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Fertility Decline in Prussia, 1875–1910: A Pooled Cross-Section Time Series Analysis

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'My wife could have had a nice porter's job, if we didn't have children.' Shoemaker, aged 30, Catholic, resident of Berlin; 9 siblings, 2 children.

'We're a modern couple, we have no need for children... Any idiot can have children, but it's better to have none.' Landlord, aged 27, Lutheran, resident of a large city in East Prussia; 3 siblings, no children.

'Children thin the wallet.' Farmer, aged 27, Lutheran, resident of an estate in Lausitz; 9 siblings, 2 children.[1]

INTRODUCTION

The fertility transition in Europe, studied intensively for nearly a century, remains one of the great demographic puzzles of our time. Its interest is not merely historical, since our view of Europe's transition has guided research and policy regarding fertility change in the Third World. Was fertility decline driven by socio-economic development, or diffusion of knowledge about contraception, or by some combination of the two? Was declining fertility related more to ideational or to material change?

A major achievement of modern demographic research has been the compilation of time series of fertility data at regional levels within Europe, under the auspices of the Princeton European Fertility Project. However, the results of the many analyses dedicated to explaining the observed fertility decline have been less than enthusiastically received.[2] This has generally been attributed either to lack of adequate theory or, more often, to the inability to test existing theory adequately for a variety of reasons, including excessively large units of analysis, lack of useful socio-economic measures (for example, direct measures of income have rarely been used), coarsely defined independent variables, insufficient sample size, inadequate method and improperly specified models. Indeed, because of these problems important elements of fertility transition theory have not yet been adequately tested for historical Europe.

We address some of these problems by using more appropriate statistical methods to analyse a new data-set, which is in many respects richer and more consistent than those hitherto available. We examine the fertility decline in 407 small areas of Prussia from 1875 to 1910, using methods for time series of cross-sections.[3] Our primary unit of

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[1] M. Marcuse, *Der eheliche Präventivverkehr, seine Verbreitung, Verursachung und Methodik, dargestellet und beleuchtet an 300 Ehen* (Stuttgart, Enke, 1917), pp. 22, 23, 66.

[2] For a critique see J. C. Chesnais, review of *The Decline of Fertility in Europe*, *Population*, **42**, (1987), pp. 389–391; J. Cleland and C. Wilson, 'Demand theories of the fertility transition: an iconoclastic view', *Population Studies*, **41** (1987), pp. 5–30; R. A. Easterlin, 'Towards the cumulation of demographic knowledge', *Sociological Forum*, **2** (1987), pp. 835–842. See also reviews of *The Decline of Fertility in Europe*, *Population and Development Review* **12** (1986) by R. Andorka (pp. 329–334), D. Levine (pp. 335–340) and C. Tilly (pp. 323–328).

[3] We discuss our methods in detail later in this paper.

analysis is the *Kreis* (pl, *Kreise*), a small Prussian administrative unit similar to a modern census tract, although larger. On average, it is only one-fifteenth of the size of the typical unit of analysis used in the European Fertility Project, and contains some 60,000 inhabitants.

We believe that this data-set is superior in terms of quantity, refinement, consistency of definition, and availability over time of theoretically important variables to any data previously available for the study of fertility decline in Europe. No other European data-set provides as much demographic and socio-economic detail for such a vast number of people – some 40 million in 1910, or one-eighth of the population of Europe – using such small units of analysis. Furthermore, no comparable multivariate analysis of all Europe has ever been undertaken, or is likely to be undertaken because of the lack of both temporal and definitional comparability among independent variables.[4]

THEORETICAL BACKGROUND

Notestein's original formulation of transition theory[5] contained many of the elements that have subsequently been developed in greater detail: urbanization, loss of household economic function, mobility and anonymity, new skills and opportunities, the growing importance of education, rationalism, rising costs of children and declining economic roles for them, increasing child survival, increasing opportunity costs for women, and diffusion of upper-class contraception. A brief review of these hypotheses, loosely organized according to Easterlin and Crimmins's framework of demand, supply and costs of regulation will be helpful.[6]

Demand for surviving children

One line of economic theory which emphasizes the direct satisfaction that parents obtain from children, concludes that, other things being equal, couples will desire more children as their incomes rise. However, during the course of industrialization this tendency may be counterbalanced by increasing opportunities for women's employment, and by higher wages for women, which raise the opportunity cost of childbearing.[7] Modern-sector or urban employment is particularly important here, because it is less compatible with child

[4] See J. Körösy, 'Le recensement séculaire du monde en 1900. La comparabilité des ouvrages de recensement et l'activité relative des Congrès Internationaux de Statistique', *Bulletin de l'Institut International de Statistique*, **9** (1899), pp. 220–250. Friedlander *et al.*, who examined fertility decline in 600 districts of England and Wales (D. Friedlander, J. Schellekens and E. Ben Moshe, 'The transition from high to low marital fertility: Cultural or socio-economic determinants?', *Economic Development and Cultural Change*, **39** (1991), pp. 331–351), used measures for essentially two periods. Woods examined fertility in 590 districts of England and Wales in 1861, 1891, and 1911 (R. I. Woods, 'Approaches to the fertility transition in Victorian England', *Population Studies*, **41** (1987), pp. 283–311). Boonstra and van der Woude explored fertility decline during the last half of the nineteenth century in 375 districts in the Netherlands (O. W. A. Boonstra and A. M. van der Woude, 'Demographic transition in the Netherlands. A statistical analysis of regional differences in the level and development of the birth rate and of fertility 1850–1890', *A. A. G. Bijdragen*, **24** (1984), pp. 1–57. None used pooled regression techniques. Richards used a pooled cross-section time-series model in her analysis of 71 large regions covering Germany over five time periods ($n = 355$) (T. Richards, 'Fertility decline in Germany. An econometric appraisal', *Population Studies*, **31** (1977), pp. 537–553). In none of these cases were measures of income, financial services, transport–communications infrastructure, women's labour force participation in non-traditional occupations, concentrations of health workers, prevalence of church workers, or legitimate infant mortality used.

[5] F. Notestein, 'Economic problems of population change', *Proceedings of the English International Conference of Agricultural Economists* (1953), pp. 13–31.

[6] R. A. Easterlin and E. M. Crimmins, *The Fertility Revolution. A Supply Demand Analysis* (Chicago, University of Chicago Press, 1985).

[7] See R. J. Willis, 'A new approach to the economic theory of fertility behaviour', *Journal of Political Economy*, **81** (1973), pp. S14–S64, and the enormous literature which followed.

care. Furthermore, rising incomes raise the parental demand for child 'quality', and particularly education, which in turn raises the cost of children and reduces the number of children desired.[8] To the extent that more education is imposed on parents by state action, the potential labour value of children will also be reduced. For these various reasons, the relation of fertility to income may be either positive or negative; women's participation in work outside the home and outside agriculture should be negatively associated with fertility, as should the extent of education.[9]

Another line of theory emphasizes the value of children to their parents as assets: children provide labour services while young, and care and material assistance to their elderly parents, and so serve as a form of insurance against the risks of sickness or financial hardship.[10] However, such services by children are believed to yield a very low rate of return and are subject to risk in times of rapid social change when geographical and social distances between the generations increase. In these circumstances, banks or insurance plans which provide a far higher rate of return and are subject to different kinds of risk may substantially undermine the demand for children, by providing cheaper and surer versions of the same services. We expect, therefore, that increasing availability of banking and insurance services would reduce fertility. Furthermore, improved communications and transport will make access to the services provided in large cities easier for rural dwellers and should have the same effect.

The supply of surviving children

This phrase refers to bio-demographic influences on fertility, which it is believed are not consciously used to regulate fertility. In the context of marital fertility, the main factors here are breastfeeding practices, separation of spouses, and child survival. Unfortunately, we have no systematic information about breastfeeding. Separation can be important when there is substantial migration, and can be measured by the ratio of married men to married women. We expect this measure to be positively associated with both levels of and changes in fertility. When infant and child mortality are higher, couples may have more births in anticipation of child deaths, and fertility after a child's death may increase in order to replace the loss.[11] We expect, therefore, that levels of and changes in fertility will be positively related to legitimate infant mortality.

Costs of regulation

Issues that fall under this heading have in recent years played a central role in debates about the historical and contemporary decline of fertility. The leading concept is that ideas (fertility being within the rational calculus), attitudes (social acceptability of contraception), and knowledge of contraception diffuse geographically within religious, ethnic or linguistic boundaries. Indirect evidence for the importance of linguistic

[8] G. S. Becker, *A Treatise on the Family* (Cambridge, Mass., Harvard University Press, 1981).

[9] Economic theory tells us that fertility and the supply of female labour should be chosen jointly by each family within the given familial and community economic context; thus neither fertility nor female labour force participation should be regarded as the 'cause' of the other. We shall provide evidence later which suggests that our measure of female labour-force participation is an appropriate independent variable. We should also note that economic theory does not itself tell us that increasing employment opportunities for women lead to lower fertility, since increasing family incomes might do more than compensate for the rising opportunity costs of children. A large empirical literature has consistently found, however, that the effects of increased opportunities (as reflected, for example, in higher women's wages), are in fact negative.

[10] See J. C. Caldwell, *Theory of Fertility Decline* (New York, Academic Press, 1982); R. J. Willis, 'Public and private intergenerational transfers, economic growth, and demographic transition'. Paper presented at the Conference on Economic Development and Social Welfare, Taiwan, 1987.

[11] D. M. Heer, 'Infant and child mortality and the demand for children', in R. A. Bulatao and R. D. Lee (eds), *Determinants of Fertility in Developing Countries* (New York, Academic Press, 1983).

boundaries comes from the European Fertility Project.[12] There is, however, little evidence bearing on the question of what it is that is diffused. We have no direct information in our data-set about knowledge, attitudes or ideas. However, diffusion should be facilitated by improved transport and communication, so that fertility would be expected to be lower where such networks are better established. However, these networks lead to improved access to all aspects of the modern world, so that we cannot determine which aspect is responsible for any association with fertility.

Theories that cut across these categories

Not all influences fit neatly into one or other of these three categories. For example, specific religions may take positions on the acceptability of contraception. Religions may encourage literacy which has indirect effects, or discourage investment in child 'quality' for various reasons. We expect that fertility will be higher where organized religion is stronger. Previous research does suggest that fertility tends to be higher in Catholic areas. These hypotheses will be discussed in more detail later.

Whilst the gross association of urbanization with fertility is expected to be negative, this is mainly the result of the correlation between urbanization and other influences that we have already discussed. It is not clear whether the net association with fertility, after other influences have been controlled, should be positive or negative.

We do not claim to be able to isolate empirically the role of demand, supply and regulation cost variables: these categories were used only for organizational convenience. 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 socio-economic changes played an important part in the Prussian fertility decline. We intend thereby to respond to the numerous authors who have argued that such change is relatively powerless to explain the fertility transition.[13]

PRUSSIAN DATA, VARIABLES, UNITS OF ANALYSIS AND TIME PERIODS

The population of Prussia in 1910 amounted to some 40 million, larger than that of any other country in Europe except Russia and, of course, Germany, in which Prussia was the largest state. Prussia alone accounted for 12.5 per cent of the population of Europe as a whole, excluding Russia. Stretching from part of modern-day Belgium to Russia, Prussia covered virtually the entire Northern European Plain, and included the important grain-producing districts of East Prussia, as well as the largest industrial region in Europe, the Ruhr. There were few countries with such economically diverse regions. Many ethnic groups were found in Prussia, including Poles, Kassubians, Masurians, Danes and Walloons. Only the Austro-Hungarian empire exceeded Prussia in ethnic diversity. The period under consideration, 1875–1910, covers the process of transformation of a largely agrarian economy into the most powerful industrial state in Europe.[14]

[12] A. J. Coale and S. C. Watkins (eds), *The Decline of Fertility in Europe* (Princeton, Princeton University Press, 1986).

[13] See for example J. Knodel and E. van de Walle, 'Lessons from the past: policy implications of historical fertility studies', in Coale and Watkins (eds), *loc. cit.* in fn. 12; Cleland and Wilson, *loc. cit.* in fn. 2. See also E. A. Hammel, 'Cultural and economic factors in Croatian fertility decline'. Paper presented at the annual meeting of the Population Association of America, Denver, Colorado, 1992, who takes the opposite point of view.

[14] 'Even Prussia in the early 1870s was scarcely less rural than at the end of the Napoleonic wars, her agricultural population having declined merely from 73.5 to 71.5 per cent of the total in the years between 1816 and 1872... The question is not whether industrialization is established upon German territory but why by 1914 it is more securely established there than in any other continental country.' C. Trebilcock, *The Industrialization of the Continental Powers 1780–1914* (London, Longman, 1981), pp. 41–45.

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

		1867	1871	**1875**	**1880**	1882	**1885**	**1890**	**1895**	**1900**	**1905**	1907	**1910**
Fertility	General marital fertility rate (legitimate births per 1000 married women aged 15–49)*	P, R	P, R	P, R	P, R	—	P, R	P, R	P, R	P, R	P, R	—	P, R
Catholic	Percentage of Roman Catholics in total population	P	P	—	P	—	P	P	P	P	P	—	P
Slav	Percentage of population whose mother tongue is Slavic	P	—	—	—	—	—	P	—	P	—	—	—
Church	Percentage of religious personnel in population, aged 20+	O	—	—	—	O	—	—	O	—	—	O	—
Education	Teachers and associated administrative personnel, as percentage of population aged 6–13	O	—	—	—	O	—	—	O	—	—	O	—
Health	Percentage of total population employed in health services	O	—	—	—	O	—	—	O	—	—	O	—
Female Labour Force Participation Rate	Women employed outside agriculture and service occupations as a percentage of female population aged 20–69	O	—	—	—	O	—	—	—	—	—	O	—
Income	Average income of male elementary school teachers (in 1900 Marks)	*	*	*	*	—	E	E	E	E	E	—	E
Mining	Percentage of miners in population aged 20+	O	—	—	—	O	—	—	O	—	—	O	—
Urban	Percentage of urban population	—	—	P	P	—	P	P	P	P	P	—	P
Bank	Percentage of population aged 20+ employed in banking services	†	—	—	—	O	—	—	O	—	—	O	—
Insurance	Percentage of population aged 20+ employed in insurance	†	—	—	—	O	—	—	O	—	—	O	—
Communications	Percentage of population aged 20+ employed in postal, telegraph and railway work	‡	—	—	—	O	—	—	O	—	—	O	—
Infant mortality	Deaths of legitimately born infants under one year of age per 1,000 legitimate births	—	—	R	R	—	R	R	R	R	R	—	R
Married sex ratio	Ratio of number of married men/married women	—	P	—	—	—	P	P	P	P	P	—	P

E, Education census data; O, occupation census data; P, population census data; R, registration data.
* Estimate, based on change in province level income.
† Estimate, based on change in persons employed in trade per 100 population over age 20.
‡ Estimate, based on change in persons employed in postal, telegraph, railway, and other land transport per 100 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 are set equal to Slav in 1900. Stillbirths are excluded throughout.
Sources: Population, occupation and education censuses and registration data from *Preussische Statistik* (various volumes) and *Statistik des Deutschen Reichs* (various volumes).

The Prussian Statistical Bureau, in one form or another, had been collecting statistics since the seventeenth century, and continued to function after Prussia was incorporated into the German Empire in 1871. Between 1861 and 1914 the Bureau produced and published an extremely rich and comprehensive set of statistical data in an apparent attempt to record virtually every quantifiable social phenomenon. The German Empire had its own statistical office, which in theory covered all of Germany. However, the quantity and detail of its published material pale in comparison with the output of the Prussian Statistical Bureau. The collection is published in part in *Preussische Statistik*, which consists of over 300 statistical volumes that cover the period 1861–1914, with the most detailed data relating to the years between 1875 and 1910. Some of the later volumes cover the period after World War I, but lack the detail of earlier volumes.

An extraordinary amount of demographic and socio-economic data has been published for each *Kreis* and each large city.[15] Briefly, vital registration data were published in 1849, and then annually from 1862 to 1914. Population censuses were conducted every three years from 1849 to 1871, and thereafter every five years from 1875 to 1910. These included information about area, residence, households, institutions, age distribution by marital status, mother tongue, religion, place of birth and nationality. Detailed occupation, industrial, and agricultural censuses were taken in 1849, 1867, 1875, 1882, 1895, and 1907. Building censuses were conducted in 1849, 1861, 1878, 1893, and 1918. Special school censuses, in which information about schoolteachers' salaries was included, were taken in 1878 and 1882, and then every five years from 1886 to 1911. The quality as well as the quantity of Prussian census and registration material is impressive. Knodel examined nineteenth-century Prussian demographic data and found that their quality was high by the 1860s.[16] Wojtun concluded that vital registration and population counts in Prussia were virtually complete by 1864.[17]

The availability of registration, and census data for the variables used in our analysis is shown in Table 1. A detailed discussion of these variables, together with theoretical expectations and the results of previous research in which similar variables were used, will be presented later. The notes to Table 1 indicate situations in which interpolation was necessary. It was used primarily for the occupation variables and appears reasonable, since such structural variables tend to move slowly and monotonically over time. Extrapolation was used only for the occupation data for the short period 1907–10. The occupation data refer only to the primary occupations of the economically active population and include both males and females. Unfortunately, no data exist for the proportion of the population of Slav mother tongue after 1900. As a consequence the values of this variable for 1905 and 1910 are assumed to have been the same as in 1900.

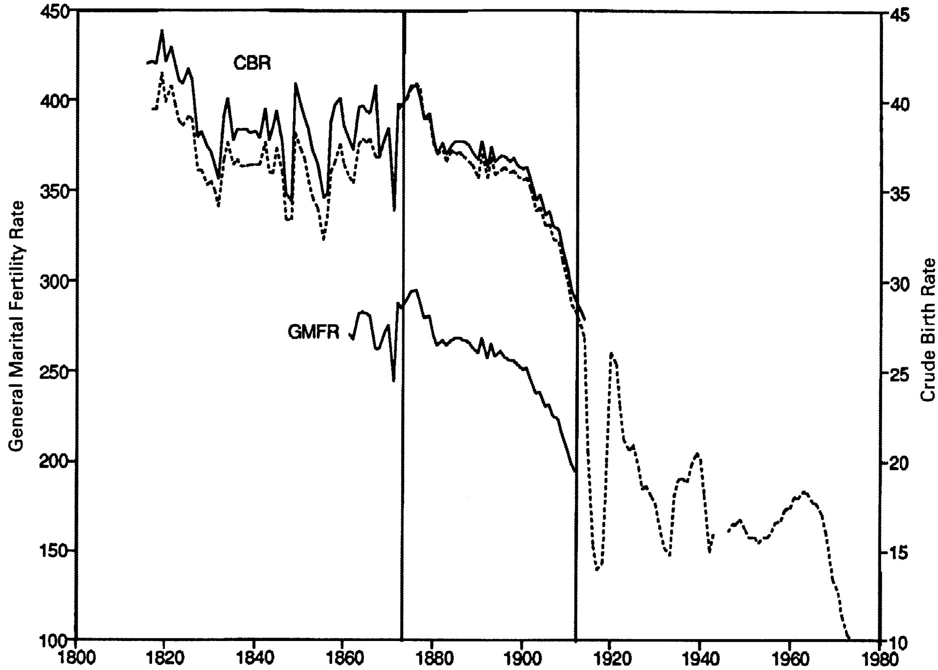
The dates used in our analysis are those ending in '0' or '5' between 1875 and 1910 which correspond to population census dates, and to the period for which the richest and most detailed data are available. Data for the census years 1867 and 1871 were not used, because in those years the general marital fertility rate is less well defined, no information on infant mortality and urbanization is available, and the income, communications, bank, and insurance variables must be roughly estimated.

The unit of analysis in this study is the *Kreis*. Because of administrative sub-division and occasional re-districting, usually as a result of urban growth, the number of *Kreise*

[15] P. R. Galloway, *Prussia: Vital Registration and Census Data Description Tables 1849 to 1914 using Kreise and Cities > 20,000 as Units of Analysis* (Graduate Group in Demography, University of California, Berkeley, 1988).

[16] J. Knodel, *The Decline of Fertility in Germany, 1871–1939* (Princeton, Princeton University Press, 1974), p. 28.

[17] B. S. Wojtun, 'Demographic Transition in West Poland, 1816–1914' (Ph.D. Dissertation, Department of Economics, University of Pennsylvania, 1968), pp. 69–131.



Sources: General Marital Fertility Rate and Crude Birth Rate in Prussia (*Preussische Statistik:* various). Crude Birth Rate in Germany (B. R. Mitchell, 1981: *European Historical Statistics,* New York, pp. 116-132).

Figure 1. General marital fertility rates and crude birth rates in Prussia, and crude birth rates in Germany (annual data). Solid lines represent Prussia, dashed lines represent Germany. Space between vertical lines indicates period of analysis (1873–1912).

in Prussia increased from 453 to 586 between 1875 and 1910. A unit of analysis with constant area over time is essential to measure temporal changes in variables. Our standardization of *Kreise* in Prussia resulted in 407 units of constant area from 1875 to 1910.

Nearly all the conclusions from the Princeton European Fertility Project are based on studies in which larger units of analysis were used. These were often called provinces, which in Prussia correspond to *Regierungsbezirke*, the next higher administrative level above the *Kreis*. These units may, in fact, be too large, and in the case of Germany, and of Prussian data in particular, analysis of such highly aggregated units can lead to unwarranted conclusions.[18] Knodel, Richards, Lesthaeghe and Wilson, and Coale and Watkins used 30 *Regierungsbezirke* as units of analysis when working with Prussia, while we shall use 407 *Kreise*.[19]

Figure 1 presents annual crude birth rates for Germany from 1817 to 1975, annual crude birth rates for Prussia 1816–1914, and annual general marital fertility rates for

[18] Germany (and Prussia) evolved from the Holy Roman Empire, which was renowned for its profusion of small bishoprics, principalities, duchies, kingdoms, counties, electorates, margravates, etc. The boundaries of the *Regierungsbezirke* in nineteenth-century Prussia often conform to the boundaries of these older states. It was to the advantage of the rulers of these states to annex lands and develop industries that would increase their economic independence. Each tended to have a small and heterogeneous working economy. Thus, relatively larger socio-economic heterogeneity would be expected within *Regierungsbezirke* than between them.

[19] Knodel, *op. cit.* in fn. 16; T. Richards, *loc. cit.* in fn. 4; R. Lesthaeghe and C. Wilson, 'Modes of production, secularization, and the pace of fertility decline in Western Europe, 1870–1930', in Coale and Watkins (eds), *loc. cit.* in fn. 12.

Prussia from 1861 to 1912. It is impossible to calculate the latter rates for Prussia before 1861 because data are lacking, or after World War I because of substantial boundary changes. It seems that fertility in Prussia and Germany began a gradual secular decline from a long-term plateau from 1880 to the 1890s, and that the decline accelerated after 1900. Knodel, who used the arbitrary definition of a 10 per cent decline established by the Princeton project, set the date of the onset of fertility decline in Germany at 1895.[20] We observe a sharp fall in fertility in 1871 as a result of the Franco-Prussian war, followed by a period of unusually high fertility extending from 1872 to around 1880, due in part to compensation for the decline in 1871, marriages of war veterans, remarriages of war widows, and perhaps also the general euphoria that followed the Prussian victory.

DEPENDENT VARIABLE

The dependent variable is the general marital fertility rate, i.e. the number of legitimate births per 1000 married women aged 15 to 49 (henceforth referred to simply as 'marital fertility'). A five-year average of legitimate births centred on the census year is used. For example, to calculate the rate for 1880, the average number of legitimate births from 1878 to 1882 is divided by the number of married women aged 15–49, shown in the census.[21]

INDEPENDENT VARIABLES

In Table 1 the availability and sources of the data used to construct the variables are shown. Summary statistical measures can be found in Table 2.[22]

[20] *Op. cit.* in fn. 16, pp. 58–62.

[21] The difference between the general marital fertility rate and the Hutterite index I_g used in the Princeton 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' (A. J. Coale and R. Treadway, 'A summary of changing distribution of overall fertility, marital fertility, and the proportion married in the provinces of Europe', in Coale and Watkins (eds), *op. cit.* in fn. 12, p. 156). To calculate I_g for each *Kreis* would require estimating the age structure by five-year groups between ages 15 and 49, for most census years. Coale and Treadway in their overview state that 'there would have been little difference in the findings of our research if these conventional measures [general, or general marital fertility rates] had been used (p. 153). Preliminary analysis of 54 Prussian cities from 1875 to 1910, where I_g can be calculated, indicates that the general marital fertility rate is strongly correlated with I_g ($r > 0.97$ for all periods). The two measures are, in effect, interchangeable.

Legitimate births are available for the entire period 1873–1912, and numbers of married women aged 15–49 are available for each census year from 1890. Thus the general marital fertility rate can be calculated directly from published data for 1890, 1895, 1900, 1905, and 1910. An age distribution for females is not available by *Kreis* in 1880 or 1885. Estimates of the numbers of married women aged 15 to 49 for these dates are based on the ratio of the number of married women aged 15–49 to the total female population in 1890 applied to the total female population at those dates. In 1875 an age distribution for women is available, but not by marital status: the number of married women aged 15–49 has been estimated by applying to the total number of women aged 15–49 in 1875 the ratio of married women aged 15–49 to all women of these ages in 1890. We make these estimates with confidence, realizing that the proportionate age distribution changes very slowly, if at all, over any given 15-year interval, and that it is the change in the number of legitimate births which will generally dictate any significant change in the general marital fertility rate.

[22] Instead of using broad economic-sector variables, such as percentage of employed labour force in industry, services or agriculture, we have decided to construct economic variables that are more directly responsive to economic theoretical expectations. Furthermore, the German occupation 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 increase of two million in this category between 1895 and 1907. (See F. B. Tipton, *Regional Variations in the Economic Development of Germany during the Nineteenth Century* (Connecticut, Wesleyan University Press, 1976).) None of our variables is affected by this problem.

Table 2. *Summary statistics*

	1875–1910	1875	1880	1885	1890	1895	1900	1905	1910
					Mean				
GMFR	261.166	282.439	275.221	269.304	265.714	265.561	259.524	243.600	227.968
Catholic	34.728	34.058	34.193	34.351	34.606	34.739	35.000	35.346	35.531
Slav	9.018	9.003	9.018	9.034	9.049	9.027	9.004	9.004	9.004
Church	0.217	0.221	0.210	0.204	0.202	0.200	0.217	0.234	0.251
Education	2.097	1.747	1.801	1.912	2.062	2.212	2.279	2.347	2.414
Health	0.190	0.136	0.132	0.143	0.165	0.186	0.219	0.253	0.286
FLFPR	10.417	6.524	8.105	9.249	10.101	10.954	11.877	12.800	13.723
Income	1117	937	1001	1063	1038	1133	1275	1245	1246
Mining	1.790	1.503	1.648	1.694	1.674	1.655	1.852	2.049	2.246
Urban	29.964	27.055	27.954	28.699	29.250	30.103	31.216	32.289	33.148
Bank	0.053	0.027	0.030	0.034	0.039	0.043	0.063	0.083	0.102
Insurance	0.038	0.016	0.018	0.022	0.027	0.032	0.047	0.063	0.078
Communications	1.113	0.670	0.722	0.816	0.938	1.060	1.312	1.565	1.817
Infant mortality	178.637	185.480	183.955	187.736	183.873	182.810	178.819	171.476	154.949
Married sex ratio	0.991	0.987	0.989	0.991	0.990	0.993	0.991	0.992	0.994
					Standard deviation				
GMFR	44.625	37.214	35.294	35.950	35.683	39.983	44.685	47.628	52.251
Catholic	36.957	37.506	37.393	37.309	37.113	37.027	36.777	36.510	36.297
Slav	21.498	21.766	21.726	21.700	21.690	21.465	21.271	21.271	21.271
Church	0.151	0.102	0.091	0.100	0.126	0.156	0.165	0.188	0.221
Education	0.707	0.611	0.605	0.617	0.646	0.698	0.691	0.706	0.743
Health	0.132	0.074	0.080	0.089	0.100	0.113	0.130	0.154	0.182
FLFPR	6.598	4.481	5.308	5.792	6.026	6.307	6.659	7.051	7.478
Income	248.587	172.113	178.915	190.209	193.001	226.540	242.263	259.905	262.790
Mining	4.913	4.372	4.793	4.878	4.755	4.678	4.910	5.222	5.600
Urban	18.962	17.924	18.021	18.294	18.740	18.968	19.348	19.613	20.007
Bank	0.091	0.077	0.083	0.082	0.077	0.074	0.084	0.099	0.116
Insurance	0.078	0.040	0.045	0.051	0.059	0.067	0.083	0.100	0.118
Communications	0.729	0.476	0.480	0.496	0.515	0.547	0.640	0.759	0.893
Infant mortality	47.856	45.900	48.244	49.714	48.645	49.442	46.926	45.091	39.901
Married sex ratio	0.030	0.031	0.028	0.028	0.025	0.024	0.034	0.034	0.030

Catholic (percentage of Roman Catholics in the total population)

Religion has been used as a variable in most fertility analyses, but is particularly interesting in Prussia. Roman Catholics amounted to 35 per cent of the population in 1900, and were either German Catholics who lived primarily in the southwest (Rhineland or Westphalia), or Polish and German Catholics who lived in the east in the great agrarian regions of Posen and East Prussia, or the important coal-mining and industrial area of Silesia. Most *Kreise* were either predominantly (over 90 per cent) Catholic or predominantly Protestant.

We expect the proportion of Catholics to be positively correlated with fertility. Catholics are often considered to hold more traditional views concerning fertility control than Protestants.[23] The Roman Catholic Church today still condemns any form of contraception, except rhythm. Golde, who based his analysis on ethnographic and historical comparisons of two neighbouring Catholic and Protestant villages in Württemberg, suggested that Protestantism, by stressing literacy for religious purposes, enabled Protestant farmers to read technical agricultural journals and facilitated a professional attitude towards farming.[24] That professionalization, in turn, led to earlier mechanization than among Catholics and to a consequent decline in the labour value of children, and thus to lower incentives for fertility.

Slav (percentage of population with Slav mother tongue)

A unique feature of nineteenth-century Prussia was the large number of Poles and other Slav speakers found within its borders, mainly in the eastern region of Posen, Silesia and East Prussia. Knodel found that fertility was relatively high in areas with high concentrations of Poles,[25] but did not examine the effects of other possible explanatory variables. Lesthaeghe found language to be an important indicator of fertility in his analysis of Belgium, and Leasure found that regional fertility in Spain was highly correlated with linguistic boundaries.[26] Watkins found a significant positive correlation between the proportion of non-French speakers and I_g in French *départements* around 1871, after controlling for income.[27] Hammel found that dialect homogeneity was of dubious relevance in an analysis of Croat fertility.[28]

Church (percentage of religious personnel in population aged 20+)

We expect that church workers typically promoted traditional ideas of fertility behaviour, so that concentrations of church workers would be associated with higher levels of fertility. This category consists of those whose primary occupation was in church activities, i.e. clergy, missionaries, and members of religious institutions. This variable has never been used in the analysis of European historical fertility decline.[29]

[23] Knodel, *op. cit.* in fn. 16, pp. 130, 141; S. C. Watkins, *From Provinces into Nations. Demographic Integration in Western Europe, 1870–1960* (Princeton, Princeton University Press, 1991), p. 83.

[24] G. R. Golde, *Catholics and Protestants: Agricultural Modernization in Two German Villages* (New York, Academic Press, 1975).

[25] *Op. cit.* in fn. 16.

[26] R. Lesthaeghe, *The Decline of Belgian Fertility 1800–1970* (Princeton, Princeton University Press, 1977); J. W. Leasure, 'Factors Involved in the Decline of Fertility in Spain, 1900–1950' (Ph.D. Dissertation, Princeton University, 1962).

[27] S. C. Watkins, *op. cit.* in fn. 23, p. 161.

[28] Hammel, *loc. cit.* in fn. 13.

[29] Variables, such as the proportions Catholic, Slav-speaking, and church workers are sometimes classed as 'cultural variables'. See E. A. Hammel, 'A theory of culture for demography', *Population and Development Review*, **16** (1990), pp. 445–486, for a discussion of the problems involved in differentiating 'cultural' from 'economic' variables.

Education (*ratio of teachers per 100 population aged 6–13*)

This variable includes teachers in elementary, high, teachers' technical and private schools, together with administrative and service personnel in education. The variable may be interpreted in two ways. It could reflect the education of the parents, and as such represent exposure to new ideas: a kind of proxy for diffusion or modernization. On the other hand, it may reflect a diminished demand for child labour. In either case, we would expect the education variable to be inversely correlated with fertility. Indeed, school attendance rates or proportions literate have been commonly used in previous research, and are usually negatively correlated with fertility.[30]

Health (*percentage of health workers in the population*)

Dissemination of knowledge about contraception may be facilitated by the availability of health workers, especially as the technology becomes more elaborate. This category includes physicians, nurses, midwives, veterinary surgeons, and associated administrative and service personnel. We would expect this variable to be negatively correlated with fertility.

Female labour force participation rate in non-traditional occupations (*FLFPR*)

This is the number of employed women (excluding those employed in agriculture, domestic service, and government service) divided by the number of women aged 20–69. We have excluded agriculture and domestic service, because they are traditional occupations for women.[31] As opportunities for women to enter the commercial and industrial sectors increase, so do the costs of child rearing, and fertility rates are expected to decline. This variable has been commonly used in contemporary studies of fertility decline and has almost always been found to be negatively correlated with fertility.

The direction of causality is, however, problematic. Do married women have fewer children because they are working, or are they working because they have fewer children? This simultaneity would be avoided, if we could examine the labour force participation rate for unmarried women only.[32] Such information is not available over time at the *Kreis* level, but is available for a number of cities in Prussia (38 in 1882, 18 in 1895, and 26 in 1907). In these cities the participation rate for all women (our variable) is very highly correlated with that for unmarried women ($r = 0.87$, 0.83, and 0.67 for 1882, 1895, and 1907 respectively). Corresponding correlations with the participation rates of married women are generally weaker ($r = 0.65$, 0.52, and 0.73). Furthermore, married women formed only 10 per cent of the female labour force in 1882, the figure

[30] The alternative – to use data on literacy – is not attractive. Information on literacy by *Kreis* is available in Prussia only for one year, 1871. However, compulsory education began in the eighteenth century and was enforced with progressively greater strictness. Negligent parents or their representatives were liable to fines, or even imprisonment. (C. M. Cipolla, *Literacy and Development in the West*, London, Penguin Books, 1969, p. 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 per cent of Prussian army recruits were illiterate, compared with 39 per cent in Austria-Hungary, 17 per cent in France, 49 per cent in Italy, and 7 per cent in Switzerland. *Ibid.* p. 118.

[31] Government service has been excluded because it is combined with domestic service in earlier censuses. Later censuses show that very few women were employed in government service.

[32] N. F. R. Crafts, 'A cross-sectional study of legitimate fertility in England and Wales, 1911', *Research in Economic History*, **9** (1984), pp. 89–107.

rising to 14 per cent by 1907.[33] Therefore, our measure reflects for the most part employment opportunities for unmarried women. As these opportunities increase (see Table 2), the perceived costs of children go up, and fertility is expected to decline. It is also possible that as participation rates increased, more single young women were exposed to new ideas in the workplace, and perhaps changed their perceptions about the utility of the traditional family.

Income (average annual real income of male elementary schoolteachers)

As has been explained earlier, income may be an important factor in determining the demand for children. According to Becker,[34] as income increases, the quantity of children should increase *ceteris paribus*. However, this increase in quantity may be offset by a demand for higher quality, as well as by an increase in costs resulting from an increase in the value of women's time. In fact, most contemporary students of fertility decline in less-developed countries have suggested that income and fertility are negatively correlated. Direct measures of income have rarely been used in the analysis of European fertility decline. This suggests the need for caution in accepting Knodel and van de Walle's assertion: 'we believe the historical record suggests the relative lack of importance of income and prices in determining the demand for children prior to or during the early stages of the fertility decline'.[35]

While some estimate of average real wages might be useful, we have used the real salary of male elementary schoolteachers as a proxy for overall income, because teaching is a well-defined occupation and facilitates cross-sectional comparison. It is also the only measure of income available for each *Kreis* for each period from 1885 to 1910. The funding of teachers' incomes came almost entirely from local taxes, though the amount was often determined by state policy.[36]

Information on income tax per head for each *Kreis* is available for 1875 and 1900 and is highly correlated with the salaries of male elementary schoolteachers ($r = 0.72$ and 0.80 respectively). Prussian male elementary schoolteachers' salaries and Germany's industrial and agricultural real wages correspond fairly well from 1880 to 1910, with average annual growth rates over the entire period of 0.9 and 0.8 per cent respectively.[37] However, from 1875 to 1880, the earliest period analysed, Prussian teachers' real salaries increased, whilst German industrial and agricultural wages fell.

[33] Dasey has suggested that married women in the labour force were probably undercounted in the occupation censuses. See R. Dasey, 'Women's work and the family: women garment workers in Berlin and Hamburg before the First World War', in R. J. Evans and W. R. Lee (eds), *The German Family. Essays on the Social History of the Family in Nineteenth- and Twentieth-Century Germany* (London: Croom Helm, 1981), pp. 228, 232.

[34] Becker, *op. cit.* in fn. 8.

[35] Knodel and van de Walle, *loc. cit.* in fn. 13, p. 416.

[36] Estimates for 1875 and 1880 are based on teachers' income data for provinces for 1875, 1880, and 1885. Using the *Kreis* data for 1910 is problematic, because of some definitional changes. The data for 1910 have, therefore, been estimated from changes in province-level income tax per head 1905–1910, applied to the data for 1905 (Statistisches Reichsamt, 'Das deutsche Volkseinkommen vor und nach dem Kriege', *Einzelschriften zur Statistik des Deutschen Reichs*, **24**, pp. 1–198. The nominal salary in each *Kreis* has been divided by a cost of living index that covers food and rent for Germany, in order to estimate the 'real' salary over time. The index with 1900 taken as a base is: 1875, 0.99; 1880, 0.99; 1885, 0.91; 1890, 0.98; 1895, 0.95; 1900, 1.00; 1905, 1.07; 1910, 1.20 (J. Kuczynski, *Die Geschichte der Lage der Arbeiter in Deutschland von 1800 bis in die Gegenwart* (Berlin, Freie Gewerkschaft, 1947, p. 73)). See also G. Bry, *Wages in Germany 1871–1945* (Princeton, Princeton University Press, 1960, pp. 325–326, 356). More recently, Desai has constructed a cost of living index for Germany which is about the same as Kuczynski's (A. V. Desai, *Real Wages in Germany, 1871–1913*. Oxford, Clarendon Press, 1968). It is not possible to construct an adequate cost of living index specific for each *Kreis*. See K. A. Schleunes, *Schooling and Society: The Politics of Education in Prussia and Bavaria 1750–1900* (London: St Martin's Press, 1989).

[37] Kuczynski, *op. cit.* in fn. 36, pp. 170–173.

In many multivariate analyses of European fertility decline, relatively crude and indirect measures of income have been used. For example, rural land revenue per head was negatively correlated with fertility in France,[38] percentage of population with bank accounts, available only at the *Regierungsbezirk* level, and only for 1900, was not significant in Germany,[39] and property taxes per head, available for only one period, were negatively correlated with urban fertility in England.[40] In his study of Great Britain, Teitelbaum used a county-level income measure taken from Hechter's work.[41] However, this measure is based on incomplete tax returns, and Hechter himself expressed serious reservations about its reliability.[42] Lindert, in his analysis of 37 U.S. states, found that income in 1900 was positively correlated with the child–woman ratio.[43] Examining French *départements*, Watkins found a significant negative correlation in France between disposable income per person aged 16–60 in 1866, and I_g in 1871.[44] Using less aggregated data, Bertillon and Mombert found that fertility levels around 1900 were negatively correlated with average rents in districts in the cities of Berlin, Hamburg, Leipzig, Munich, Dresden and Magdeburg.[45] However, these studies were based on a simple bivariate analysis.

Mining (percentage of mineworkers in the population aged 20+)

Previous authors have found a positive correlation between fertility and percentage of the labour force employed in mining.[46] Haines attributed this to 'early-peaking income earnings profile over the life cycle, low levels of women's labour force participation outside the home, and low child costs.[47] This was supported by his multivariate analysis of 26 Prussian *Kreise* dominated by mining.[48] Friedlander *et al.*, and Woods also found a high correlation between fertility and proportions engaged in mining in England and Wales, although Mosk found mining districts in Japan to be characterized by moderate fertility.[49]

Urban (percentage of population living in places with more than 2000 inhabitants)

This is the definition that was used by the Prussians, and as such sets rather a low limit to urbanization. The urban sector is typically the source of new ideas, and high population density facilitates their rapid spread.

[38] E. van de Walle, 'Alone in Europe. The French fertility decline until 1850', in C. Tilley (ed.), *Historical Studies of Changing Fertility* (Princeton, Princeton University Press, 1978).

[39] Knodel, *op. cit.* in fn. 16, p. 235.

[40] Crafts, *loc. cit.* in fn. 32.

[41] M. S. Teitelbaum, *The British Fertility Decline: Demographic Transition in the Crucible of the Industrial Revolution* (Princeton, Princeton University Press, 1984); M. Hechter, *Internal Colonialism, the Celtic Fringe in British National Development 1536–1966* (Berkeley, University of California Press, 1975).

[42] Hechter, *op. cit.* in fn. 41, p. 162.

[43] P. H. Lindert, *Fertility and Scarcity in America* (Princeton, Princeton University Press, 1978), p. 150.

[44] Watkins, *op. cit.* in fn. 23, p. 161.

[45] J. Bertillon, 'La natalité selon le dégré d'aisance. Étude à ce point de vue de Paris, Londres, Berlin et Vienne', *Bulletin de l'Institut International de Statistique*, **9** (1899), pp. 163–176; P. Mombert, *Studien zur Bevölkerungsbewegung in Deutschland in den letzten Jahrzehnten mit besonderer Berücksichtigung der ehelichen Fruchtbarkeit* (Karlsruhe, Braunsche, 1907).

[46] E. A. Wrigley, *Industrial Growth and Population Change. A Regional Study of the Coalfield Areas of North West Europe in the Later Nineteenth Century* (Cambridge, Cambridge University Press, 1962), p. 154; M. Haines, *Fertility and Occupation. Population Patterns in Industrialization* (New York, Academic Press, 1979), p. 57.

[47] Haines, *op. cit.* in fn. 46, p. 57.

[48] *Ibid.* p. 82.

[49] Friedlander *et al.*, *loc. cit.* in fn. 4; Woods, *loc. cit.* in fn. 4; C. Mosk, 'Fertility and occupation, mining districts in prewar Japan', *Social Science History*, **5** (1981), pp. 293–315.

Bank (percentage of bank workers in population aged 20+)

This is a general measure of the importance of banking services in the population, and may serve as a useful indicator of wealth or the spread of financial services which may offer not only alternative investments, but also alternative forms of security in old age. 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 to be a form of investment, with some expectation of returns, the variable would function as an investment alternative. In either case, it should be negatively correlated with fertility.[50] Knodel 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 was not significant in a multivariate model.[51] Steckel found, in a multivariate analysis of 638 rural families in the United States 1850–60, that the number of banks per head was significantly negatively correlated with marital fertility.[52]

Insurance (percentage of insurance workers in population aged 20+)

Contemporary studies of fertility decline in less-developed countries have often found that parents perceive children as a kind of social security, especially in old age, as well as a way of maintaining income during sickness. The development of an effective insurance service would tend to replace this role, leading in turn to a decrease in the demand for children. In the German Empire, of which Prussia formed part, legislation was enacted in the 1880s to initiate programmes for government-backed universal insurance against sickness and accidents, together with an invalidity, old age and survivor pension system.[53] The administration of these schemes was undertaken primarily by government agencies and by employer-formed mutual associations under the authority of the Imperial Insurance Office.[54] In his analysis of the growth of occupational groups in Germany from 1882 to 1907, Clapham found that within the trade and transport group the number of persons employed in insurance grew fastest, reflecting its increasing importance.[55] 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.

Communications (percentage of postal, telegraph, and railway workers in the population aged 20+)

This variable serves as a convenient proxy for the development of communication and transport systems, which in turn may reflect the diffusion of new ideas, including contraception.[56] As such, we would expect it to be negatively correlated with fertility.

[50] J. S. Hammer, 'Children and savings in less developed countries', *Journal of Development Economics*, **23** (1986), pp. 107–118.

[51] Knodel, *op. cit.* in fn. 16, pp. 235–236.

[52] R. H. Steckel, 'The fertility transition in the United States. Tests of alternative hypotheses', in C. Goldin and H. Rockoff (eds), *Strategic Factors in Nineteenth Century American Economic History* (Chicago, University of Chicago Press, 1992), p. 364.

[53] W. H. Dawson, *Social Insurance in Germany 1883–1911. Its History, Operation, Results* (London: Unwin, 1912); G. A. Ritter, *Social Welfare in Germany and Britain. Origins and Development* (New York, Berg, 1986).

[54] Dawson, *op. cit.* in fn. 53, pp. 72–74, 106, 109, 130–132, 173, 181, 278.

[55] J. H. Clapham, *Economic Development in France and Germany, 1815–1914* (Cambridge, Cambridge University Press, 1961).

[56] We have not been able to separate postal workers from telegraph and railway workers because of the manner in which the classifications in the occupation census are constructed.

Infant mortality (legitimate infant mortality rate)

This is defined as the number of deaths of legitimately born children during their first year of life, multiplied by 1,000 divided by the number of legitimate births. Five-year averages centred on census years are used. As infant mortality declined, the number of births needed to attain a desired or expected family size would decrease, assuming that the couple had some notion of desired or expected family size. However, it has been shown that in some places the decline of fertility preceded that of mortality,[57] which suggests that the two variables may not be causally related. Nonetheless, most previous research has suggested that infant mortality is positively correlated with fertility. 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 rates of illegitimate infant mortality might tend to blur the actual effect of infant mortality. Legitimate infant mortality rates have not been used in previous research on the European fertility transition.

Married sex ratio (married men per 100 married women)

The ratio of married men to married women is included as a control variable to measure the separation of spouses due to temporary or permanent relocation of the husband or wife. The variable should be positively correlated with fertility.

METHOD

In most previous research on fertility decline, only a few periods were analysed, and usually only effects on fertility level were estimated. In only one other study were pooled cross-sectional and time series techniques used.[58] We focus on the analysis of fertility level and the pace of fertility decline.[59]

We use a pooled cross-section time-series approach, with fixed effects. This will allow us to distinguish between the role of variables in explaining differences between *Kreise* in the general level of fertility on the one hand, and changes over time in fertility within *Kreise* on the other. Demographic transition theory seeks to explain the causes of fertility decline within *Kreise*, but was not developed to explain the pattern of long-standing fertility differences between *Kreise*. Such long-standing differences reflect relatively invariant features of each area – climate, topography, and ecology. These features, some of them observed and others not, may be empirically associated with other variables in ways which distort their estimated coefficients in the analysis of fertility levels. By using a fixed-effects model, we can concentrate on the causes of changes in fertility over time. This model allows each *Kreis* to have its own average fertility level, and attempts only to explain the temporal pattern of deviations from that average. We are thus able to focus on the central issues of the demographic transition.

We examine three regressions. Equation (1) uses ordinary least squares on the pooled data, Equation (2) on means, while Equation (3) uses fixed effects. In terms of analysis

[57] F. van de Walle, 'Infant mortality and the European demographic transition', in Coale and Watkins (eds), *loc. cit.* in fn. 12.

[58] Richards, *loc. cit.* in fn. 4.

[59] We do not examine the onset of fertility decline. Attempts to determine consistently the onset of marital fertility decline in *Kreise* resulted in many difficulties. In some cases the turning point was obvious, in others it was less clear. In some *Kreise*, fertility began to decline gradually from 1880 to 1890, and then dropped very steeply from 1890 to 1910. Did fertility begin to decline in 1880 or in 1890? If five- or ten-year cycles were included, the situation would become even more complex.

of variance, Equation (2) produces estimates of variation between *Kreise*, whilst Equation (3) generates estimates of variation within *Kreise*.[60]

We first run ordinary least squares on the pooled data. Let Y be the dependent variable (marital fertility). X_k will represent the k independent variables shown in Table 1, C is a constant, and a a regression coefficient; e is the error term, N is the number of *Kreise* in each census (407) and T the number of censuses (8), and the sample size is $NT = 3,256$.

$$Y_{it} = C + a_1 X_{1it} + a_2 X_{2it} + a_3 X_{3ait} + \dots a_k X_{kit} + e_{it} \quad (1)$$

for $t = 1, 2 \dots, T$ and $i = 1, 2 \dots, N$.

The estimated coefficients from this equation may be difficult to interpret because they mix effects on levels with those on change. In order to examine the effect of average levels of independent variables on the average level of marital fertility we run a regression with Equation (2). This produces an estimate of variation between *Kreise*. Sample size is 407.

$$\bar{Y}_i = C + b_1 \bar{X}_{1i} + b_2 \bar{X}_{2i} + b_3 \bar{X}_{3i} + \dots b_k \bar{X}_{ki} + e_i \quad (2)$$

for $i = 1, 2 \dots, N$.

The fixed-effects model produces estimates of variation within *Kreise*. It is the most appropriate model for the study of fertility decline, as discussed above. We introduce 407 *Kreis* dummies, W, with coefficients d. The non-dummy coefficients show how changes in their levels affect changes in the levels of fertility net of individual *Kreis* effects. By examining the impact of changes in independent variables on changes in fertility we can get some idea about which variables may be important in determining the pace of fertility decline, which is perhaps more interesting than an examination of determinants of fertility levels. In a two-period model this equation yields exactly the same estimates as a regression of the first differences of the dependent variable on first differences of the independent variables without a constant. Sample size is 3,256.

$$Y_{it} = c_1 X_{1it} + c_2 X_{2it} + c_3 X_{3it} + \dots a_k X_{kit} + d_1 W_{1t} + d_2 W_{2t} + \dots d_N W_{Nt} + e_{it} \quad (3)$$

for $t = 1, 2 \dots, T$; $i = 1, 2 \dots, N$; and where $W = 1$ for the ith unit of analysis, $i = 1, \dots, N$ and 0 otherwise.

We assess the usefulness of adding *Kreis* area dummies to the pooled data regressions, using tests described by Pindyck and Rubinfeld.[61] These procedures allow us to test the joint significance of any sub-set of independent variables. *Kreis* area dummies were tested and found to be jointly significant in Equation (3). Because in Equation (1) effects on level and pace are mixed, we shall focus our interpretation on the results of Equations (2) and (3).[62]

[60] The regressions as a group are discussed in detail by Maddala. We have used the software package 386 TSP. See G. S. Maddala, *Econometrics* (New York, McGraw-Hill, 1977), pp. 320–331. For the package see B. H. Hall, C. Cummins and R. Schnake, *Time Series Processor Version 4.2. Reference Manual* (Palo Alto, TSP International, 1992).

[61] R. S. Pindyck and D. L. Rubinfeld, *Econometric Models and Economic Forecasts* (New York, McGraw-Hill, 1981), pp. 118, 255.

[62] The estimated coefficients from regressions in Equations (2) and (3) are mathematically related. The dummy estimates d (produced from Equation (3)) are regressed on the right-hand side of variables shown in Equation (2) (the average level of independent variables). The regression generates k coefficients, which we shall call M_K. The 'between' estimate minus the 'within' estimate is $M_K = b_k - c_k$.

It has been shown that the random-effects model may be somewhat more efficient under certain conditions (Pindyck and Rubinfeld, *op. cit.* in fn. 61; G. G. Judge, R. C. Hill, W. E. Griffiths, H. Lutkepohl and T. C. Lee, *Introduction to the Theory and Practice of Econometrics* (New York, Wiley, 1988), pp. 515–560). However, because our *Kreis* dummies are significantly related to the average level of our independent variables, estimation of the variance-components model is probably not appropriate in this case (Maddala, *op. cit.* p. 331).

REGRESSION RESULTS

The basic results are presented in Table 3. Looking at level effects (Equation 2), we see that only three variables are statistically significant: Catholic, Slav, and Mining. Health is barely significant. All four variables have the expected signs. These results support previous findings that religion, ethnicity, and concentration of mineworkers are very important indicators of fertility level (discussed earlier).[63]

Pace effects are shown in Equation (3), which is theoretically the more interesting model. All variables which are statistically significant have the expected sign, except Catholicism.[64] Church, Education, Female Labour Force Participation, and Mining are all important, as are the three financial and communications variables, Bank, Insurance and Communication, and the two demographic variables, Infant Mortality and Married Sex Ratio. Changes in ethnicity, concentrations of health workers, income, and urbanization are not associated with fertility decline.[65]

A correction for autoregressive disturbance in Equation (3), using Cochrane and Orcutt's iterative procedure, produces estimates and significance levels that are similar for all except two variables: the Income estimate becomes positive and significant, and the Mining estimate becomes significantly negative. We show later that neither variable is important in predicting fertility decline. There are no problems with serial correlation in Equation (2) and we are not interested in interpreting Equation (1).

We have not lagged any of our independent variables, because we know of no theory that suggests appropriate lags. Furthermore, we cannot lag annually because our data are quinquennial. We do not permit coefficient estimates to vary across broad regions of Prussia (but see P. R. Galloway, 'Fertility decline in Prussia. A regional analysis'. Paper presented at the IUSSP Seminar on Old and New Methods in Historical Demography. A Critical Appraisal, Mallorca, 1991) for a preliminary analysis. We have not considered that the pace of decline may be related to the levels of explanatory variables, rather than their changes, nor that the pace of fertility decline may be related to its initial level. These and other possibilities, including non-linear specification, urban fertility decline, the impact of voting behaviour on fertility decline, and determinants of non-marital fertility, will be explored in later studies.

[63] We have examined the possibility that the slopes of the coefficients may vary over time by interacting the dependent variables X with time dummies Z, whilst also including the time dummies in the equation with coefficients c. This is important, because we know that fertility levels in 1875 may have been affected by the Franco-Prussian war. Furthermore, the effects of some variables on fertility may have changed over time. The following regression yields exactly the same estimates 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. In other words, the regression estimates show the effect of levels of independent variables on the level of marital fertility for each of the eight census periods.

$$Y_{it} = a_1 X_{1it} Z_{i1} + a_2 X_{2it} Z_{i2} + \dots a_k X_{kit} Z_{iT} + cZ + c_1 Z_{i1} + \dots + c_1 Z_{iT} + e_{it}, \quad \text{for} \quad t = 1, 2, \dots, T,\ i = 1, 2, \dots, N,$$

where $Z = 1$ for the tth census $t = 1, \dots, T$, and 0 otherwise.

An F-statistic is also calculated, the result of a test which determines whether inclusion of the set of interacted time dummies of a given independent variable adds more to explained variance than using the non-interacted variable alone. In other words, it tells us whether or not the estimate of the independent variable changes significantly over time. Estimates on 'Catholic' become significantly stronger (more positive) over time while urban and income estimates go from unexpectedly positive values early on to become significantly negative by 1910. None of the estimates on other variables shows any significant changes over time.

One interpretation of the change over time in income might be that during the early stages of fertility transition, higher incomes will allow the family to 'afford' more children and, because of the need for security in old age and the value of children around the farm, they do, indeed, have more children. On the other hand, during the later stages of the transition, the value of children appears to become negative as income increases, perhaps due to changes in attitudes and the perceived costs of children, all possibly related to the institution of state-sponsored social security and the increased value of women's time. It is interesting to note that legislation was passed in Germany during the 1880s to establish government-backed universal social insurance.

[64] The sign of this variable is puzzling, but may have been caused by significant migration of Catholics into areas of relatively rapid fertility decline, usually cities. We shall show later that this variable is not an important predictor of fertility decline.

[65] To examine changes in pace effects over time, we take the first differences of general marital fertility rates, Y' and the first differences of all the independent variables, X'. We then interact each independent variable with a time dummy. This yields the same estimates as running a regression for Education (3) seven times, for the quinquennia 1875–80 to 1905–10. Because of first differencing we are left with seven time periods, so that the sample size is $407 \times 7 = 2{,}849$.

Table 3. *Summary of regression results*

	Expected sign	Equations					
		(1)		(2)		(3)	
Observations		3.256		407		3,256	
R^2		0.625		0.681		0.920	
Corrected R^2		0.624		0.670		0.908	
Dependent variable		GMFR		GMFR		GMFR	
Constant		202.478	0	189.374	0		
Religion and: ethnicity							
Catholic	+	0.704	0	0.693	0	−2.138	0
Slav	+	0.257	0	0.348	0	−0.283	19
Church	+	12.018	0	1.013	93	23.231	0
Structural, standard:							
Education	−	−7.817	0	−5.488	6	−9.075	0
Health	−	−41.302	0	−32.456	4	−6.596	19
FLFPR	−	−0.980	0	−0.529	6	−1.235	0
Income	−	−0.021	0	−0.014	19	−0.002	51
Mining	+	1.230	0	1.032	0	0.757	0
Urban	−	0.345	0	0.034	75	0.107	25
Structural, financial and communications:							
Bank	−	−21.924	1	−36.020	11	−55.325	0
Insurance	−	−22.968	1	29.251	23	−133.466	0
Communications	−	−5.904	0	−0.453	86	−7.333	0
Demographic:							
Infant mortality	+	0.012	30	−0.052	7	0.242	0
Married sex ratio	+	81.616	0	91.828	6	40.674	3
Kreis dummies:							
1						213.785	0
2						216.531	0
3						252.012	0
.							
.							
.							
407						400.886	0

Notes: The numbers to the right of estimates are percentage significance levels. Equation (2) uses the means of the variables over the eight censuses.

One measure of the relative importance of a variable is its incremental contribution to R^2.[66] In the level-effects model (Equation 2) it is shown in Figure 2 that religion makes by far the most important contribution to explained variance, followed by ethnicity and mining. In the pace model (Equation 3) infant mortality makes the largest incremental contribution to explained variance, followed by insurance, religion, communication and female labour force participation. Explaining changes in fertility is not only more interesting theoretically than explaining fertility levels but is also more complex.

$$Y'_{it} = a_1X'_{1it}Z_{t1}+a_2X'_{2it}Z_{t2}+ \dots,\ a_k{}^{x}X'_{kit}Z_{tt}+e_{it} \quad \text{for} \quad t=1,2,\dots,T \quad \text{and} \quad i=1,2,\dots N$$

where $Z = 1$ for the tth census, $t = 2,\dots, T$ and 0 otherwise.

We test whether the value of an independent variable changes significantly across time by an F-test. Catholicism, Education, Infant Mortality, Female Labour Force Participation, Income, Communications, Insurance, Mining, and Married Sex Ratio all differ significantly over time. Unfortunately, most of these estimates are too irregular to draw broad conclusions. Only three variables show an obvious trend over time: Female Labour Force Participation, Communications, and Mining. The first two of these become more strongly negative in 1905 and 1910. Mining becomes less important over time, perhaps because of legislation relating to child labour.

[66] H. Theil, *Principles of Econometrics* (New York, Wiley, 1971), pp. 168–169.

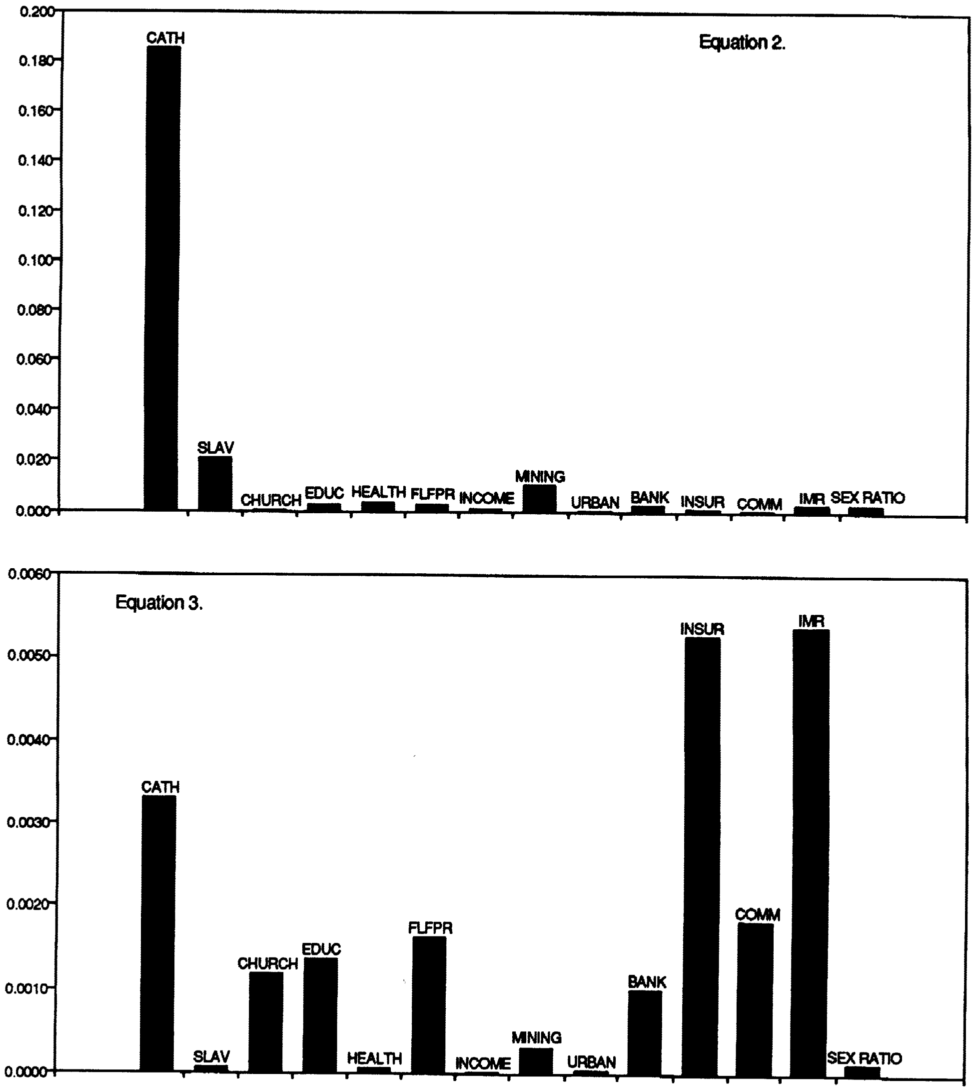


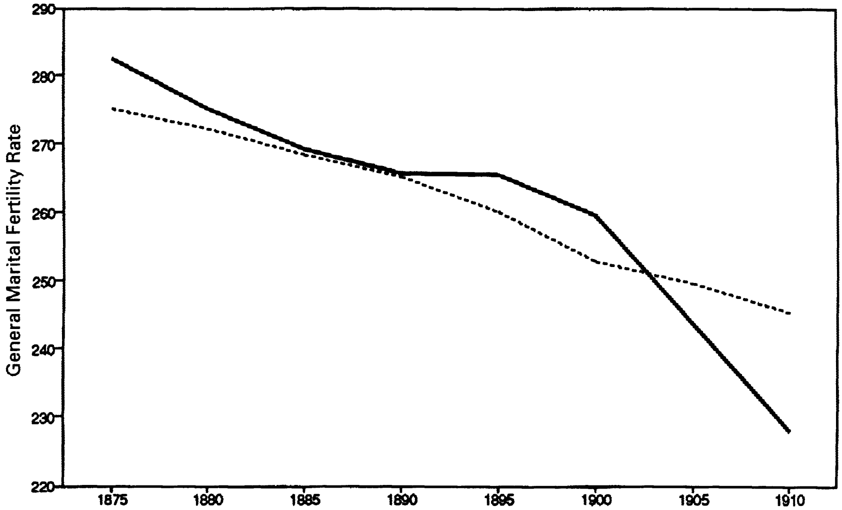
Figure 2. Incremental contribution to R^2 from Equations (2) and (3).

PREDICTION

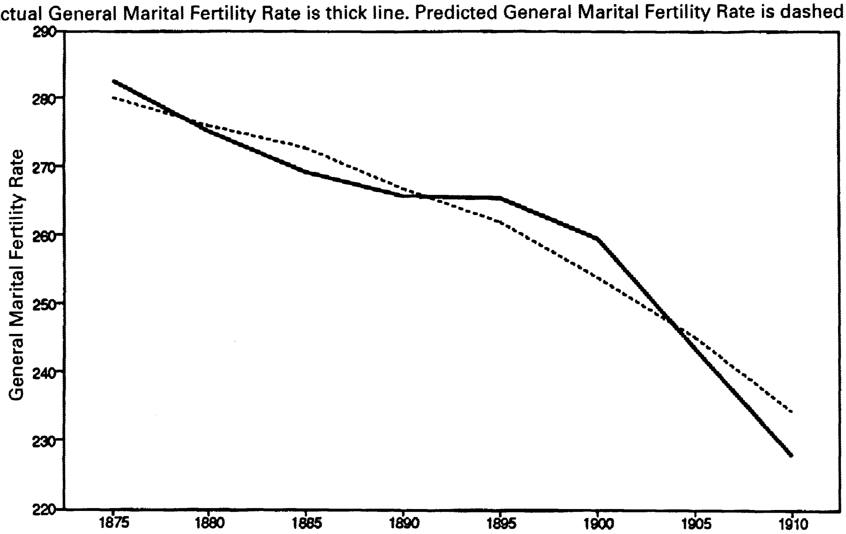
The predictive power of the simplest model (Equation 1) is shown in Figure 3, where period means across all *Kreise* of the independent variables are inserted into the equation to predict actual average period marital fertility over all Prussian *Kreise*. A similar calculation for Equation (3), which includes *Kreis* area dummies, significantly improves the overall fit.[67] We observe the expected high levels of fertility relative to predicted levels in 1875, which are probably associated with the aftermath of the Franco-Prussian war.

[67] In an earlier study, Richards (*loc. cit.* in fn. 4) used similar methods, but the far less detailed European Fertility Project data, to study fertility decline in 71 *Regierungsbezirke* in Germany. She found that 'once we allow for different regional means, this model really does very well in explaining change' (p. 551). However, in our study we have been able to examine nine times as many observations by using much smaller units of analysis, as well as a much richer set of independent variables.

Decline in average General Marital Fertility Rate in Prussia predicted by Eq. 1.
Actual General Marital Fertility Rate is thick line. Predicted General Marital Fertility Rate is dashed line.



Decline in average General Marital Fertility Rate in Prussia predicted by Eq. 3.
Actual General Marital Fertility Rate is thick line. Predicted General Marital Fertility Rate is dashed line.



Sources: Table 2 and Eqs. 1 and 3 in Table 3.

Figure 3. Actual and predicted general marital fertility rate in Prussia, 1875–1910.

The later cyclical deviation of actual from predicted general marital fertility rates may reflect fluctuations in general economic conditions.[68]

Of course, fertility in each of the 407 *Kreise* can be predicted from Equation (3), resulting in 407 different predicted trajectories. The power of this equation to predict fertility change in extreme cases may be seen in Figure 4. The upper thick line is the

[68] The German economy expanded rapidly between 1850 and 1870, but experienced somewhat slower growth during the so-called 'Great Depression' between 1873 and 1896. This was followed by sustained development until World War I. See W. O. Henderson, *The Rise of German Industrial Power 1834–1914* (Berkeley, University of California Press, 1975), pp. 175–177. 'The pattern of German economic growth between 1850 and 1914 consists, therefore, of two technologically distinct surges of expansion, separated by a phase of short-lived recession' (C. Trebilcock, *op. cit.* in fn. 14, p. 48).

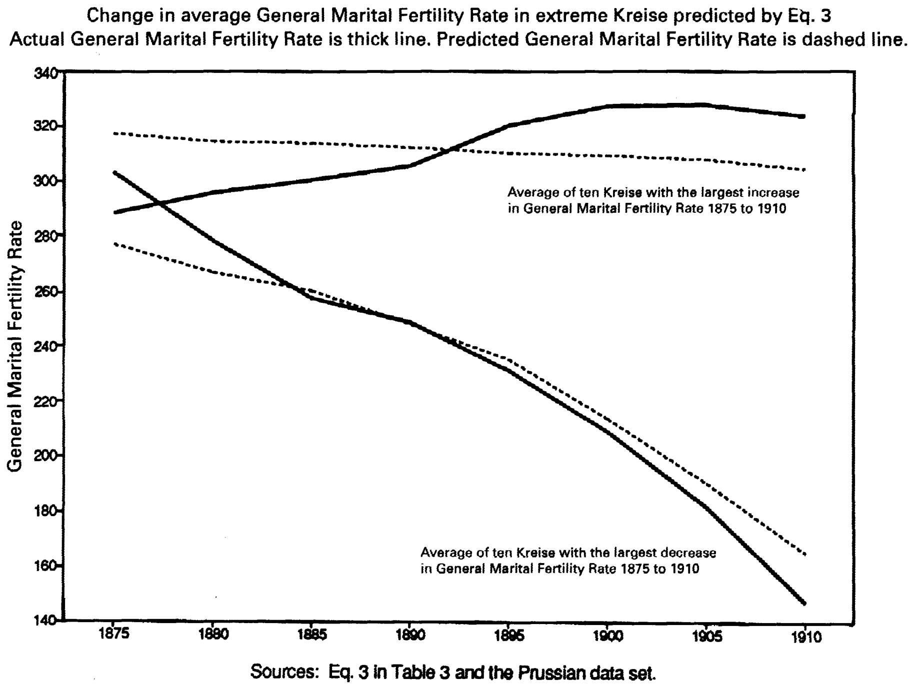


Figure 4. Actual and predicted general marital fertility rate in extreme *Kreise* in Prussia, 1875–1910.

average marital fertility of the ten *Kreise* in which the increase was largest between 1875 and 1910. The upper dotted line is the corresponding predicted rate from Equation (3). Corresponding lines for the average of the ten *Kreise* with the largest *decrease* in marital fertility during this period are also shown. Note that marital fertility was about the same in 1875 in both extreme cases. Equation 3 very accurately predicts the actual decline in the rate in the fastest-declining *Kreise*, whilst predicting successfully a near-level rate in the ten *Kreise* in which the actual rate increased slightly.

Decomposition

We can obtain some idea of the relative contribution of each independent variable in predicting fertility decline by examining the components of change in the predicted average marital fertility. In Figure 3 we showed that Equation (3) – our preferred model – predicts a decline from 280 or 234 or 46 between 1875 and 1910. We note that this figure is closely matched by the actual change. In Table 4 we present in detail the components of this decline for 1875–90, 1890–1900, 1900–10, and the entire period 1875–1910. This table is summarized graphically in Figure 5. In the decomposition, only six variables are important: Female Labour Force Participation, Communications, Insurance, Infant Mortality, Education, and Banking. Table 4 and Figure 5 show that infant mortality and the two financial variables become more important over time, whilst education is important only during the early and middle stages of the transition. The contribution of communications is relatively constant. Whilst female labour force participation tends to decline with time, it makes the largest contribution to predicted change in marital fertility over the entire interval 1875–1910, followed closely by communications and insurance. The contributions of the other variables, including religion and ethnicity, are marginal. In fact structural factors, including financial

Table 4. *Components of change in average GMFR in Prussia predicted by Equation (3)*

	1875–90	1890–1900	1900–10	1875–1910
	GMFR units			
Catholic	−1.17	−0.84	−1.14	−3.15
Slav	−0.01	0.01	0.00	−0.00
Church	−0.45	0.35	0.80	0.69
Education	−2.86	−1.97	−1.22	−6.05
Health	−0.19	−0.36	−0.44	−0.99
FLFPR	−4.42	−2.19	−2.28	−8.89
Income	−0.18	−0.44	0.05	−0.57
Mining	0.13	0.13	0.30	0.56
Urban	0.23	0.21	0.21	0.65
Bank	−0.62	−1.34	−2.19	−4.15
Insurance	−1.40	−2.74	−4.15	−8.29
Communications	−1.97	−2.74	−3.70	−8.41
Infant mortality	−0.39	−1.22	−5.77	−7.39
Married sex ratio	0.13	0.04	0.10	0.27
Total	−13.17	−13.11	−19.44	−45.72
	Per cent			
Catholic	8.89	6.42	5.85	6.89
Slav	0.10	−0.10	0.00	0.00
Church	3.44	−2.64	−4.10	−1.51
Education	21.72	15.04	6.29	13.24
Health	1.44	2.75	2.28	2.17
FLFPR	33.56	16.72	11.73	19.45
Income	1.40	3.34	−0.28	1.25
Mining	−0.99	−1.02	−1.54	−1.23
Urban	−1.78	−1.60	−1.06	−1.42
Bank	4.71	10.25	11.24	9.08
Insurance	10.64	20.87	21.35	18.13
Communications	14.93	20.92	19.05	18.40
Infant mortality	2.95	9.32	29.70	16.15
Married sex ratio	−1.02	−0.28	−0.52	−0.60
Total	100.00	100.00	100.00	100.00
	Category (per cent)*			
Religion and ethnicity	12.43	3.69	1.75	5.38
Standard structural	55.35	35.23	17.43	33.46
Financial and communication	30.28	52.04	51.65	45.61
Demographic	1.93	9.04	29.18	15.56
Total	100.00	100.00	100.00	100.00

* Religion and ethnicity includes Catholic, Slav, and Church. Standard structural includes Education, Health, FLFPR, Income, Mining, and Urban. Financial and communication includes Bank, Insurance, and Communications. Demographic includes Infant mortality and Married sex ratio.

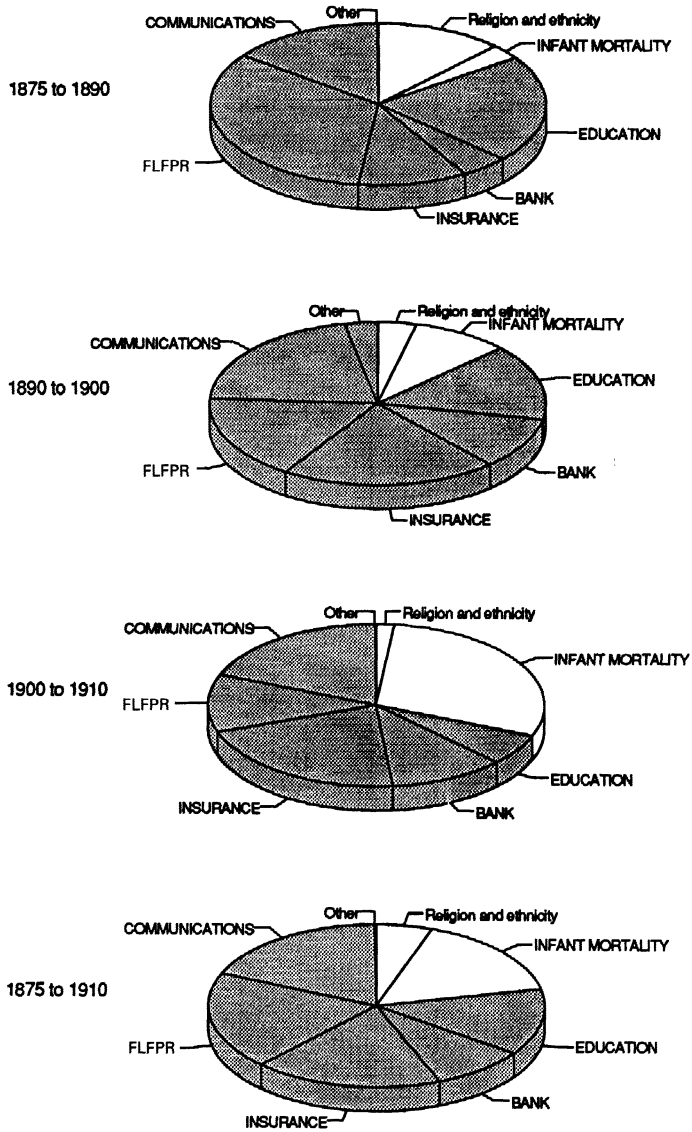
Sources: Table 2 and Equation (3) in Table 3.

services, account for some 80 per cent of the predicted decline from 1875 to 1910, infant mortality for some 15 per cent, and the religious and ethnic variables for only 5 per cent. It is clear that changes in religion and ethnicity, which some have viewed as 'cultural' variables, are only weakly associated with changes in fertility.[69]

SUMMARY

We have examined fertility level and the pace of fertility decline in 407 *Kreise* in Prussia from 1875 to 1910 using a very rich and detailed data-set and pooled cross-section time-series methods. Our variables include religion, ethnicity, concentrations of church

[69] The structure of our analysis does not allow us to determine whether fertility decline began earlier or proceeded more rapidly in some regions than in others. These questions are left for later analysis.



Source: Table 4.

Figure 5. Components of change in average general marital fertility rate in Prussia predicted by Equation (3). Source: Table 4. Shaded areas represent structural factors.

workers, legitimate infant mortality rate, and sex ratio among the married population. We have also used standard structural variables, such as teachers per child, proportion of health workers, proportions of miners, and urbanization. Our measures of female labour force participation in non-traditional sectors, income, concentration of bank workers, proportion employed in insurance, and proportion of communication workers, have seldom been used in previous analyses of fertility decline. Pooled cross-section time-series statistical techniques have been applied to studies of fertility decline on only one previous occasion.

Religion is by far the most important indicator of fertility level, followed by ethnicity and proportion of miners. None of the other variables is significantly associated with fertility level. However, changes in religion, ethnicity, and proportion of miners contribute little to the explanation of fertility decline.

Our analysis of fertility decline is more interesting theoretically than the analysis of fertility level. Our results strongly support expectations derived from socio-economic models of fertility decline, and suggest that inferences drawn from previous research have resulted in an unwarranted rejection of the importance of structural economic factors.[70] The increase in the number of women employed in non-traditional occupations, growth of financial institutions, development of transport and communication infrastructure, reduction in infant mortality, and improvement in education are the forces that drove fertility decline in nineteenth-century Prussia.

[70] See, e.g., Knodel and van de Walle, *loc. cit.* in fn. 13; Cleland and Wilson, *loc. cit.* in fn. 2.