $*$ 100/TOTAL POPULATION)

Some 35 percent of the Prussian population in 1900 were Catholics, the rest primarily Protestants. The Catholics were concentrated in the southwest in the Rheinland and Westfalen and in the east in Posen and Schlesien. Many of the Catholics in the east were Slavic-speaking.

Religion is often used in fertility analyses and is often an important predictor of fertility level, but it is difficult to interpret (Lutz, 1987). The Catholic church has generally been opposed to most contraceptive practices (Noonan, 1966: 421 and 476). In a study of 300 married couples in Germany in 1915, Marcuse (1917) found that 71 percent of the non-Catholic couples contracepted, while only 29 percent of the Catholic couples used contraception. We expect the proportion Catholic to be positively correlated with fertility level.

Table 1. Definitions and sources of variables used in the analysis

		1867	1871	1875	1880	1882	1885	1890	1895	1900	1905	1907	1910
GMFR	General marital fertility rate (legit. births * 1000/married females 15–49)	P,R	P,R	P,R	P,R		P,R	P,R	P,R	P,R		P,R	P,R
CATHOLIC	Catholic population * 100/ total population	P	P		P		P	P	P	P	P		P
SLAV	Slavic speaking population * 100/ total population	P						P		P			
CHURCH	Religious employees * 100/ population over age 20	O				O			O			O	
EDUCATION	Teaching employees * 100/ population aged 6–13	O				O			O			O	
HEALTH	Health employees * 100/ total population	O				O			O			O	
FLFPR	Female labour force part. rate = employed females * 100/ female population aged 20–69. (excludes agriculture and service)	O				O						O	

Table 1. Continued

		1867	1871	1875	1880	1882	1885	1890	1895	1900	1905	1907	1910
INCOME	Average real income of male elementary school teachers (in 1900 Marks)	*	*	*	*		E	E	E	E	E		E
MINING	Mining employees * 100/ all employed persons	O				O			O			O	
MANU-FACTURING	Manufacturing employees * 100/ all employed persons	O				O			O			O	
URBAN	Urban population * 100/ total population			P	P		P	P	P	P	P		P
BANK	Banking employees * 100/ population over age 20	**				O			O			O	
INSURANCE	Insurance employees * 100/ population over age 20	**				O			O			O	
COMMUNI-CATIONS	Post, telegraph, and railway employees * 100/ population over age 20	***				O			O			O	

Table 1. Continued

		1867	1871	1875	1880	1882	1885	1890	1895	1900	1905	1907	1910
POPULATION	Population (in thousands)	P	P	P	P	P	P	P	P	P	P		P
INFANT MORTALITY	Legitimate infant mortality rate (legit. deaths < 1*1000/legit. births)			R	R		R	R	R	R	R		R
MARRIED SEX RATIO	Married males/married females		P		P		P	P	P	P	P		P

E = Education census data. O = Occupation census data. P = Population census data. R = Registration data.
*Estimated based on change in Province level income.
**Estimated based on change in persons employed in trade per population over age 20.
***Estimated based on change in persons employed in post, telegraph, railway, and other land transport per population over age 20.
Bold type indicates years used in the analysis. Gaps are filled by interpolation, except for some data for 1910 which are extrapolated from 1907. SLAV for 1905 and 1910 is set equal to SLAV in 1900. Stillbirths are excluded throughout. MANUFACTURING and POPULATION are used only in the analysis of cities. URBAN is used only in the analysis of Kreise. In the analysis of Kreise, MINING is calculated slightly differently, using population over age 20 as the denominator.
Sources: Population, occupation, and education censuses and registration data from Preussische Statistik (various volumes) and Statistik des Deutschen Reichs (various volumes).

Table 2. Summary statistics of variables used in the analysis of the 54 cities and 407 Kreise of Prussia

	Mean									Standard deviation
	1875	1880	1885	1890	1895	1900	1905	1910	1875–1910	1875–1910
GMFR										
Cities	280.572	261.355	248.347	241.270	231.193	218.012	193.320	163.638	229.713	51.167
Kreise	282.439	275.221	269.304	265.714	265.561	259.524	243.600	227.968	261.166	44.625
CATHOLIC										
Cities	28.785	28.840	28.865	29.397	29.531	29.618	29.948	30.031	29.377	28.763
Kreise	34.058	34.193	34.351	34.606	34.739	35.000	35.346	35.531	34.728	36.957
SLAV										
Cities	2.026	2.226	2.425	2.625	2.613	2.601	2.601	2.601	2.465	8.878
Kreise	9.003	9.018	9.034	9.049	9.027	9.004	9.004	9.004	9.018	21.498
CHURCH										
Cities	0.207	0.188	0.184	0.187	0.191	0.222	0.254	0.285	0.215	0.225
Kreise	0.221	0.210	0.204	0.202	0.200	0.217	0.234	0.251	0.217	0.151
EDUCATION										
Cities	3.558	3.622	3.778	4.005	4.232	4.255	4.277	4.300	4.003	1.441
Kreise	1.747	1.801	1.912	2.062	2.212	2.279	2.347	2.414	2.097	0.707
HEALTH										
Cities	0.335	0.349	0.363	0.380	0.396	0.450	0.503	0.557	0.417	0.239
Kreise	0.136	0.132	0.143	0.165	0.186	0.219	0.253	0.286	0.190	0.132

Table 2. Continued

	Mean									Standard deviation
	1875	1880	1885	1890	1895	1900	1905	1910	1875–1910	1875–1910
FLFPR										
Cities	14.826	18.734	20.664	21.955	23.247	24.538	25.829	27.121	22.114	6.956
Kreise	6.524	8.105	9.249	10.101	10.954	11.877	12.800	13.723	10.417	6.598
INCOME										
Cities	1343.8	1432.9	1518.7	1453.1	1687.8	1881.5	1901.7	1912.0	1641.4	387.0
Kreise	937.2	1001.0	1063.3	1037.5	1133.3	1275.3	1245.3	1246.3	1117.4	248.6
MINING										
Cities	2.494	2.779	2.820	2.697	2.574	2.627	2.681	2.738	2.676	7.702
Kreise	1.503	1.648	1.694	1.674	1.655	1.852	2.049	2.246	1.790	4.913
MANUFACTURING										
Cities	43.219	45.284	47.634	50.173	52.711	53.427	54.143	54.859	50.181	11.797
URBAN										
Kreise	27.055	27.954	28.699	29.250	30.103	31.216	32.289	33.148	29.964	18.962
BANK										
Cities	0.168	0.182	0.193	0.205	0.217	0.273	0.329	0.386	0.244	0.196
Kreise	0.027	0.030	0.034	0.039	0.043	0.063	0.083	0.102	0.053	0.091

Table 2. Continued

	Mean									Standard deviation
	1875	1880	1885	1890	1895	1900	1905	1910	1875–1910	1875–1910
INSURANCE										
Cities	0.128	0.142	0.159	0.179	0.200	0.268	0.335	0.403	0.227	0.213
Kreise	0.016	0.018	0.022	0.027	0.032	0.047	0.063	0.078	0.038	0.078
COMMUNICATIONS										
Cities	1.714	1.802	1.874	1.956	2.038	2.341	2.644	2.948	2.165	0.982
Kreise	0.670	0.722	0.816	0.938	1.060	1.312	1.565	1.817	1.113	0.729
POPULATION										
Cities	69.938	79.552	90.001	106.691	119.599	139.323	159.781	178.590	117.934	223.579
INFANT MORTALITY										
Cities	213.485	209.041	215.089	205.428	198.771	190.500	174.292	148.881	194.436	46.019
Kreise	185.480	183.955	187.736	183.873	182.810	178.819	171.476	154.949	178.637	47.856
MARRIED SEX RATIO										
Cities	1.012	1.005	1.005	1.007	1.005	1.009	1.005	1.000	1.006	0.021
Kreise	0.987	0.989	0.991	0.990	0.993	0.991	0.992	0.994	0.991	0.029

Notes: MANUFACTURING and POPULATION are used only in the analysis of cities.
MINING is defined slightly differently in the cities and Kreise (Table 1). Of course each city is 100 percent URBAN.
Source: Table 1.

4.2. SLAV (SLAVIC MOTHER TONGUE POPULATION $*$ 100/TOTAL POPULATION)

There were a large number of ethnic Poles and other Slavic speaking persons in 19th century Prussia, located primarily in the east in Posen, Schlesien, and Ostpreussen. Regions with high concentrations of Poles were associated with relatively high fertility in Germany (Knodel, 1974), but this was based on a bivariate analysis. Language has generally been found to be an important indicator of fertility level (Leasure, 1962; Lesthaege, 1977; Watkins, 1991), although Hammel (1992) found that dialect differences were unimportant in an analysis of Croatian fertility. Based on most earlier research, we expect the proportion Slavic-speaking to be associated with high levels of fertility.

4.3. CHURCH (RELIGIOUS EMPLOYEES $*$ 100/POPULATION OVER AGE 20)

This category includes those whose primary occupation is involved with church activities. We expect that, in general, church-workers' views of fertility behaviour were traditional, and that Catholic church-workers were actively opposed to contraceptive use. As a consequence concentrations of church-workers would be associated with elevated levels of fertility. This variable has never been used in the analysis of European historical fertility decline.

4.4. EDUCATION (TEACHERS $*$ 100/POPULATION AGED 6–13)

Literacy data by city are available in Prussia only for the year 1871. However, compulsory education began in the 18th century and was enforced over time with progressively greater strictness (Cipolla, 1969: 84). School attendance was nearly universal in most *Kreise* during the period under consideration. By 1875 illiteracy had virtually disappeared except among Polish peasants in the eastern regions. By 1880 only 2 percent of Prussia's army recruits were illiterate compared to 39 percent in Austria-Hungary, 17 percent in France, 49 percent in Italy, and 7 percent in Switzerland (Cipolla, 1969: 118).

Because literacy was almost universal in Prussia and because literacy data are not generally available over time, we use a variable that measures educational quality. Our variable includes teachers in elementary, high, teachers', technical, and private schools, along with administrative and service personnel. The variable may be interpreted in two ways. It may reflect the education of the parents and as such represent exposure to new ideas, a kind of proxy for diffusion or modernization, or represent opportunity costs of parental time. On the other hand, it may indicate a diminished demand for child labour. In either case we would expect education to be inversely correlated with fertility. Indeed, school attendance rate or literacy have been commonly used in previous research and are almost universally negatively correlated with fertility. Proportion literate was negatively correlated with fertility in the urban districts of Russian provinces in 1897 (Coale, Anderson and Härm, 1979: 65), as well as in urban districts in England in 1891 (Woods, 1987: 303) and 1911 (Crafts, 1984: 94).

4.5. HEALTH (HEALTH EMPLOYEES ∗ 100/TOTAL POPULATION)

This category includes doctors, nurses, midwives, veterinarians and associated administrative and service personnel. It is likely that health-workers transmitted information about fertility behaviour and contraceptive technology. Woycke (1988: 51) found that 'medical personnel were another important source of contraceptive information and equipment'. We would expect this variable to be negatively correlated with fertility.

4.6. FLFPR (FEMALE LABOUR FORCE PARTICIPATION RATE IN NON-TRADITIONAL OCCUPATIONS)

This is the number of employed women (excluding those employed in agriculture, domestic service and government service)[14] divided by the number of all women aged 20–69. As opportunities for women to enter the commercial and industrial sectors increase, the opportunity costs of child-rearing increase, and fertility rates should decline. This is a common variable used in contemporary studies of fertility decline, though rarely in historical studies, and is found to be almost always negatively correlated with fertility. Crafts (1984: 94) found that the unmarried female labour force participation rate was significantly negatively correlated with fertility in urban districts of England in 1911.

It might be argued that because married women began to have fewer children, they were more readily absorbed into the non-traditional workforce, thus reversing the direction of causality suggested in our hypothesis. We will show that this reverse causality is unlikely. FLFPR can be calculated for all cities and for all *Kreise* from the occupation censuses. Recall that our measure, FLFPR, includes both married and unmarried women. For some cities, data are available which enable us to calculate married-FLFPR and unmarried-FLFPR separately for the occupation census years 1882, 1895, and 1907. Increases in the relative costs of children can be proxied by increases in the unmarried-FLFPR. This measure is preferred to the married-FLFPR because of the problem of simultaneity discussed above (see also Crafts, 1984: 91–92). We find that FLFPR is highly correlated with unmarried-FLFPR ($r = 0.87$, 0.83, and 0.67 for the periods 1882, 1895, and 1907). FLFPR strongly reflects the demand for unmarried female labour, especially in the early periods. Corresponding correlations for married-FLFPR are generally weaker ($r = 0.65$, 0.52, and 0.73). Also note that married-FLFPR is very low, ranging from 3.75 percent in 1882 to only 6.46 percent in 1907.[15]

We believe that increasing FLFPR may have inhibited marital fertility in the following ways: (1) Increasing percentages of married women actually joined the labour force, but the overall numbers are very small. Women working outside the home generally have lower fertility. (2) The husband and wife perceive the increased possibility of the wife's employment, thereby increasing perceived costs of children. (3) A dramatic increase in female child labour force participation rate (employed unmarried females 10–19 divided by all females 10–19) from 15.6 in 1882 to 24.0 in 1907 may have resulted in changes in tastes for children among younger women, who later went on to marry (Preussische Statistik, vols. 66, 76, and 206; Statistik des Deutschens Reichs, vol. 207). However, this increase in female child labour force participation rate would tend to decrease child costs, a countervailing effect.

4.7. INCOME (MALE ELEMENTARY SCHOOL TEACHERS' AVERAGE ANNUAL REAL INCOME)

As explained earlier, income is hypothesized to be an important factor in determining demand for children. According to Becker (1981), as income increases, quantity of children should increase, *ceteris paribus*. However, the increase in quantity may be offset by a demand for higher quality. There may also be an increase in costs resulting from an increase in the value of female time. In fact, most contemporary studies of fertility decline in less developed countries find that income and fertility are, in general, negatively correlated (Mueller and Short, 1983). Direct income measures have only occasionally been used in the analysis of European fertility decline.

We use male elementary school teacher's real salary as a proxy for overall income because it is a well-defined occupation, it facilitates cross-sectional comparison, and it is the only income measure available for each city for each period from 1885 to 1910. The funding for teacher's income came almost entirely from local taxes (Schleunes, 1989).[16]

Most studies of income proxies and fertility find the expected negative correlation (Knodel, 1974; Lindert, 1978; van de Walle, 1978; Teitelbaum, 1984; Watkins, 1991). Looking at strictly urban analyses, Bertillon (1899: 169–171) and Mombert (1907: 149–159) found that fertility level around 1900 was negatively correlated with average rent in districts in the cities of Berlin, Hamburg, Leipzig, Munich, Dresden, and Magdeburg. However, these studies were based on a simple bivariate analysis. In the only other historical study of urban fertility using an income proxy, property taxation per capita, available for only 1911, was negatively correlated with urban fertility in England (Crafts, 1984: 94).

4.8. MINING (MINING EMPLOYEES ∗ 100/ALL EMPLOYED PERSONS)[17]

Previous research has found a consistent positive correlation between fertility and percent of the labour force employed in mining (Wrigley, 1962; Haines, 1979; Laux, 1983; Crafts, 1984; Woods, 1987; Friedlander et al., 1991). Haines attributed this to 'early peaking income-earnings profile over the life cycle, low levels of female labour-force participation outside the home, and lower child costs' (1979: 57). This was supported by his multivariate analysis of twenty-six Prussian *Kreise* dominated by mining (1979: 76–82).

We suggest another hypothesis: elevated fertility in mining towns may be caused by a relatively high demand for child labour, because children are more likely to be employed in mining towns than in other towns and thus make a greater contribution to the family budget. Concerning Ruhr employers, 'it was common practice, especially where a single firm dominated a community, to attempt to hire all boys of the immediate areas as soon as they came of working age' (Spencer, 1984: 41). In the four mining towns in our study, Dortmund, Bochum, Duisburg, and Essen 12.4, 13.0, 12.9, and 10.9 percent respectively of all employed persons in mining were males under the age of 20 in 1882 while, on average, 11.6 percent of all employed persons in all cities were males under age 20 (Preussische Statistik: vol. 76 part 2, 232–686). This suggests a somewhat greater demand for male child labour in the mining towns.[18]

We are able to calculate two measures of relative demand for child labour from the occupational censuses of 1882 and 1907 (Preussische Statistik: vols. 66, 76, and 206; Statistik des Deutschens Reichs: vol. 207): employed unmarried persons under age 20 as a percent of all employed persons by sex, and child labour force participation rate (number of employed unmarried persons 10–19 divided by all persons 10–19).[19] We regress each of these two measures on MINING. There is no significant correlation. However, because almost all employed children in mining were boys, it is more appropriate to restrict our measures of demand for children to male children only. In this case we find the expected significant and positive correlation between our measures of demand for male child labour and MINING in both 1882 and 1907.

We suggest that the consistently high fertility levels found in mining towns are associated with relatively high levels of demand for male child employment. Of course, this demand for male child employment is not restricted to mining and almost certainly includes other occupations related to mining.

4.9. MANUFACTURING (MANUFACTURING EMPLOYEES $*$ 100/ALL EMPLOYED PERSONS)

This variable includes manufacturing, textile, chemical, construction, and other industrial workers. It excludes mining workers. In an analysis of seven types of cities by fertility level in Prussia, Laux (1983: 31–32) found that mining and manufacturing cities had higher fertility in 1880 than other city types, but by 1905, the other year he examines, only the fertility of mining cities was significantly different from the other six. He attributes the 1880 results as 'giving support to the hypothesis of a distinct proletarian type of reproductive behaviour' (Laux, 1983: 31), but does not elabourate further.

One component of this type of reproductive behaviour might be demand for child labour, as with MINING. In 1882, employed unmarried persons under age 20 accounted for, on average, 20.3 percent of all persons employed in manufacturing, compared to 14.2 in trade, and 6.8 in service (Preussische Statistik: vol. 76 part 2, 232–686). We regress each of our two measures of overall demand for child labour on MANUFACTURING. MANUFACTURING and both measures of demand for child labour are significantly positively correlated in both 1882 and 1907. Regressions by sex indicate that this relationship is a result of the demand for young female labour. In the 38 cities in 1882 an average of 81 percent of the unmarried females under age 20 employed in manufacturing were employed in textile and clothing occupations (Preussische Statistik: vol. 76 part 2, 232–686). In 26 cities in 1907 this figure stood at 71 percent (Statistik des Deutschen Reichs: vol. 207, 357–511). Therefore the positive correlation between MANUFACTURING and demand for child labour is likely driven by the demand for young female employment in the manufacture of textiles and clothing.[20] If fertility is related to expected returns from child labour, then fertility will be higher in towns dominated by manufacturing. We expect MANUFACTURING, like MINING, to be positively correlated with fertility.

The omitted category, 100-MINING-MANUFACTURING, is best described as the tertiary sector, agriculture being negligible. If the estimated coefficient of the sum of both MINING and MANUFACTURING is found to be significantly positive, then the coefficient of the tertiary sector, the omitted category, must be significantly negative.[21]

4.10. BANK (BANKING EMPLOYEES $*$ 100/POPULATION AGED 20 AND OVER)

This is a general measure of the importance of banking services to the population, and may serve as a useful indicator of wealth or the spread of financial services. To the extent that the variable measures wealth, it would be associated with fertility in a manner similar to income as discussed above. To the extent that parents consider children as a form of investment, with some expectation of return, the variable would function as an investment alternative, perhaps yielding a higher and less risky return. In either case it should be negatively correlated with fertility.

Knodel (1974: 235–236) found a strong negative bivariate correlation between an index of savings accounts and marital fertility in 34 large districts of Prussia in 1900, but the relationship fell to insignificance in a multivariate model. Steckel (1992: 364) found that the number of banks per capita was significantly negatively correlated with marital fertility in a multivariate analysis of 638 rural families in the United States 1850–1860. Hammer (1986) found the expected negative correlation between fertility and savings in less developed countries.

4.11. INSURANCE (INSURANCE EMPLOYEES * 100/POPULATION AGED 20 AND OVER)

Contemporary studies of fertility decline in less developed countries often find that parents perceive children as functioning as a kind of social security, especially in old age, as well as a way of maintaining income when ill. The development of an effective insurance service would tend to replace this role, leading in turn to a decrease in the demand for children. The German Empire, of which Prussia was part, enacted legislation in the 1880s to initiate programmes for government-backed universal sickness and accident insurance along with an invalidity, old age and survivor pension system (Dawson, 1912; Ritter, 1986). The success of the enforcement of these programmes in the various regions of Prussia is difficult to assess. Social legislation continued throughout the period, and it was not until 1911 that the insurance law was fully implemented (Clapham, 1961: 337). The administration of these programmes was undertaken primarily by government agencies and by employer-formed mutual associations under the authority of the Imperial Insurance Office (Dawson, 1912: 72–74,106–109,130–132,173–181, 278). In his analysis of the growth of occupation groups in Germany from 1882 to 1907 Clapham (1961: 365) found that within the trade and transport group, the number of persons employed in insurance grew fastest, reflecting its growing importance. Our insurance variable includes employers and employees working in life, home, accident, fire, crop, livestock and transport insurance. It excludes government employees. An insurance variable has never been used in previous research on European fertility decline.

4.12. COMMUNICATIONS (POST, TELEGRAPH AND RAILWAY EMPLOYEES * 100/POPULATION AGED 20 AND OVER)

This variable is a useful proxy for the development of communication and transportation systems, which in turn may facilitate the diffusion of new ideas, including contraception, and integration into the national and international market economies. We expect this variable to have a negative correlation with fertility.

4.13. POPULATION (CITY POPULATION IN THOUSANDS)

We suspect that the larger the population of a city the greater the likelihood for the innovation and spread of ‘modern’ ideas, such as fertility control. Carlsson suggests that diffusion of contraceptive knowledge, if it occurred at all, probably began in the metropolitan centres (1966: 150). As a consequence we expect city population size to be negatively correlated with fertility. Earlier studies of urban fertility find the expected negative correlation in the urban sectors of Russian provinces (Coale, Anderson and Härm, 1979: 65) and in Spanish cities (Reher and Iriso-Napal, 1989: 420), although the coefficients in Spanish cities were not significant.

4.14. INFANT MORTALITY (LEGITIMATE INFANT MORTALITY RATE)

INFANT MORTALITY is defined as the number of deaths under age one of legitimate born children times 1000 divided by number of legitimate births. Five year averages centred around census years are used. As infant mortality declined, the number of births needed to reach a desired or expected family size would decrease, assuming the couple had some notion of desired or expected family size. Therefore we expect that a decrease in infant mortality should cause a decrease in fertility.

Some authors suggest that a measure of child mortality, such as ${}_4q_0$ or ${}_5q_0$, might be more appropriate than infant mortality. Unfortunately such detailed mortality measures are unavailable at the *Kreis* level and are unavailable for most cities. Among the 36 provinces (Regierungsbezirke) of Prussia, where such data are available for 1890–91, we find that the correlation r between ${}_1q_0$ and ${}_5q_0$ is 0.96, and in the 15 largest cities, this correlation is 0.98 (Galloway et al., 1998: 186–187). This suggests the ${}_1q_0$ and ${}_5q_0$ are virtually interchangeable for the purposes of our analysis.

Most previous research analyzing historical fertility levels suggests that infant mortality is generally positively correlated with fertility. In the urban sectors of Russian provinces in 1897 Coale, Anderson and Härm (1979: 65) found only a weak negative correlation with fertility. Reher and Iriso-Napal (1989: 420) found that child mortality was negatively correlated with fertility in urban Spain in 1900 as does Woods (1987: 303) in urban England in 1891. However, Woods (1987: 303) finds the expected positive correlation with fertility, as does Crafts (1984: 94), in urban districts of England in 1911. See Galloway et al. (1988).

Fertility variations can also affect infant mortality. Using two stage least squares techniques, Galloway et al. (1998: 202) find that changes in fertility are significantly positively correlated with changes in infant mortality and that changes in infant mortality are significantly positively correlated with changes in fertility in *Kreise* and cities of Prussia from between 1870 and 1910.

Because we are concerned with marital fertility, it makes more sense to use the legitimate infant mortality rate, especially in urban areas where the confounding influences of high illegitimacy and high illegitimate infant mortality might tend to blur the actual infant mortality effect. The legitimate infant mortality rate has never been used in European fertility transition research.

4.15. MARRIED SEX RATIO (MARRIED MALES PER 100 MARRIED FEMALES)

The ratio of married males to married females is included as a control variable to measure spousal separation. We believe the variable is useful for controlling the effects of temporary migration, and resulting reductions in coital frequency. This variable should be positively correlated with fertility.

5. Urban and rural differences

Sharlin suggests that 'for whatever reason urban places are more receptive to initiating family limitation' (1986: 259). These reasons may include better access to information concerning contraception, differences in perceived value of children, and a greater receptivity to newer ideas in urban areas when compared to rural areas. Indeed, urban areas in Prussia exhibited different fertility patterns than rural areas. While fertility was initially fairly similar across different degrees of urbanization in 1875, it declined much more rapidly in more urbanized areas than in rural areas, as is shown dramatically in Figure 1.

There are a number of reasons why fertility patterns and changes might be different in urban areas. First, there may be something special about highly urbanized areas which is conducive to lower fertility, other things equal. In this case, the other variables will all continue to operate in the same way in urban areas, but in addition, urban areas have lower fertility than would have been predicted. We will call this the 'Low Urban Fertility Hypothesis'.

Second, variables influencing fertility such as education or income may have different values in urban areas. Such variables may also change more rapidly in urban areas during periods of generally rapid social and economic change. These explanations represent a kind of null hypothesis, since in them cities *per se* have no particular effect on fertility. Urban fertility could then be completely explained by the same model which explained rural fertility, so the analysis need not even distinguish between urban and rural areas. We will call this the 'Structurally Similar Hypothesis'. Under this hypothesis, cities are special, but only in that the variables take on special values or trends in them. Third, something about the urban context may enhance a variable's influence on fertility. We will call this the 'Enhanced Effects Hypothesis'. Fourth, it is possible that some variables, like income, might actually have opposite effects in the cities compared to rural areas. We call this the 'Structurally Different Hypothesis'.

Using the *Kreis* data set, we will estimate an empirical fertility model with linearly specified explanatory variables, including degree of urbanization.[22] Under the 'Low Urban Fertility Hypothesis', the urbanization variable, URBAN, will have a significant negative coefficient. To test the other three hypotheses we will also include in the model interactions of all variables (except URBAN) with URBAN. Then under the 'Structurally Similar Hypothesis', the coefficients on the interactions are statistically insignificant. Under the 'Enhanced Effects Hypothesis', at least some coefficients on urban interactions lead to significantly stronger effects in urban than in rural areas. Under the 'Structurally Different Hypothesis', the estimated interactions are sufficiently strong for the total effect of a given variable in the urban sector to have the opposite sign of that effect in the rural sector, and both are statistically significant.

There has been little empirical study of differences in the effects of urban and rural settings on variables. Mueller and Short (1983: 611–615) found that income and wealth were sometimes positively associated with fertility in rural areas of less developed countries, while they were negatively associated with fertility in urban areas. This finding would support the ‘Structurally Different Hypothesis’. We might expect that the regression estimates for some of our variables may reflect saturation effects in the cities, an example of the ‘Enhanced Effects Hypothesis’. For example, because there was already a high concentration of banks in the cities, an increase in banking employees may not have as great an impact on decreasing fertility in the cities as the same increase in banking employees might in the countryside. The same may hold for our insurance, communications, teaching and church-worker variables.

6. Method

We analyze our data using pooled cross-section time series methods. Most prior research on historical fertility decline analyzed only a few periods, used only simple OLS, and usually estimated only the effects of the levels of the independent variables on the level of fertility. In only two other studies of fertility decline in Europe were pooled cross-section time series methods used (Richards, 1977; Galloway et al., 1994). The procedure is somewhat more common among analyses of LDC fertility decline (see Richards, 1983 for a survey).[23]

Cross-section time series methods permit us to distinguish between the way in which a variable such as income affects the average level of fertility from one city to another, and the way in which changes in income affect changes in fertility. When we estimate a single OLS equation on all the cross-sections (eight census periods) pooled together, the resulting estimated coefficients may mix these two kinds of effects, leading to difficulties in interpretation. Eq. 1C (‘C’ for Cities) below is such a model. We let *Y* be the dependent variable, GMFR. *X* represents the independent variables shown in Table 1, *K* is a constant, *a* is a regression coefficient, and *e* is the error term. *N* is the number of cities in each census (54) and *T* is the number of censuses (8); thus the sample is 54 $*$ 8 which is 432.

$$\begin{aligned} Y_{it} &= K + a_1 X_{1it} + a_2 X_{2it} + a_3 X_{3it} + \dots + a_k X_{kit} + e_{it} \\ &\quad \text{for } t = 1, 2, \dots, T \\ &\quad \text{for } i = 1, 2, \dots, N. \end{aligned} \tag{1C}$$

6.1. LEVEL EFFECTS

We can examine the effects of the levels of independent variables on the level of fertility by regressing the mean over the eight census periods of GMFR on the mean over the eight census periods of each independent variable as shown in Eq. 2C below. Sample size is 54. We will refer to the estimated coefficients of this model as ‘level effects’ (these reflect the ‘between’ component of covariance).

$$\overline{Y}_i = K + a_1\overline{X}_{1i} + a_2\overline{X}_{2i} + a_3\overline{X}_{3i} + \dots + a_k\overline{X}_{ki} + e_i$$
$$\text{for } i = 1, 2, \dots, N. \tag{2C}$$

6.2. PACE EFFECTS

If we estimate a single OLS equation using all the cross-sections pooled together and include a separated dummy variable for each city, thereby permitting each to have its own intercept term or 'fixed effect', the estimated coefficients will reflect only the influence of changes in the variable on changes in fertility. This method specifically exploits the longitudinal features of our data set. We believe that this method best represents hypotheses about the fertility transition. This approach allows us to investigate changes over time in fertility within the cities. Demographic transition theory seeks to explain the causes of fertility decline within areas, but it was not developed to explain the pattern of long-standing fertility differentials between areas. Such long-standing differentials reflect relatively invariant features of each area – cultural, geographic, ecological. These features, some observed and some not, may be empirically associated with other variables in ways which distort their estimated coefficients in an analysis of fertility levels. By using a pooled cross-section time series with fixed effects model, we can concentrate on the causes of fertility change over time. In this way, we are able to focus on the central issues of the demographic transition. We will refer to the estimated coefficients of this model as 'pace effects' (these reflect the 'within' component of covariance).

We allow each city to have its own intercept term by introducing 54 city dummies, *W*, with coefficients *d*, as shown in Eq. 3C below. In a two period model this equation yields exactly the same estimates as a regression of the first difference of the dependent variable on first differences of the independent variables without a constant, although with the eight periods we are using, the estimates will differ somewhat from estimates on first differences.

$$\begin{aligned} Y_{it} = {} & a_1X_{1it} + a_2X_{2it} + a_3X_{3it} + \dots + a_kX_{kit} + d_1W_{1t} + d_2W_{2t} + \\ & \dots + d_NW_{Nt} + e_{it} \\ & \text{for } t = 1, 2, \dots, T \\ & \text{for } i = 1, 2, \dots, N \\ & \text{where } W_{it} = 1 \text{ for } i\text{th unit of analysis } i = 1, \dots, N \text{ and 0 otherwise.} \end{aligned} \tag{3C}$$

In essence we have effectively partitioned the variance in the data set into a component that is 'between-city' variation in the average levels of fertility (Eq. 2C), and 'within-city' variation over time about the average level (Eq. 3C). The regression coefficients in Eq. 3C solely reflect covariance with the 'within-city' variation. That is, these coefficients are estimated solely on the basis of optimal explanation of the historical change within each city.

Most of our analysis is devoted to the interpretation of the ‘within’ model, or ‘pace effects’. It is also called the ‘fixed effects’ model (Hall et al., 1992: 201; Pindyck and Rubinfeld, 1981: 118, 255). We will also examine the estimates from Eq. 2C, the ‘level effects’. Interpreting the estimates from Eq. 1C is problematic because Eq. 1C mixes level and pace effects.

6.3. URBAN INTERACTIONS

We expect that the independent variables associated with fertility decline might function differently in more urban *Kreise* when compared to more rural *Kreise*. We examine the possibility that the slopes of the coefficients may vary by level of urbanization by interacting the independent variables, *X*, with the variable URBAN (percent of population living in urban areas) designated *U* with *b* as its coefficient. We construct three equations as above, and call them Eqs. 1KU, 2KU, and 3KU where ‘KU’ indicates the use of the urban interaction terms with *Kreise* as our units of analysis.

$$\begin{aligned} Y_{it} = {} & K + a_1X_{1it} + a_2X_{2it} + a_3X_{3it} + \dots + a_kX_{kit} + b_1U_{it}X_{1it} + \\ & b_2U_{it}X_{2it} + b_3U_{it}X_{3it} + \dots + b_kU_{it}X_{kit} + e_it \\ & \text{for } t = 1, 2, \dots, T \\ & \text{for } i = 1, 2, \dots, N. \end{aligned} \tag{1KU}$$

$$\begin{aligned} \overline{Y}_i = {} & K + a_1\overline{X}_{1i} + a_2\overline{X}_{2i} + a_3\overline{X}_{3i} + \dots + a_k\overline{X}_{ki} + b_1\overline{U_iX_{1i}} + \\ & b_2\overline{U_iX_{2i}} + b_3\overline{U_iX_{3i}} + \dots + b_k\overline{U_{it}X_{kit}} + e_i \\ & \text{for } i = 1, 2, \dots, N. \end{aligned} \tag{2KU}$$

$$\begin{aligned} Y_{it} = {} & a_1X_{1it} + a_2X_{2it} + a_3X_{3it} + \dots + a_kX_{kit} + b_1U_{it}X_{1it} + \\ & b_2U_{it}X_{2it} + b_3U_{it}X_{3it} + \dots + b_kU_{it}X_{kit} + d_1W_{1t} + d_2W_{2t} + \\ & \dots + d_NW_{Nt} + e_{it} \\ & \text{for } t = 1, 2, \dots, T \\ & \text{for } i = 1, 2, \dots, N \\ & \text{where } W_{it} = 1 \text{ for } i\text{th unit of analysis } i = 1, \dots, N \text{ and 0 otherwise.} \end{aligned} \tag{3KU}$$

We have limited the analysis in this paper in a number of ways. We do not explore the possibility of lagged influences. We do not allow coefficient estimates to vary across broad regions of Prussia (but see Galloway, 1991 for a preliminary analysis). We have not considered that the pace of decline may be related to the level of explanatory variables rather than to their changes, nor that the pace of fertility decline may be related to its initial level. It might be appropriate to estimate changes in fertility and some of the independent variables, such as legitimate infant mortality rate, as elements of an interacting demographic system using two stage least squares and full information maximum likelihood estimation. These and other possibilities will be explored elsewhere (see Galloway et al., 1998).

We include a bivariate correlation matrix as Appendix Table 2. The highest (absolute value) correlation between variables in the city data is 0.63, in the *Kreis* data 0.67.

7. City regression results

The regression results for the Prussian cities and for all *Kreise* in Prussia[24] are displayed in Table 3. We focus on Eqs. 2C and 3C, the level and pace effects. To simplify our presentation we group the variables into four conventional categories: cultural; standard structural; financial and communications; and demographic.[25]

7.1. LEVEL EFFECTS

In terms of level effects (Eq. 2C), every estimated coefficient, where statistically significant, has the expected sign. The variables having significant coefficients are Catholicism, female labour force participation, mining, manufacturing, banking and communications. The two economic sector variables, mining and manufacturing, have significantly positive coefficients relative to the omitted category which is the tertiary sector, suggesting that the demand for child labour may have an important influence on fertility levels. By implication the tertiary sector (trade and services) would be significantly negatively associated with fertility level.[26]

7.2. PACE EFFECTS

Looking at pace effects (Eq. 3C), every estimated coefficient, where statistically significant, has the expected sign. Estimated coefficients for language, education, female labour force participation, income, insurance, communications, and the three demographic variables (population size, infant mortality, and married sex ratio) are significant. None of the economic sector variables is important in terms of pace of fertility decline. Population size itself has no significant impact on fertility level, but it appears that large increases in population, obviously found only in rapidly growing large cities, seem to be associated with the pace of fertility decline.

Of the variables most associated with culture, estimated coefficients for CATHOLIC in terms of level and SLAV in terms of pace are significant. Estimated coefficients for CHURCH and HEALTH are insignificant in both regressions.[27,28]

Table 3. Summary of regression results for Prussian cities and for all Kreise in Prussia

	Expected	Prussian cities						All Prussia					
	sign	Eq. 1C		Eq. 2C		Eq. 3C		Eq. 1K		Eq. 2K		Eq. 3K	
Unit of analysis		City		City		City		Kreis		Kreis		Kreis	
Observations		432		54		432		3256		407		3256	
R-squared		0.733		0.888		0.896		0.625		0.681		0.920	
Corr. R-squared		0.723		0.844		0.876		0.624		0.670		0.908	
Dependent variable		GMFR		GMFR		GMFR		GMFR		GMFR		GMFR	
Constant		210.845	1	422.365	3			202.478	0	189.374	0		
Religion and language:													
CATHOLIC	+	0.981	0	0.581	0	–0.044	95	0.704	0	0.693	0	–2.138	0
SLAV	+	–0.122	47	0.275	32	2.010	2	0.257	0	0.348	0	–0.283	19
CHURCH	+	3.862	67	25.989	19	–2.113	83	12.018	0	1.013	93	23.231	0
Structural, standard:													
EDUCATION	–	–4.539	0	–4.064	18	–4.585	1	–7.817	0	–5.488	6	–9.075	0
HEALTH	–	–32.237	0	–1.314	94	7.693	60	–41.302	0	–32.456	4	–6.596	19
FLFPR	–	–3.161	0	–1.264	2	–3.571	0	–0.980	0	–0.529	6	–1.235	0
INCOME	–	–0.020	0	0.004	69	–0.022	0	–0.021	0	–0.014	19	–0.002	51
MINING	+	0.484	8	1.828	0	0.161	79	1.230	0	1.032	0	0.757	0

Table 3. Continued

	Expected	Prussian cities						All Prussia					
	sign	Eq. 1C		Eq. 2C		Eq. 3C		Eq. 1K		Eq. 2K		Eq. 3K	
MANUFACTURING	+	0.652	0	0.761	3	0.357	35						
URBAN	–							0.345	0	0.034	75	0.107	25
Structural, financial and communications:													
BANK	–	–26.920	1	–44.682	2	–11.139	40	–21.924	1	–36.020	11	–55.325	0
INSURANCE	–	–6.556	39	17.901	14	–43.001	1	–22.968	1	29.251	23	–133.466	0
COMMUNICATIONS	–	–9.261	0	–5.276	5	–5.959	3	–5.904	0	–0.453	86	–7.333	0
Demographic:													
POPULATION	–	0.002	81	–0.007	56	–0.041	1						
INFANT MORTALITY	+	0.103	1	–0.042	52	0.337	0	0.012	30	–0.052	7	0.242	0
MARRIED SEX RATIO	+	96.803	24	–193.165	28	354.038	0	81.616	0	91.828	6	40.674	3
City dummies:													
DUMMY CITY #1						–59.136	48						
DUMMY CITY #2						–91.142	27						
DUMMY CITY #3						–64.413	41						
.						.	.						
.						.	.						
.						.	.						
DUMMY CITY #54						22.030	80						

Table 3. Continued

	Expected sign	Prussian cities			All Prussia			
		Eq. 1C	Eq. 2C	Eq. 3C	Eq. 1K	Eq. 2K	Eq. 3K	
Kreis dummies:								
DUMMY KREIS #1							213.785	0
DUMMY KREIS #2							216.531	0
DUMMY KREIS #3							252.012	0
.							.	.
.							.	.
.							.	.
DUMMY KREIS #407							400.886	0

Notes: The numbers to the right of the estimates are t-statistic probability values in percent based on a two-tailed test.
Probability values from 0 to 5 percent generally indicate statistical significance.
Results for all Prussia (Eqs. 1Ks 2K, and 3K) are from Galloway et al. (1994: 152).

Table 4. Summary of regression results for the Kreis urban interaction model

	All Prussia					
	Eq. 1KU		Eq. 2KU		Eq. 3KU	
Unit of analysis	Kreis		Kreis		Kreis	
Observations	3256		407		3256	
R-squared	0.640		0.706		0.927	
Corr. R-squared	0.637		0.685		0.916	
Dependent variable	GMFR		GMFR		GMFR	
Constant	368.4420	0	339.2570	0		
CATHOLIC	0.5515	0	0.6266	0	–1.9142	0
SLAV	0.3446	0	0.2801	5	–0.4122	5
CHURCH	–5.1560	53	–5.4316	82	6.2314	34
EDUCATION	–6.5202	0	–1.4592	80	–10.6997	0
HEALTH	–22.1077	4	–45.2371	15	–11.4876	23
FLFPR	–1.1775	0	–0.9989	9	–0.0596	82
INCOME	–0.0282	0	–0.0525	1	0.0136	0
MINING	1.5691	0	1.3277	2	1.4742	0
URBAN	–6.6200	0	–5.0904	13	–3.4757	1
BANK	–93.1079	0	–84.3180	32	–40.3399	3
INSURANCE	–29.8658	38	174.8390	10	–197.2600	0
COMMUNICATIONS	–1.7298	32	–4.8772	32	–5.6313	0
INFANT MORTALITY	0.0075	71	0.0366	49	0.1592	0
MARRIED SEX RATIO	–72.6768	3	–25.6197	78	–45.9419	20
Interaction terms:						
CATHOLIC*URBAN	0.0058	0	0.0022	42	0.0087	0
SLAV*URBAN	–0.0046	5	0.0004	95	0.0225	0
CHURCH*URBAN	0.6021	1	0.3786	60	0.4937	1
EDUCATION*URBAN	0.0187	64	–0.0546	63	0.0496	26
HEALTH*URBAN	–0.6889	1	0.2272	79	–0.0217	89
FLFPR*URBAN	0.0069	23	0.0167	30	–0.0345	0
INCOME*URBAN	0.0002	23	0.0007	12	–0.0004	0
MINING*URBAN	-0.0106	11	–0.0016	92	–0.0337	0
BANK*URBAN	0.9728	1	0.3290	78	0.1264	71
INSURANCE*URBAN	0.1891	71	–2.4333	14	2.1526	0
COMMUNICATIONS*URBAN	–0.1069	2	0.1741	19	–0.1355	0

Table 4. Continued

	All Prussia					
	Eq. 1KU		Eq. 2KU		Eq. 3KU	
INFANT MORTALITY*URBAN	0.0004	54	–0.0029	7	0.0028	0
MARRIED SEX RATIO*URBAN	6.5011	0	4.4244	19	3.4469	1
Kreis dummies:						
DUMMY KREIS #1					300.2290	0
DUMMY KREIS #2					304.8150	0
DUMMY KREIS #3					339.4160	0
.					.	.
.					.	.
.					.	.
DUMMY KREIS #407					465.0230	0

Notes: The numbers to the right of the estimates are t-statistic probability values in percent based on a two-tailed test.
Probability values from 0 to 5 percent generally indicate statistical significance.

8. Urban and rural differences

8.1. LEVEL EFFECTS

The insignificant coefficient for URBAN in Eq. 2K in Table 3 suggests that, for level effects, we reject the ‘Low Urban Fertility Hypothesis’. The regression results of the urban interaction model are presented in Table 4. In terms of level effects (Eq. 2KU), none of the urban interaction terms is important. This suggests that there is no difference between urban and rural sectors in the operation of any of the variables, or in their associations with relevant unobserved variables. Thus for levels, the ‘Structurally Similar Hypothesis’ is appropriate for all variables. In other words, the effect of each variable on fertility is the same in both rural and urban settings when examining level effects.

8.2. PACE EFFECTS

The picture is very different, and more complicated, when looking at pace effects. As with level effects, the ‘Low Urban Fertility Hypothesis’ is rejected (see Eq. 3K in Table 3). In order to facilitate explication of the other hypotheses, we plot the estimated regression coefficients for Eqs. 3C, 3K, and 3KU in Figure 2 (that is, pace effects for cities alone, for *Kreise* without urban interactions, and for *Kreise* with urban interactions). The vertical axis is the value of the estimated regression coefficient, and the horizontal axis represents percent urban. The numbers attached to each column are t-statistic significance levels in percent. As an example, let us look at the panel which shows the estimated coefficients for female labour force

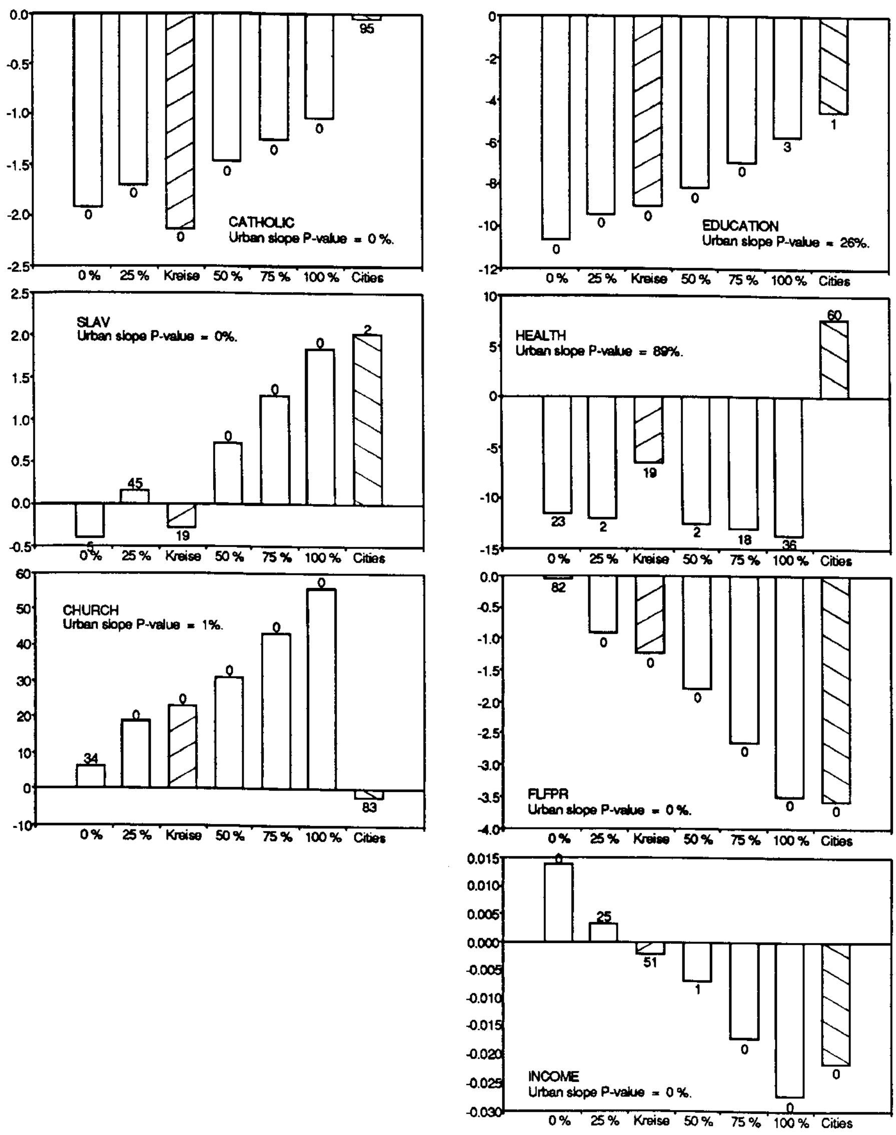

Figure 2. Regression coefficients from the pace effects model (Eqs. 3KU, 3K and 3C).

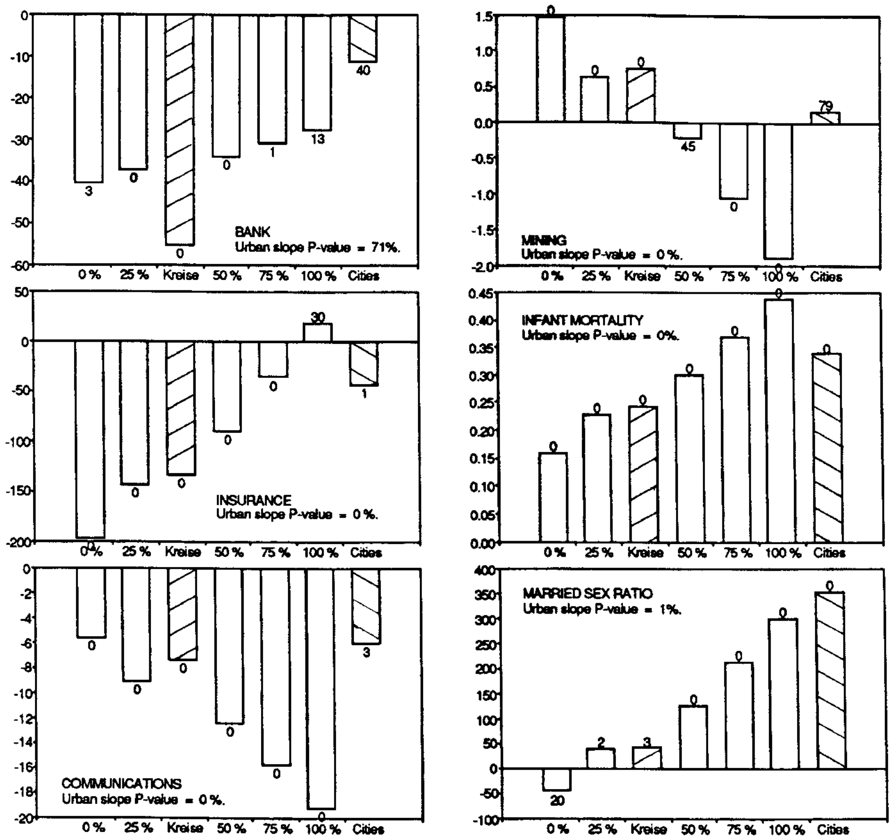

Figure 2. Continued.
The y-axis is the value of the regression coefficient. The numbers along the x-axis are percent urban.
The white columns are labelled according to percent urban and are calculated from Eq. 3KU.
The "Urban slope P-value" is the t-statistic probability value (in percent) of the urban interacted term from Eq. 3KU.
The hatched column labelled "Kreise" is from Eq. 3K. The Kreise are on average about 30 percent urban.
The hatched column labelled "Cities" is from Eq. 3C. The cities are 100 percent urban.
The numbers attached to the columns are t-statistic probability values in percent based on a two-tailed test
Probability values from 0 to 5 percent generally indicated statistical significance.
Sources: Tables 3 and 4.

participation rate (FLFPR) in detail. The hatched column labeled ‘Cities’ is from Eq. 3C, the hatched column labeled ‘*Kreise*’ is from Eq. 3K. The former is 100 percent urban, of course, the latter, about 30 percent urban on average (Table 2). Looking at only these two columns, the estimated coefficient for FLFPR appears to be of greater magnitude in the cities.

To determine if the effect of FLFPR is significantly different in urban and rural sectors, we examine the five white columns labeled 0%, 25%, 50%, 75%, and 100%, which represent percent urban. These, along with corresponding t-statistic significance levels, are calculated from Eq. 3KU. At 0% urban, the completely rural sector, the estimate is near zero and insignificant. At 100% urban the estimate is strongly negative and significant. Ideally, the last two columns of the panel, ‘100%’ urban and ‘Cities’ should be about the same, even though the data sets used are different. Finally, the urban slope P-value is highly significant. In other words the urban interaction on FLFPR is significant, suggesting significant differences in the impact of FLFPR on fertility in the rural and urban sectors. These results support the ‘Enhanced Effects Hypothesis’ for FLFPR.

Only three variables have insignificant urban interactions, and thus support the ‘Structurally Similar Hypothesis’ for pace effects: HEALTH, EDUCATION, and BANK. The estimated coefficients for health-worker concentration are for the most part unimportant and the urban interaction term is insignificant. The education and banking variables appear to be more important in the rural sector than in the cities, but the urban interaction term for each variable is not significant. All the estimated coefficients for the other variables indicate the operation of the ‘Enhanced Effects Hypotheses’ except income and perhaps mining, which support the ‘Structurally Different Hypothesis’.

Estimated coefficients for CATHOLIC are not important in the cities, and elsewhere have unexpected negative signs. This finding is difficult to explain. Estimated coefficients for SLAV, on the other hand, seem to be significantly more important in the cities than in the countryside. In the *Kreise* analysis, estimated coefficients for CHURCH appear to be significantly more important in the urban than in rural areas. However the estimated coefficient for CHURCH is not significant in the analysis of cities. Therefore we reserve judgment on the possibility of different urban and rural effects.

The estimated coefficients for variables representing female labour force participation rate, communications, infant mortality rate, and married sex ratio appear to be stronger in the cities than the countryside, while insurance effects are weaker in the cities than the rural sector.

As suggested earlier, income has a positive effect on fertility in the countryside, but a negative effect in the more urbanized areas, consistent with Mueller and Short (1983). Mining seems to operate in a similar manner, but the lack of significance in the city regression suggests caution in this interpretation.

9. Multiple correlation and incremental contributions

The proportion of variance explained, R^2, is shown in Tables 3 and 4. We see in Eq. 1C (the city analysis) that the non-dummy variables alone explain 73 percent of the variance. Adding the 54 city dummies (Eq. 3C) increases the amount of variance explained to around 90 percent, an increase of 17 percent. We contrast this with our analysis of the 407 small areas covering all of Prussia. Here Eq. 1K explained only 63 percent of the variance, while Eq. 3K explained 92 percent, an increase of almost 30 percent.[29] The point is that the non-dummy variables in our model account for a much greater proportion of the variance explained when the analysis is restricted to cities.

We use incremental contributions to R^2 in an attempt to measure the contribution of each explanatory variable separately (Theil, 1971: 167–169). The top two panels of Figure 3 clearly reveal the overwhelming importance of Catholicism in both urban and rural sectors in explaining the variation in fertility level.

Looking at pace effects in cities (Eq. 3C in Figure 3) we see that the most important contributions are made by female labour force participation rate, infant mortality rate, married sex ratio and income. The bottom panel of Figure 3 shows contributions of variables in terms of pace effects using data for all of Prussia. Here infant mortality rate and the development of insurance services dominate. Catholicism is moderately strong but recall that the sign on the estimated coefficient is unexpectedly negative.[30]

10. Predicting city fertility decline

The predictive power of the pace effects model, Eq. 3C, is shown in the top panel of Figure 4 where period means across all cities of the independent variables are inserted into the equation to predict average period GMFR. Our estimated coefficients using the pace model closely match the actual change in GMFR.[31]

Some scholars have argued that analyses like this one are unable to establish causality, and instead merely establish that many kinds of changes were taking place at the same time in the course of economic development. This view is sometimes expressed by saying that these different measured items moved together down the river of time, carried by the underlying current of development, and all went over the dam together – not because they were causally related, but rather because they were all aspects of the same underlying process. The actual cause of change, in this view, is some unobserved variable or a set of complex interacting processes which defy the mechanical determinism of a linear regression. It is certainly true that it is difficult to establish causality through regression analysis. However, the individual histories of 54 cities provide us with very diverse chronologies, in some of which one variable changes while the others do not. By focusing on the associations over time within each city we are able to move the analysis well beyond what is possible either with cross-sectional analysis or with simple time series analysis. We see that in some cities fertility declined very

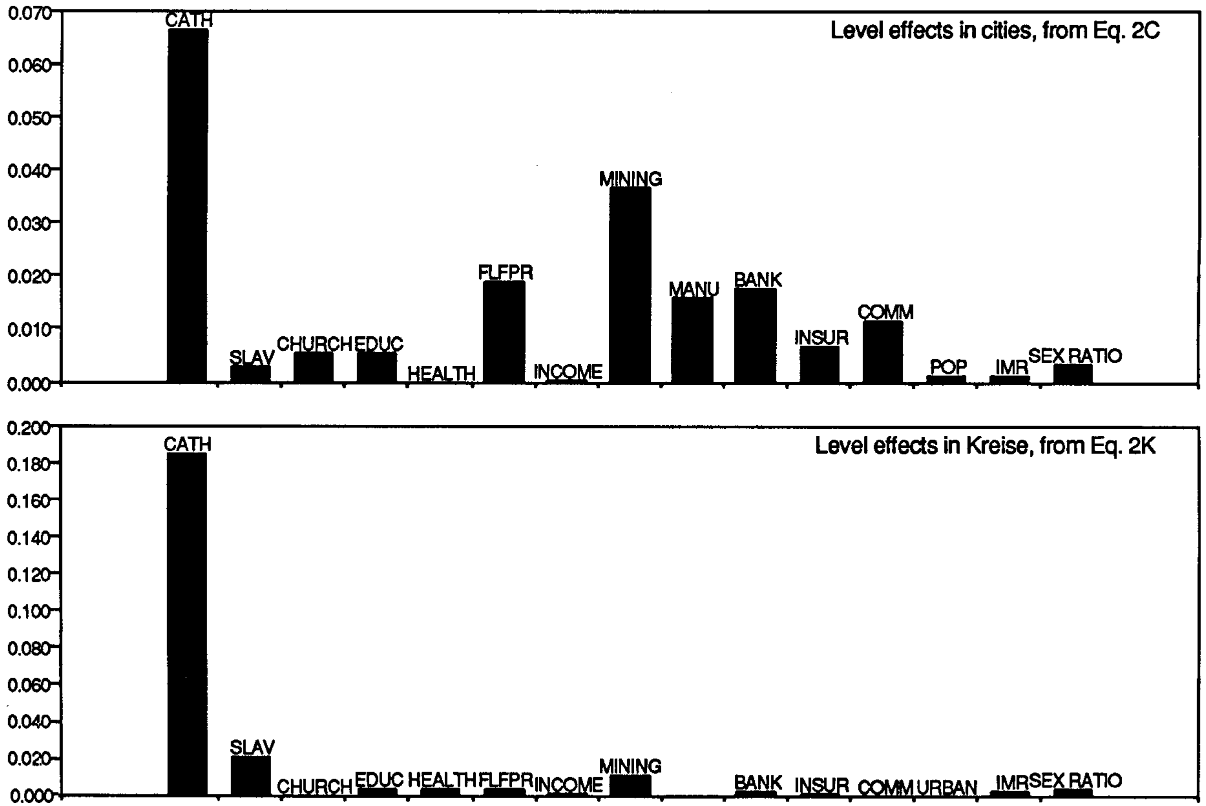

Figure 3. Relative power of variables in accounting for fertility variation (incremental contribution to R-squared).

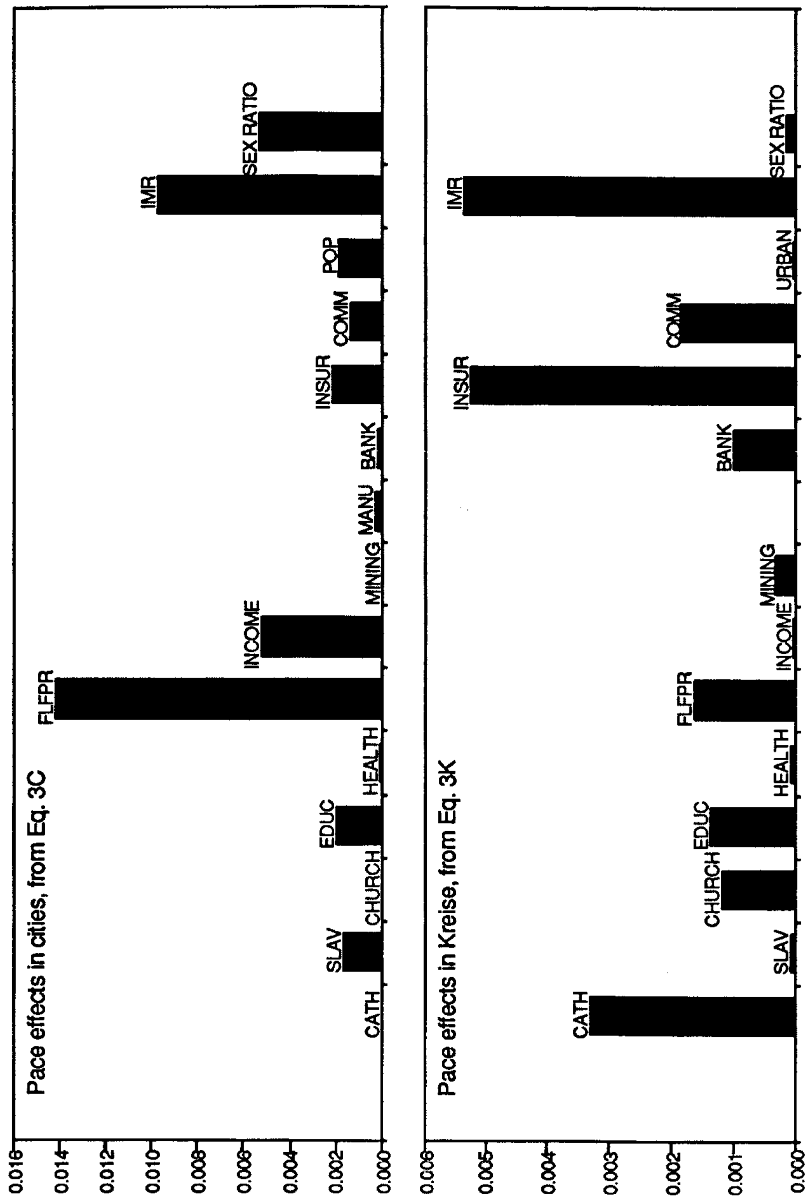

Figure 3. Continued.

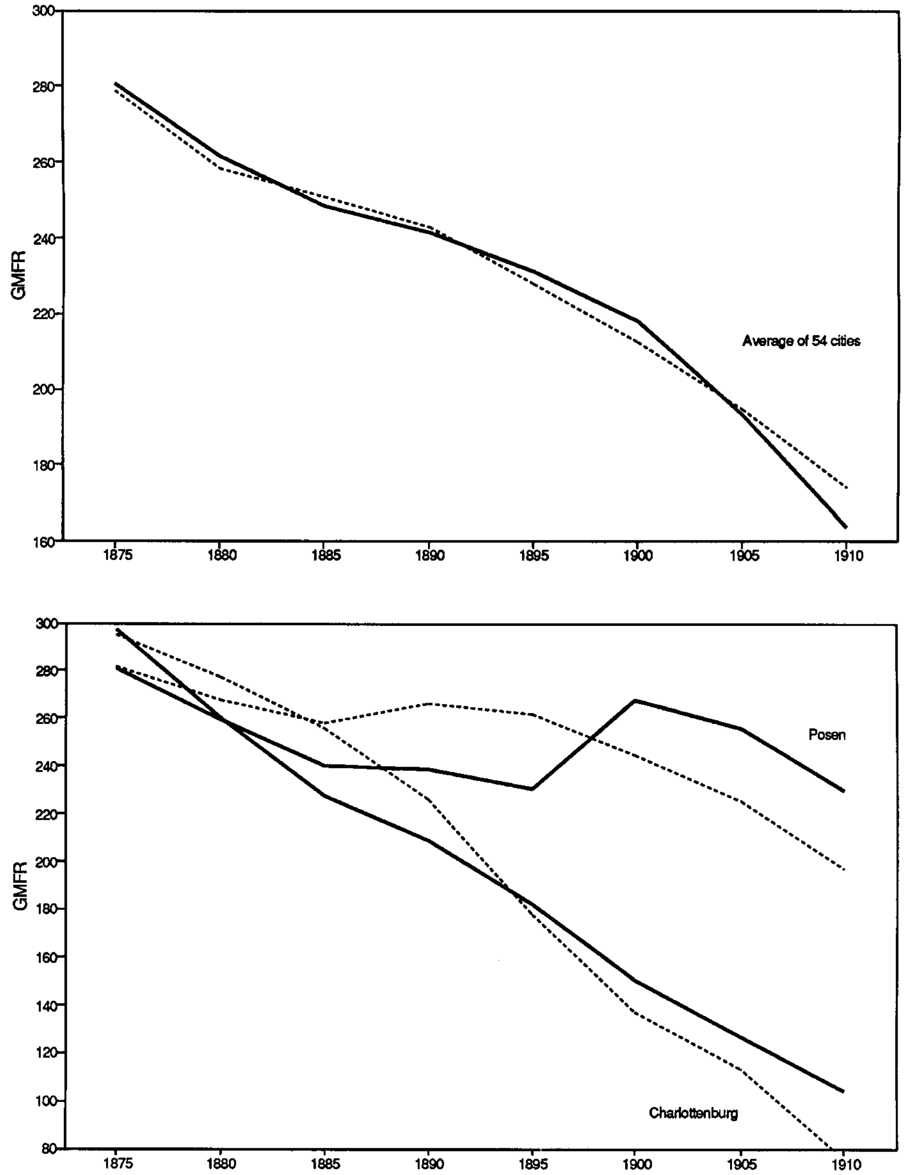

Figure 4. Average GMFR in 54 cities, in Posen city, and in Charlottenburg city predicted by Eq. 3C, 1875 to 1910. Actual GMFR is thick line. Predicted GMFR is dashed line.

little, and in others it declined very sharply (Appendix Table 1). Our analysis is not only able to account for the average decline across all cities, but it is also able to distinguish between those individual cities that had rapid or slow fertility declines. This is shown by the bottom panel of Figure 4, which plots the actual and predicted fertility trajectories from 1875 to 1910 for the cities with the least and the greatest fertility declines, Posen and Charlottenburg, based on the 'pace' model, Eq. 3C.

11. Components of change in predicted city fertility

We can get some idea of the relative contribution of each independent variable to the prediction of estimated average fertility decline by examining the components of change in predicted GMFR. In Figure 4, we saw that Eq. 3C, our preferred model, predicted a decline in GMFR of 279 to 174, or –105, from 1875 to 1910, which very nearly matched the actual decline.

Table 5 presents a detailed accounting of the importance of each explanatory variable in bringing about the decline in GMFR averaged across cities. This is shown for the time periods 1875 to 1890, 1890 to 1900, 1900 to 1910, and the entire time period 1875 to 1910 using Eq. 3C. In this decomposition, only five variables are important: FLFPR (female labour force participation), INFANT MORTALITY, INCOME, INSURANCE, and COMMUNICATIONS. Infant mortality, insurance and communications variables become more important over time. Income seems to be most important during the middle of the period. While female labour force participation rate tends to decline over time, it makes by far the largest contribution to predicted change in GMFR over the entire interval (1875 to 1910). The contribution of the other variables, including the cultural variables, is marginal. Changes in the economic sector variables often used in analyses of fertility decline. We find mining and manufacturing, and by implication the tertiary sector are not important. On the whole, structural factors, including financial services and communications, account for some 72 percent of the decline in predicted GMFR from 1875 to 1910, demographic factors some 29 percent, with cultural factors being negligible.[32]

The components of change in average GMFR in cities from 1875 to 1910 are shown graphically in Figure 5 and compared to the results of our analysis of *Kreise* (Galloway et al., 1994: 156). The results of the analysis of all Prussian *Kreise* can be characterized as reflecting the more rural sector of Prussia,[33] while the results of our city analysis are obviously completely urban.

Female labour force participation rate in non-traditional occupations is the most important component of predicted GMFR decline in both sectors, but is much more powerful in the cities. Infant mortality is about equally important in both sectors. Income, on the other hand, is consequential only in the cities. This is consistent with Mueller and Short's (1983) finding. Of the two financial variables, only insurance is important in the cities, while both banking and insurance play major roles in Prussia overall. Communications and education are more important in the rural sector than in cities. Cultural variables are not important predictors of fertility change in either sector.

12. Summary and implications

When examining urban and rural differences, we find that each of our variables operates the same way on fertility in both urban and rural sectors in terms of level effects. However, when looking at fertility change (that is, pace effects), language, female labour force participation, communications, infant mortality, and married

Table 5. Components of change in average GMFR in Prussian cities and all of Prussia predicted by Eqs. 3C and 3K

	Prussian cities 1875–1890	Prussian cities 1890–1900	Prussian cities 1900–1910	Prussian cities 1875–1910	All Prussia 1875–1910
Amount of change (in GMFR units):					
CATHOLIC	–0.03	–0.01	–0.02	–0.06	–3.15
SLAV	1.21	–0.05	0.00	1.16	–0.00
CHURCH	0.04	–0.07	–0.13	–0.16	0.69
EDUCATION	–2.05	–1.15	–0.21	–3.40	–6.05
HEALTH	0.35	0.54	0.82	1.71	–0.99
FLFPR	–25.45	–9.22	–9.22	–43.90	–8.89
INCOME	–2.37	–9.29	–0.66	–12.31	–0.57
MINING	0.03	–0.01	0.02	0.04	0.56
MANUFACTURING	2.49	1.16	0.51	4.16	
URBAN					0.65
BANK	–0.41	–0.76	–1.25	–2.42	–4.15
INSURANCE	–2.19	–3.79	–5.82	–11.81	–8.29
COMMUNICATIONS	–1.44	–2.29	–3.62	–7.35	–8.41
POPULATION	–1.49	–1.33	–1.60	–4.42	
INFANT MORTALITY	–2.72	–5.04	–14.04	–21.80	–7.39
MARRED SEX RATIO	–1.77	0.64	–2.97	–4.11	0.27
Total	–35.81	–30.67	–38.19	–104.67	–45.72

Table 5. Continued

	Prussian cities 1875–1890	Prussian cities 1890–1900	Prussian cities 1900–1910	Prussian cities 1875–1910	All Prussia 1875–1910
Share of change (percent):					
CATHOLIC	0.08	0.03	0.05	0.05	6.89
SLAV	–3.36	0.16	0.00	–1.10	0.00
CHURCH	–0.12	0.24	0.35	0.16	–1.51
EDUCATION	5.72	3.73	0.54	3.25	13.24
HEALTH	–0.96	–1.76	–2.16	–1.63	2.17
FLFPR	71.08	30.07	24.15	41.94	19.45
INCOME	6.61	30.28	1.73	11.76	1.25
MINING	–0.09	0.04	–0.05	–0.04	–1.23
MANUFACTURING	–6.94	–3.79	–1.34	–3.97	
URBAN					–1.42
BANK	1.14	2.48	3.28	2.31	9.08
INSURANCE	6.12	12.37	15.25	11.28	18.13
COMMUNICATIONS	4.03	7.48	9.47	7.02	18.40
POPULATION	4.17	4.33	4.18	4.22	
INFANT MORTALITY	7.59	16.42	36.77	20.82	16.15
MARRIED SEX RATIO	4.94	–2.08	7.79	3.92	–0.60
Total	100.00	100.00	100.00	100.00	100.00

Table 5. Continued

	Prussian cities 1875–1890	Prussian cities 1890–1900	Prussian cities 1900–1910	Prussian cities 1875–1910	All Prussia 1875–1910
Share of change by category (percent):					
Religion and language	–3.41	0.43	0.39	–0.89	5.38
Structural, standard	75.41	58.57	22.88	51.31	33.46
Structural, financial and communications	11.29	22.32	27.99	20.62	45.61
Demographic	16.70	18.67	48.73	28.97	15.56
Total	100.00	100.00	100.00	100.00	100.00

Notes: See Table 3 for category definitions.
Sources: Table 2 and Eqs. 3C and 3K in Table 3.

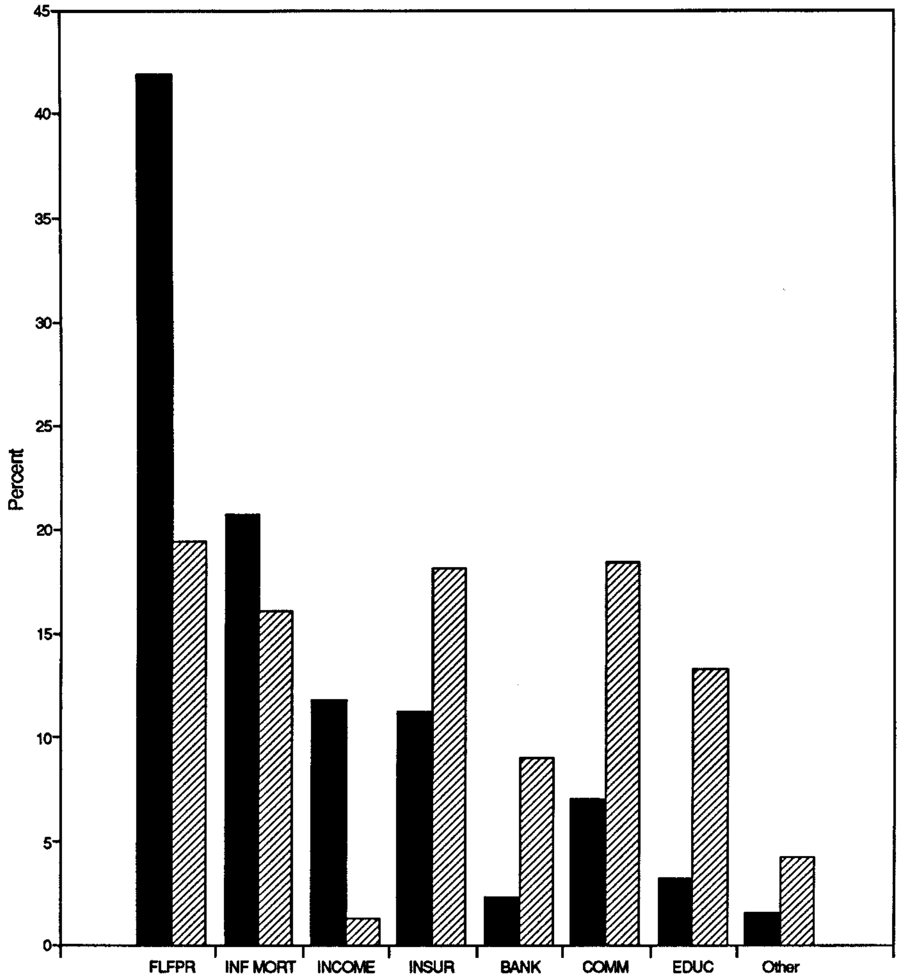

Figure 5. Components of change in predicted average GMFR from 1875 to 1910 in Prussian cities and in all Kreise in Prussia.
Black column represents Prussian cities. Hatched column represents all Kreise in Prussia.
Source: Table 5.

sex ratio are more important in the urban sector, while insurance services appear to be more important in the rural sector. Income has a positive impact on fertility decline in rural areas, and a negative impact in urban settings.

Catholicism is by far the most important factor affecting fertility level in both urban and rural sectors. Analysis of economic sector variables in cities suggests that mining and manufacturing are each significantly positively associated with fertility level, perhaps reflecting demand for child labour.

Among the more important findings from our study is the strong relationship between growth of female labour force participation in non-traditional occupations and the pace of fertility decline, especially in cities. The development of financial institutions, especially insurance services in the rural sector, and the growth of communications and transportation are also strongly associated with fertility decline. While these relationships are theoretically expected, they have rarely, if ever, been examined in the analysis of historical European fertility decline. Decreasing infant mortality is also an important predictor of fertility decline. We note that changes in so-called cultural variables, such as religion and language, contribute little to fertility decline.

Drawing inferences from an analysis of European fertility decline and applying them to contemporary less-developed countries is risky. Nineteenth century Prussia differed in many ways from less-developed countries today, not the least being that virtually the entire population was literate before the onset of fertility decline. Infant mortality was very high in Prussia, and even by 1910 was higher than many less-developed countries today which have yet to experience the fertility transition. On the other hand, certain characteristics of nineteenth century Prussia were similar to many less-developed countries today. At the onset of fertility decline, Prussia's economy was basically agrarian and its financial and communications infrastructure was still in its infancy.[34] Our findings suggest that increasing female labour force participation in non-traditional occupations appears to be one of the most important steps toward reducing fertility, particularly in the cities. Fertility decline in the rural sector would be accelerated by reducing infant mortality, creating effective insurance programmes and thereby eliminating the need for children as 'social security' substitutes, improving education, and expanding communication and transportation infrastructure.

Acknowledgements

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Appendix Table 1. Population, I_g, and GMFR in Prussian cities 1875 and 1910

City	Population 1875	Population 1910	Population % change	I_g 1875	I_g 1910	I_g % change	GMFR 1875	GMFR 1910	GMFR % change	GMFR change
Berlin	966,858	2,071,257	2.18	0.654	0.300	–2.22	256.8	111.5	–2.38	–145.2
Breslau	239,050	512,105	2.18	0.680	0.431	–1.31	257.3	160.3	–1.35	–97.0
Koln	135,371	516,527	3.83	0.818	0.436	–1.80	310.9	166.1	–1.79	–144.7
Magdeburg	122,789	279,629	2.35	0.733	0.332	–2.26	282.2	121.4	–2.41	–160.8
Konigsberg	122,636	245,994	1.99	0.655	0.514	–0.69	238.3	185.6	–0.71	–52.7
Hannover	106,677	302,375	2.98	0.643	0.326	–1.94	250.1	121.2	–2.07	–128.9
Frankfurt am Main	103,136	414,576	3.97	0.545	0.326	–1.46	213.0	125.5	–1.51	–87.4
Danzig	97,931	170,337	1.58	0.728	0.526	–0.93	264.3	194.3	–0.88	–70.0
Altona	96,503	172,628	1.66	0.625	0.364	–1.55	236.1	135.2	–1.59	–100.8
Barmen	86,504	169,214	1.92	0.851	0.401	–2.15	329.6	152.4	–2.20	–177.2
Stettin	80,972	236,113	3.06	0.674	0.382	–1.62	253.5	142.8	–1.64	–110.6
Dusseldorf	80,695	358,728	4.26	0.779	0.439	–1.64	300.5	170.8	–1.61	–129.7
Elberfeld	80,589	170,195	2.14	0.812	0.415	–1.91	316.3	155.8	–2.02	–160.5
Aachen	79,606	156,143	1.92	0.884	0.517	–1.53	331.6	189.4	–1.60	–142.2
Krefeld	62,905	129,406	2.06	0.857	0.426	–2.00	321.0	154.2	–2.09	–166.8
Posen	60,998	156,691	2.70	0.736	0.599	–0.59	280.8	229.6	–0.58	–51.3
Halle	60,503	180,843	3.13	0.684	0.394	–1.58	261.2	146.2	–1.66	–115.1
Dortmund	57,742	214,226	3.75	0.816	0.531	–1.23	331.8	212.0	–1.28	–119.8
Essen	54,790	294,653	4.81	0.927	0.496	–1.79	366.7	197.3	–1.77	–169.3
Kassel	53 043	153,196	3.03	0.662	0.422	–1.28	255.1	160.7	–1.32	–94.4
Erfurt	48,030	111,463	2.41	0.686	0.419	–1.40	264.1	156.2	–1.50	–107.8

Appendix Table 1. Continued

City	Population 1875	Population 1910	Population % change	I_g 1875	I_g 1910	I_g % change	GMFR 1875	GMFR 1910	GMFR % change	GMFR change
Frankfurt Oder	47,180	68,277	1.06	0.716	0.389	–1.74	268.7	141.1	–1.84	–127.6
Gorlitz	45,310	85,806	1.82	0.648	0.336	–1.88	247.3	121.9	–2.02	–125.4
Potsdam	45,003	62,243	0.93	0.613	0.337	–1.71	227.8	120.1	–1.83	–107.7
Wiesbaden	43,674	109,002	2.61	0.681	0.315	–2.21	260.2	118.8	–2.24	–141.4
Duisburg	37,380	229,483	5.18	0.908	0.588	–1.24	355.4	233.2	–1.20	–122.2
Kiel	37,246	211,627	4.96	0.660	0.370	–1.65	253.0	147.0	–1.55	–106.0
Munster	35,705	90,254	2.65	0.779	0.578	–0.85	277.1	212.7	–0.76	–64.4
Elbing	33,510	58,636	1.60	0.746	0.554	–0.85	274.3	203.4	–0.85	–70.9
Trier	32,972	49,112	1.14	0.780	0.573	–0.88	290.3	214.8	–0.86	–75.5
Munchen Gladbach	31,970	66,414	2.09	0.893	0.602	–1.13	340.7	223.3	–1.21	–117.4
Liegnitz	31,442	66,620	2.15	0.712	0.433	–1.42	270.1	157.3	–1.54	–112.8
Bromberg	31,308	57,696	1.75	0.727	0.491	–1.13	273.6	178.2	–1.23	–95.4
Osnabruck	29,850	65,957	2.27	0.751	0.522	–1.04	294.4	196.4	–1.16	–98.1
Koblenz	29,282	56,487	1.88	0.731	0.457	–1.34	276.8	171.1	–1.37	–105.7
Bochum	28,368	136,931	4.50	0.897	0.649	–0.92	378.9	259.3	–1.08	–119.5
Bonn	28,075	87,978	3.26	0.777	0.531	–1.09	285.6	197.4	–1.06	–88.2
Stralsund	27,765	33,988	0.58	0.594	0.423	–0.97	214.2	154.1	–0.94	–60.2
Halberstadt	27,757	46,481	1.47	0.690	0.399	–1.57	261.9	147.6	–1.64	–114.3
Brandenburg	27,371	53,595	1.92	0.645	0.352	–1.73	240.8	131.3	–1.73	–109.5
Spandau	26,888	84,855	3.28	0.805	0.345	–2.42	319.8	127.6	–2.63	–192.3

Appendix Table 1. Continued

City	Population 1875	Population 1910	Population % change	I_g 1875	I_g 1910	I_g % change	GMFR 1875	GMFR 1910	GMFR % change	GMFR change
Bielefeld	26,567	78,380	3.09	0.825	0.369	–2.30	332.7	142.2	–2.43	–190.6
Flensburg	26,474	60,922	2.38	0.581	0.428	–0.87	213.3	160.0	–0.82	–53.3
Remscheid	26,066	72,159	2.91	0.867	0.402	–2.19	337.5	156.2	–2.20	–181.3
Charlottenburg	25,847	305,978	7.06	0.766	0.277	–2.90	297.5	104.2	–3.00	–193.3
Guben	23,704	38,593	1.39	0.686	0.357	–1.87	255.9	133.0	–1.87	–122.9
Nordhausen	23,570	32,564	0.92	0.721	0.396	–1.71	275.4	146.2	–1.81	–129.3
Kottbus	22,612	48,643	2.19	0.733	0.292	–2.62	282.5	104.9	–2.83	–177.6
Hildesheim	22,581	50,239	2.28	0.666	0.408	–1.40	247.1	148.3	–1.46	–98.8
Hanau	22,409	37,472	1.47	0.642	0.364	–1.62	246.3	136.8	–1.68	–109.6
Landsberg	21,379	39,339	1.74	0.767	0.427	–1.67	282.6	154.4	–1.73	–128.3
Muhlhausen	20,926	35,091	1.48	0.737	0.414	–1.64	278.2	151.5	–1.74	–126.7
Tilsit	19,753	39,013	1.94	0.729	0.553	–0.79	246.4	190.3	–0.74	–56.1
Beuthen	19,367	67,718	3.58	0.829	0.690	–0.52	323.4	263.5	–0.59	–59.9
Minimum	19,367	32,564	0.58	0.545	0.277	–2.90	213.0	104.2	–3.00	–193.3
Maximum	966,858	2,071,257	7.06	0.927	0.690	–0.52	378.9	263.5	–0.58	–51.3
Average	69,938	178,590	2.54	0.736	0.437	–1.53	280.6	163.6	–1.59	–116.9
Standard deviation	129,404	285,188	1.22	0.089	0.096	0.53	38.8	37.5	0.57	37.8
Coefficient of variation	1.85	1.60	0.48	0.12	0.22	–0.34	0.14	0.23	–0.36	–0.32

Note: % change is percent change per annum 1875 to l910.

Appendix Table 2. Bivariate correlation matrices for cities and Kreise

Cities:	GMFR	CATH.	SLAV	CHURCH	EDUC.	HEALTH	FLFPR	INCOME	MINING	MANU.	BANK	INSUR.	COMM.	POP.	INFANT MORT	SEX RATIO
GMFR	1.00	0.45	0.14	0.11	–0.43	–0.22	–0.45	–0.28	0.42	–0.17	–0.51	–0.36	–0.33	–0.25	0.23	0.35
CATHOLIC	0.45	1.00	0.26	0.56	–0.02	0.39	0.04	0.23	0.34	–0.11	–0.04	–0.01	0.05	–0.05	–0.09	0.30
SLAV	0.14	0.26	1.00	0.04	0.05	–0.00	–0.02	–0.16	0.25	–0.20	–0.00	0.02	0.07	–0.04	0.07	0.14
CHURCH	0.11	0.56	0.04	1.00	0.11	0.52	0.06	0.14	–0.07	–0.22	0.03	0.06	0.17	–0.07	–0.07	0.14
EDUCATION	–0.43	–0.02	0.05	0.11	1.00	0.63	0.03	0.17	–0.28	–0.33	0.44	0.13	0.13	0.06	–0.09	–0.09
HEALTH	–0.22	0.39	–0.00	0.52	0.63	1.00	0.10	0.26	–0.17	–0.21	0.34	0.15	0.17	0.07	–0.20	–0.02
FLFPR	–0.45	0.04	–0.02	0.06	0.03	0.10	1.00	0.24	–0.33	0.62	0.23	0.24	0.08	0.25	–0.11	–0.31
INCOME	–0.28	0.23	–0.16	0.14	0.17	0.26	0.24	1.00	0.15	0.15	0.47	0.36	0.21	0.37	–0.43	0.04
MINING	0.42	0.34	0.25	–0.07	–0.28	–0.17	–0.33	0.15	1.00	–0.23	–0.17	–0.09	0.06	–0.05	–0.15	0.58
MANUFACTURING	–0.17	–0.11	–0.20	–0.22	–0.33	–0.21	0.62	0.15	–0.23	1.00	0.03	0.06	–0.07	0.10	–0.25	–0.31
BANK	–0.51	–0.04	–0.00	0.03	0.44	0.34	0.23	0.47	–0.17	0.03	1.00	0.43	0.35	0.45	–0.32	–0.07
INSURANCE	–0.36	–0.01	0.02	0.06	0.13	0.15	0.24	0.36	–0.09	0.06	0.43	1.00	0.44	0.29	–0.12	–0.06
COMMUNICATIONS	–0.33	0.05	0.07	0.17	0.13	0.17	0.08	0.21	0.06	–0.07	0.35	0.44	1.00	0.05	–0.25	0.00
POPULATION	–0.25	–0.05	–0.04	–0.07	0.06	0.07	0.25	0.37	–0.05	0.10	0.45	0.29	0.05	1.00	–0.00	–0.07
INFANT MORTALITY	0.23	–0.09	0.07	–0.07	–0.09	–0.20	–0.11	–0.43	–0.15	–0.25	–0.32	–0.12	–0.25	–0.00	1.00	0.02
MARRIED SEX RATIO	0.35	0.30	0.14	0.14	–0.09	–0.02	–0.31	0.04	0.58	–0.31	–0.07	–0.06	0.00	–0.07	0.02	1.00

Appendix Table 2. Continued

Kreise:	GMFR	CATH.	SLAV	CHURCH	EDUC.	HEALTH	FLFPR	INCOME	MINING	URBAN	BANK	INSUR.	COMM.	INFANT MORT	SEX RATIO
GMFR	1.00	0.62	0.41	0.20	–0.48	–0.29	–0.27	–0.34	0.19	–0.33	–0.38	–0.33	–0.27	0.05	–0.07
CATHOLIC	0.62	1.00	0.30	0.49	–0.20	0.13	0.11	0.00	0.12	–0.18	–0.10	–0.09	0.01	–0.01	–0.11
SLAV	0.41	0.30	1.00	–0.13	–0.26	–0.23	–0.25	–0.28	–0.01	–0.17	–0.13	–0.11	–0.11	0.13	–0.18
CHURCH	0.20	0.49	–0.13	1.00	0.09	0.33	0.13	0.11	–0.05	–0.02	0.02	–0.01	0.16	–0.12	–0.03
EDUCATION	–0.48	–0.20	–0.26	0.09	1.00	0.61	0.39	0.54	–0.13	0.59	0.63	0.52	0.43	–0.05	0.18
HEALTH	–0.29	0.13	–0.23	0.33	0.61	1.00	0.48	0.54	–0.01	0.40	0.50	0.44	0.48	–0.10	0.10
FLFPR	–0.27	0.11	–0.25	0.13	0.39	0.48	1.00	0.64	0.04	0.53	0.47	0.47	0.39	0.13	0.10
INCOME	–0.34	0.00	–0.28	0.11	0.54	0.54	0.64	1.00	0.23	0.63	0.62	0.57	0.56	–0.14	0.24
MINING	0.19	0.12	–0.01	–0.05	–0.13	–0.01	0.04	0.23	1.00	0.00	0.01	0.01	0.19	–0.09	0.31
URBAN	–0.33	–0.18	–0.17	–0.02	0.59	0.40	0.53	0.63	0.00	1.00	0.57	0.60	0.44	0.07	0.19
BANK	–0.38	–0.10	–0.13	0.02	0.63	0.50	0.47	0.62	0.01	0.57	1.00	0.67	0.47	–0.06	0.16
INSURANCE	–0.33	–0.09	–0.11	–0.01	0.52	0.44	0.47	0.57	0.01	0.60	0.67	1.00	0.48	0.05	0.14
COMMUNICATIONS	–0.27	0.01	–0.11	0.16	0.43	0.48	0.39	0.56	0.19	0.44	0.47	0.48	1.00	–0.17	0.21
INFANT MORTALITY	0.05	–0.01	0.13	–0.12	–0.05	–0.10	0.13	–0.14	–0.09	0.07	–0.06	0.05	–0.17	1.00	0.10
MARRIED SEX RATIO	–0.07	–0.11	–0.18	–0.03	0.18	0.10	0.10	0.24	0.31	0.19	0.16	0.14	0.21	0.10	1.00

Notes

[1] For critiques see, for example, Chesnais (1987), Cleland and Wilson (1987), Easterlin (1987), Andorka (1986), Levine (1986), and Tilly (1986).

[2] *Kreise* are small administrative districts covering all of Prussia. For an analysis of *Kreise*, see Galloway et al. (1994).

[3] Only Laux (1983, 1989) and Reher and Iriso-Napal (1989) examined fertility level in cities. Laux (1983, 1989) analyzed fertility level in 64 Prussian cities in 1880 and 1905 using multiple classification analysis (seven city-types and four regions) and found that these classifications were statistically significant. Reher and Iriso-Napal (1989) examined fertility level in the provincial capital cities of Spain using data for 1887, 1900, and 1920, although three of their eight independent variables use 1920 data in the 1887 and 1900 regressions. Woods (1987) examined fertility level in urban districts in England Wales in 1861, 1891, and 1911. Woods defined urban districts as those with a population density of 100 or more persons per square kilometer in 1861 (1987: 363). Coale, Anderson and Härm (1979) analyzed urban sectors of 50 provinces in Russia. However, they used the Russian statistical authorities' definition of urban, so that some places with less than 1000 population were classified as urban (1979: 49). None of these studies used measures of religion, language, income, financial services, transport-communications infrastructure, female labor force participation rate in non-traditional occupations, concentrations of health workers, prevalence of church workers, or legitimate infant mortality.

Crafts (1984) examined fertility level in urban districts of England using 1911 data. He examined unmarried female labour force participation rate, property tax per capita, in-migration rate as a proxy for relative income, child mortality, illiteracy, textile workers per total workers, coal miners per total workers, and domestic servants per capita. He reported regressions for earlier periods, but half of his independent variables in these regressions used 1911 data.

None of the above studies used pooled cross section time series methods.

[4] *Kreise* tended to split over time. In order to maintain spatial consistency over time, we had to combine many of the split *Kreise*. This resulted in 407 *Kreise*, each with a constant area, from 1875 to 1910. Only seven of the 407 *Kreise* were 100 percent urban.

[5] See Lee et al. (1994) for an attempt to explore these relationships using non-linear techniques.

[6] We intend thereby to respond to the numerous authors who have argued that such change is relatively powerless to explain the fertility transition. See, for example, Knodel and van de Walle (1986), and Cleland and Wilson (1987). See also Galloway et al. (1994: 156–158) and Hammel (1992) who argue the opposite.

[7] We allow the boundaries of the cities to change from census to census, but the numerators for the calculation of GMFR and legitimate infant mortality rate always correspond to the denominators in terms of area. We believe it is appropriate to allow city boundaries to change over time because most of the population in the area incorporated into a city at any given date was probably functionally part of the city anyway. In an analysis of all *Kreise* (small administrative units) in Prussia, we found that because of administrative subdividing and occasional redistricting, the number of *Kreise* in Prussia increased from 453 to 586 from 1875 to 1910 (Galloway et al., 1994: 140–141). In this case we sought to maintain a unit of analysis with constant area over time. The tedious process of combining and recombining *Kreise* in Prussia resulted in 407 units with constant areas from 1875 to 1910. If we applied the same criteria to cities, i.e., maintaining constant area from 1875 forward, we would have only seven cities to examine.

[8] The difference between GMFR and the Hutterite index I_g used in the Princeton European Fertility Decline Project is that the latter incorporates the Hutterite fertility schedule 'in order to express the fertility of a population (or of a segment) relative to the maximum that might be attained' (Coale and Treadway, 1986: 156). In reference to GFR and GMFR Coale and Treadway in their overview of the Princeton European Fertility Project say 'there would have been little difference in the findings of our research if these conventional measures had been used' (1986: 153). Using data for the 54

Prussian cities for the periods 1875, 1880, 1885, 1890, 1895, 1900, 1905 and 1910, we find that GMFR is highly correlated with I_g (r's exceed 0.97 in all periods). The two measures are in fact interchangeable.

[9] The graph shows the average GMFR for all 54 cities from 1875 forward. Because of lack of data for earlier periods, GMFR for 1861, 1864, 1867, and 1871 reflect the average for 28, 30, 40, and 48 cities respectively. There are 407 *Kreise* which together comprise all of Prussia (see Galloway et al., 1994: 140-141). GMFR for the *Kreise* reflect the average of the 407 *Kreise* throughout.

[10] The number of *Kreise* according to level of urbanization is: 129 *Kreise* 0–19%; 191 *Kreise* 20–39%; 60 *Kreise* 40–59%; 16 *Kreise* 60–79%; and 11 *Kreise* 80–100%. This suggests that the *Kreis* data set is dominated by predominantly rural *Kreise*.

[11] We will analyze infant mortality decline in another study.

[12] See Galloway et al. (1994: 138–140) for an overview of the vast quantity of data collected and published by the Prussian statistical authorities between 1864 and 1914. Knodel (1974: 24) found that the Prussian demographic data quality was high by the 1860s. Wojtun (1968: 69–131) concluded that the Prussian registration and census data were virtually complete by 1864. The Prussian authorities made a considerable effort to ensure consistency in definition of occupational categories across censuses. Each new occupation census included a list showing the precise correspondence between any new occupational definitions and the occupational definitions of earlier censuses.

[13] Interpolation is used primarily for the occupation variables and appears reasonable since these tend to move slowly and monotonically over time. Occupation data were also extrapolated for the short period after 1907, to 1910. The occupation data refer only to the primary occupations of the employed labor force and include both males and females. Unfortunately, no data exist for proportion Slavic-speaking after 1900. As a consequence, the 1905 and 1910 data for this variable are assumed to be identical to the 1900 data.

[14] In some of the earlier occupational censuses, government and domestic service were combined into one category. Because very few women were employed in government service in 1907, we believe our measure of FLFPR includes virtually all employed women in non-traditional occupations. Agriculture and domestic service are considered traditional occupations for women.

[15] Married women comprised only 10 percent of the female labour force in 1882, rising to 14 percent by 1907. However, Dasey (1981: 228, 232) suggests that married women in the labour force were probably undercounted in the occupation censuses.

[16] Estimates for 1875 and 1880 are made based on Province-level teachers' income data for 1875, 1880 and 1885. Using the 1910 city data is problematic because of changes in definitions of some terms. As a consequence the city level data for 1910 are estimated based on changes in Province level income tax per capita 1905 to 1910 applied to the 1905 data (Statistischen Reichsamt, 1932: 72).

The nominal salary in each city is divided by a cost-of-living index covering food and rent for Germany in order to estimate a 'real' salary over time. It is not possible to construct an adequate cost-of-living index specific to each city. The German cost-of-living index is as follows where 1900 equals 1.00: 1875 0.99, 1880 0.99, 1885 0.91, 1890 0.98, 1895 0.95, 1900 1.00, 1905 1.07, and 1910 1.20 (Kuczynski, 1947: 173; see also Bry, 1960: 325–326, 356). More recently, Desai (1968: 36, 117) constructed a cost-of-living index for Germany which is about the same as Kuczynski's.

We find a significant correlation (r = 0.68) between teachers' salaries and the median wage of skilled and unskilled workers in 1907 in the 20 cities for which data are available(Kaiserliche Statistischen Amte, 1908: 2–3). Using another data set we find the minimum wage of carpenters in 46 cities in 1906 was significantly correlated (r = 0.46) with teachers' salaries (Kuczynski, 1913). In another study (Galloway et al., 1994: 146) we found a high correlation between *Kreis* income tax per capita and male elementary school teacher's salaries, r = 0.72 in 1875 and r = 0.80 in 1900. Prussia male elementary school teacher's real salaries and Germany industrial and agricultural average real wage (Kuczynski, 1947: 170–173) correspond fairly well from 1880 to 1910, with average annual growth rates over the entire period of 0.9 percent and 0.8 percent respectively. However from 1875 to 1880, our earliest period analyzed, Prussian teachers experienced an increase in real salary while German industrial and agricultural real wages declined.

17 In general the German occupational censuses do not lend themselves to calculation of economic sector variables due to a peculiar redefinition of female agricultural labourers which led to an improbable 2 million increase in this category between 1895 and 1907 (Tipton, 1976: 153–158). However, city populations are probably not affected by this problem because there were few agricultural workers in cities. Within the cities it is possible to disaggregate the employed labour force into five categories which sum to 100 percent: agriculture, mining, manufacturing, trade (merchandising and commercial services), and non-commercial services (primarily government, military, and domestic service).

18 Virtually no women of any age were employed in mining.

19 Both measures of demand for child labour may be flawed because of occupational and age misreporting, as well as differences among cities in the enforcement of compulsory education and child labour laws. Occupational distribution data by age groups 0–19, 20–69, and 70 and over and by marital status were published for 38 cities in Prussia in 1882 (Preussische Statistik, vol 76, part 2, 232–686). We estimated the 1882 population aged 10–19 by applying the ratio of the population aged 10–19 to population aged 0–19 in 1880 to the population aged 0–19 in 1882 for each city (Preussische Statistik, vol. 66, 78–86). Of the 38 cities for which data were available in 1882, similar data are available for 26 cities in 1907 (Statistik des Deutschen Reichs: vol. 207, 357–511). We use the 1905 age distribution to estimate the population aged 10–19 (Preussische Statistik: vol. 206, 202–241). Occupation data for persons aged 0–19 in 1907 include married and unmarried persons. However, very few persons married before age 20 in Prussia. Therefore the measures we calculate are comparable over time.

20 This finding is supported by Dasey who notes that in the clothing industry ‘factories and workshops employed large numbers of young girls, often supposedly in training, and the majority of their women workers were under 21 years’ (1981: 238).

21 Both trade and service, which together make up the so-called tertiary sector, are, where significant, negatively correlated with our measures of demand for child labour.

22 Our urbanization variable, URBAN, is defined as the percentage of the total *Kreis* population living in places with a population exceeding 2,000 inhabitants. This is the definition of urbanization used by the Prussian Statistical Office.

23 Attempts to determine consistently the onset of marital fertility decline in cities resulted in many difficulties. In some cases the turning point was obvious, in others, it was less clear. In some cities fertility began to decline gradually from 1880 to 1890, and then began to drop very steeply from 1890 to 1910. Is the onset of fertility decline 1880 or 1890? Include five or ten year cycles and the picture becomes even more complicated. Rather than estimating some point, often arbitrary, of onset of fertility decline, we focus on the analysis of pace of fertility decline.

24 For purposes of comparison, we include a set of regressions using our Kreis data set and call them Eqs. 1K, 2K, and 3K where ‘K’ stands for ‘*Kreis*’. There are 407 *Kreise* in Prussia. The *Kreis* data set as a whole reflects for the most part a rural analysis with the average level of *Kreis* urbanization only 30 percent (Table 2). The *Kreis* regressions have been examined at length in Galloway et al. (1994).

25 The groupings are somewhat arbitrary, depending on how one chooses to distinguish cultural proxies from economic and structural proxies. The distinction is not obvious. ‘Cultural’ variables can be argued to be ‘economic’ variables, and ‘economic’ variables can be argued to be ‘cultural’ variables, depending on how one chooses to define ‘culture’ and ‘economic’.

26 We suspect that the coefficients of some of the independent variables used to predict fertility level may change over time. We examine the possibility that the coefficients may vary over time by interacting the independent variables, X, with time dummies, Z, while also including the time dummies in the equation with coefficients c. This pooled OLS cross-section time series regression yields exactly the same estimated coefficients as running eight separate cross-section regressions, although the pooled regression constrains the error terms to have the same variance in each period

making the variance of estimates somewhat smaller. An F-statistic is also calculated, to test whether including the set of interacted time dummies of a given independent variable adds any more to explained variance than using just the non-interacted independent variable alone. In other words, it tells us whether the value of the independent variable changes significantly across time, and constitutes a test of structural homogeneity over time.

$$Y_{it} = a_1 X_{1it} Z_{i1} + a_2 X_{2it} Z_{i2} + a_3 X_{3it} Z_{i3} + \cdots + a_k X_{kit} Z_{iT} + c_1 Z_{i1} + c_2 Z_{i2} + \cdots + c_T Z_{iT} + e_{it}$$

for $t = 1, 2, \ldots, T$

for $i = 1, 2, \ldots, N$

where $Z_{it} = 1$ for tth census $t = 1, \ldots, T$ and 0 otherwise.

Only the estimated coefficients for SLAV, MANUFACTURING, and the time dummies change significantly over time. SLAV moves from insignificantly negative early on to the theoretically expected significant and positive sign by 1910. MANUFACTURING is more strongly positively associated with fertility level in 1875, and diminishes to an insignificant association by 1910, supporting Laux's earlier finding (1983: 31).

[27] The estimated coefficients for city dummies in Eq. 3C are individually not significant, but as a group are jointly significant (Pindyck and Rubinfeld, 1981: 18, 255).

We correct for first order autoregressive disturbances using the maximum likelihood iterative procedure (Hall et al., 1992: 28–33). We use a correction procedure that ensures that lagged values for one city are not taken from the values of another city. The correction in Eq. 3C results in an important change of statistical significance in only one variable. The estimated coefficient for SLAV goes from significance before the correction to near insignificance after the correction (p-value of 2 percent goes to a p-value of 13 percent). Note that Eq. 2C does not have serial correlation problems and we are not interested in interpreting Eq. 1C.

In many fixed effects models, serious problems may arise because of the limited number of degrees of freedom, a condition that led to the formulation of the random effects (or error-components) model. Because of our large sample size, we expect to encounter few problems with degrees of freedom. However, it has been shown that the random effects model may be somewhat more efficient under certain conditions (Pindyck and Rubinfeld, 1981: 256–258; Judge et al., 1985: 515–560). In the random effects model we find that three estimated coefficients are different from the fixed effects model. The estimated coefficient for CATHOLIC shifts sign to positive and becomes significant, the estimated coefficient for SLAV becomes insignificant, and the estimated coefficient for MANUFACTURING goes from insignificant to significant. We will show later that these variables contribute very little to the predicting power of Eq. 3C.

[28] To examine possible significant variations in pace effects over time we take the first difference of GMFR, call it Y', and the first difference of all the independent variables, call them X'. We then interact each independent variable with a time dummy. This yields exactly the same regression coefficients as running the preceding fixed effects regression seven times: one regression for the period 1875–1880, one for 1880–1885, and so on up to 1905–1910. Because of the first differencing we are left with seven time periods, so the sample size is $54 * 7$ which 378. An F-test is undertaken to see whether the value of an independent variable changes significantly across time.

$$Y'_{it} = a_1 X'_{1it} Z_{i1} + a_2 X'_{2it} Z_{i2} + a_3 X'_{3it} Z_{i3} + \cdots + a_k X'_{kit} Z_{iT} + e_{it}$$

for $t = 1, 2, \ldots, T$

for $i = 1, 2, \ldots, N$

where $Z_{it} = 1$ for tth census $t = 2, \ldots, T$ and 0 otherwise.

The estimated coefficients for five variables appear to vary significantly over time. The estimated coefficients for EDUCATION, INCOME, MANUFACTURING, POPULATION, and INFANT

MORTALITY tend to jump around from census to census, but show no obvious temporal trend. The instability of the estimated coefficients is not surprising given the relatively small number of observations for each census year.

[29] There is not much difference in explained variance between Eqs. 1K and 1KU, or between Eqs. 3K and 3KU.

[30] We calculated the incremental contribution to R-squared using Eqs. 2KU and 3KU. In these cases we estimate the joint contribution by combining each term with its URBAN interaction term. The results were virtually identical to those obtained using Eqs. 2K and 3K.

[31] See (Galloway et al., 1994: 153–155) for a similar analysis of *Kreise*.

[32] The structure of our analysis does not allow us to determine whether fertility decline began earlier or proceeded more rapidly in some cultural regions than in others. These questions are left to a later analysis. Instead, we observe here that changes in several variables that might be viewed as 'cultural' are only weakly associated with changes in fertility.

[33] The average *Kreis* was about 30 percent urban.

[34] Prussia's agricultural population was 71.5 percent of the total in 1872. Transport's share of national product in 1880 in Germany was 3 percent, the same as in Italy. Railway track per square mile in 1870 was 0.033 in Germany, 0.029 in France, 0.022 in Italy, and 0.089 in the United Kingdom. By 1913, railway network density in Germany was about the same as in the United Kingdom. Deposits in commercial banks as a proportion of GNP in 1880 in Prussia was 3.0 compared to 35.7 in the United Kingdom (Trebilcock, 1981: 41, 433, 444–445).

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