Demography, Vol. 31, No. 2, May 1994

Fertility Decline in Prussia: Estimating Influences on Supply, Demand, and Degree of Control*

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Change in marital fertility in 407 Prussian *Kreise* from 1875 to 1910 is modeled to depend on the gap between the number of desired surviving births, N*, divided by child survival, s, and the number that would be born under natural marital fertility, M, given the age at marriage. Some fraction of this gap is averted, depending on the propensity to avert unwanted births, D. Although none of these components is observed directly, we can estimate each indirectly under strong assumptions. Decline in N*/s accounts for twice as much of the decline in fertility as does an increase in D. Natural fertility rose during the period. Unwanted births increased slightly, despite a tripling of births averted. The most important causes of decline in N* were increases in female labor supply, real income, and health workers. A rising level of education is the most important cause of increasing propensity to avert births. Demand-side changes were important causes of the transition, but changes in readiness to contracept also were important, as was the interaction of the two.

Some scholars have argued that the diffusion of attitudes or knowledge related to contraception is a plausible explanation for the fertility transition in European and Third World populations. One might respond, however, that any readiness of the population to

* The research on which this paper was based was funded by Grant RO1-HD25841 from the National Institute of Child Health and Human Development. We are grateful to Mark Montgomery and Jacob Klerman and two anonymous referees for comments on an earlier draft.

limit births would be irrelevant as long as the desired number of births was high in relation to natural fertility and child survival (Lee 1987). Because population growth rates averaged little more than zero before 1800 in most of Europe and in most centuries,[1] the average couple would have limited its births intentionally only if the desired fertility was at or below replacement levels; this seems unlikely. It seems more plausible that the diffusion of contraception-related knowledge or attitudes would lead to reduced fertility only when other changes either had reduced the number of surviving children that people desired or had increased the number they would have in the absence of limitation.

Other scholars have emphasized the role of structural socioeconomic changes that alter the desired number of children and thereby lead to fertility decline. Changes in the desired number of children, however, will have no effect on fertility outcomes without a readiness and ability to limit births. We can imagine a population in which the gap between natural fertility and the desired number of children had grown quite large, while birth control was still unknown or unthinkable. Such a population would have a very high potential for rapid fertility decline. Once the idea or method of control was introduced, adoption would occur rapidly and fertility would decline accordingly.

These considerations lead us to expect specific interactions between desired numbers of surviving children, natural fertility, child survival, and knowledge and attitudes regarding contraception. These interactions are modeled explicitly in Easterlin and Crimmins's (1985) framework for fertility analysis. They are also consistent with Coale's (1973) classic discussion of the fertility transition, in which he enumerated three preconditions for decline: 1) fertility must be within the rational calculus of couples; 2) couples must decide that it would be desirable to have fewer births than otherwise; 3) the means to limit births must be known and available. If the second condition is not fulfilled, then decline is unlikely to occur even if the first and the third are met.

For these reasons we believe that these several influences on fertility and its eventual decline must be studied not only in conjunction but also in interaction. One cannot soundly test either the structural or the diffusionist hypothesis without assessing them together because neither, according to their own internal logic, could apply universally. Several studies of contemporary international cross-sectional data have examined the relative importance of structural socioeconomic variables relative to programmatic variables[2] in explaining fertility differences and change (Hernandez 1984; Mauldin and Berelson 1978; Mauldin and Ross 1991). These studies generally have found that both structural and programmatic variables are important, but that they interact: each enhances the power of the other.

In this paper we construct a new model of fertility determinants, based on the insights of Easterlin and Crimmins's (1985) framework and in a form suitable for analysis of aggregate data. We then estimate and test the model on a uniquely rich and detailed data set for Prussia, 1875 to 1910.

DATA, PERIOD, AND UNITS OF ANALYSIS

The population of Prussia in 1910 was about 40 million. It was the largest political unit in Europe (excluding Russia) and one of the most culturally diverse. About one-third of the population was Catholic, the rest primarily Lutheran. Nine percent of the population was Slavic-speaking. In 1875 the bulk of the Prussian population was employed in the agricultural sector, but by 1910 Prussia had become Europe's most powerful industrial economy (Trebilcock 1981). This period of rapid industrial development was accompanied by the onset of long-term fertility decline.[3] We examine our model of fertility determinants within this uniquely dynamic and varied historical setting.

Although incorporated into the German Empire in 1871, Prussia maintained its own statistical office and continued to publish a wealth of data until the office was disbanded in the early 1930s. The most detailed data were published from 1875 to 1910. The data used in this analysis are derived from the eight quinquennial Prussian censuses held from 1875 to 1910, combined with annual vital registration data and supplemented by other sources for special purposes. The observational units are 407 *Kreise*.[4]

The Prussian censuses provide information about the individual *Kreise* at five-year intervals from 1875 to 1910. From the censuses we have constructed measures of income, female employment in nontraditional occupations, proportion Catholic, proportion Slavic, resources devoted to education, and respective employment in banking, insurance, transportation and communications, church work, health care, and mining. Vital registration totals are available annually for *Kreise*. These provide marital and extramarital births, infant deaths separately for these births, marriages, and total deaths. We construct a period measure of marital completed fertility, which is our dependent variable. Table 1 provides definitions and other details about the various measures we use in this study. Table 2 lists the mean values and standard deviations for the entire period and for each census year. The data set is described elsewhere in greater detail (Galloway 1988; Galloway, Hammel, and Lee 1994; Galloway, Lee, and Hammel 1993).

Most of the variables show strong trends over the 35-year period. For example, female labor force participation doubled, the proportion of the labor force in banking quadrupled, and the proportion in insurance grew fivefold. Other variables, such as percent Catholic or the ratio of married females to married males, show little change. The proportion of births surviving to age 15, s, rose slightly, from .686 to .718. All the variables, whether or not they trend on average, exhibit very wide variation in both levels and trends across the *Kreise*. This is also true of fertility, which increased over the period in quite a few *Kreise* while declining far more rapidly than average in many others. This rich variation at the local level, rather than the average trends, forms the primary basis for model estimation.

In two earlier papers we estimated linear models to assess the influence of several factors on fertility change among the *Kreise* and cities in Prussia from 1875 to 1910 (Galloway et al. 1993, 1994). These models can be regarded as linear approximations to the actual processes by which fertility was affected. In particular, they may be viewed as linear approximations to the model that we develop and estimate below. We used pooled cross-section time-series methods with fixed effects for *Kreise* to estimate the models for all the *Kreise* in Prussia (Galloway et al. 1994) and for all the cities of Prussia (Galloway et al. 1993). The models performed very well: a high proportion ($R^2 = .92$) of the variation in fertility change within *Kreise* was explained, and almost all coefficients had the signs predicted by theory. Some variables stressed in structural transition theory, notably increasing female labor force participation and declining infant mortality, emerged as particularly important. Other variables not studied previously—banking, insurance, and transportation/communications—also played notable roles. Thus our earlier work strongly supported the view that structural changes can go far towards explaining the demographic transition in Prussia, contrary to the view that they are relatively powerless to account for Europe's fertility transition.[5]

A FRAMEWORK FOR ANALYZING FERTILITY CHANGE

We suppose that in each *Kreis* and in each period there is a characteristic level of natural fertility, M (we suppress subscripts for the *Kreis* and the year). This level is defined as the number of live births the average married woman would have in the absence of

Table 1. Definitions and Sources of Variables Used in the Analysis

		1867	1871	**1875**	**1880**	1882	**1885**	**1890**	**1895**	**1900**	**1905**	1907	**1910**
F	Completed Marital Fertility (TMY × GMFR/1000)			PR	PR		PR	PR	PR	PR	PR		PR
TMY	Total Married Years of Females (Sum of ((married females 15–19/ all females 15–19) + , . . ., + (married females 45–49/ all females 45–49))) × 5[a]			P	P		P	P	P	P	P		P
SMAM	Singulate Mean Age at First Marriage of Females[b]			P	P		P	P	P	P	P		P
GMFR	General Marital Fertility Rate (legitimate births × 1000/married females 15–49)	PR	PR	PR	PR		PR	PR	PR	PR	PR		PR
s	Proportion of Births Surviving to Age 15 (88171.74 − (105.50 × IMRLEG))[c]			R	R		R	R	R	R	R		R
BREAST-FEEDING	Percentage of Mothers Who Have Ever Breastfed			[d]	[d]		[d]	[d]	[d]	[d]	[d]		[d]
INFANT MORTALITY	Legitimate Infant Mortality Rate (legitimate deaths<1 × 1000/ legitimate births)			R	R		R	R	R	R	R		R
MARRIED SEX RATIO	Married Males/Married Females		P				P	P	P	P	P		P
INCOME	Average Real Income of Male Elementary School Teachers (in 1900 marks)	[e]	[e]	[e]	[e]		E	E	E	E	E		E
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	

(continued)

Table 1. *(continued)*

		1867	1871	**1875**	**1880**	1882	**1885**	**1890**	**1895**	**1900**	**1905**	1907	**1910**
FLFPR	Female Labor Force Participation Rate = Employed Females × 100 / Female Population Age 20–69 (excludes agriculture and service)	O				O						O	
MINING	Mining Employees × 100 / Population over Age 20	O				O			O			O	
BANK	Banking Employees × 100/ Population over Age	[f]				O			O			O	
INSURANCE	Insurance Employees × 100 / Population over Age 20	[f]				O			O			O	
COMMUNI – CATIONS	Postal, Telegraph, and Railway Employees × 100 / Population over Age 20	[g]				O			O			O	
URBAN	Urban Population × 100 / Total Population			P	P		P	P	P	P	P		P

Notes: Bold type indicates years used in the analysis. Gaps are filled by interpolation except for some data for 1910, which are extrapolated from 1907. Stillbirths are excluded from all calculations.

E = Education census data
O = Occupation census data
P = Population census data
R = Registration data

[a]TMY for each *Kreis* is based on the regression of TMY on GNR (married females 15–49/all females 15–49) and SMAM, using data from the 36 *Regierungsbezirke* of Prussia. The resulting equation is used to estimate TMY for each *Kreis* using *Kreis* GNR and *Regierungsbezirk* SMAM.

[b]The variable SMAM is available only for each of the 36 *Regierungsbezirke* of Prussia. Each *Kreis* within a given *Regierungsbezirk* is assigned the SMAM of that *Regierungsbezirk*.

[c]The equation for s is based on the regression of l_{15} on ${}_1q_0$ in 36 *Regierungsbezirke* in Prussia, 1890–1891.

[d]BREASTFEEDING is based on breastfeeding data for 36 *Kreise* in 1900 (Röse 1905:162–66).

We regress BREASTFEEDING on CATHOLIC, SLAV, MINING, FLFPR, URBAN, and INFANT MORTALITY using these 36 *Kreise*. We apply the resulting equation to all *Kreise* in all census periods to arrive at an estimate of BREASTFEEDING for each *Kreis*.

[e]Estimate based on change in province – level income.

[f]Estimate based on change in persons employed in trade per population over age 20.

[g]Estimate based on change in persons employed in postal, telegraph, railway, and other land transport per population over age 20.

Sources: Population, occupation, and education censuses and registration data from *Preussische Statistik* (various volumes) and *Statistik des Deutschen Reichs* (various volumes).

Table 2. Means and Standard Deviations of Variables

	1875 to 1910	1875	1880	1885	1890	1895	1900	1905	1910
Means									
F, Completed Marital Fertiality	5.310	5.706	5.555	5.420	5.372	5.391	5.321	5.015	4.701
TMY, Total Married Years	20.414	20.259	20.241	20.172	20.265	20.355	20.576	20.684	20.758
SMAM	25.428	25.586	25.586	25.629	25.571	25.568	25.330	25.156	24.994
GMFR	261.166	282.439	275.221	269.304	265.714	265.561	259.524	243.600	227.968
s, Proportion of Births Surviving to Age 15	0.693	0.686	0.688	0.684	0.688	0.689	0.693	0.701	0.718
BREASTFEEDING	82.994	86.264	84.923	83.676	82.839	81.974	81.610	81.353	81.315
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	0.992	0.991	0.992	0.993
INCOME	1117.392	937.216	1001.015	1063.281	1037.504	1133.276	1275.306	1245.255	1246.279
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
MINING	1.790	1.503	1.648	1.694	1.674	1.655	1.852	2.049	2.246
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
URBAN	29.964	27.055	27.954	28.698	29.250	30.103	31.216	32.289	33.148
Standard Deviations									
F, Completed Marital Fertility	0.871	0.753	0.711	0.733	0.724	0.794	0.886	0.933	0.985
TMY, Total Married Years	1.374	1.412	1.419	1.337	1.356	1.259	1.334	1.434	1.316
SMAM	0.693	0.708	0.708	0.652	0.677	0.653	0.631	0.624	0.594
GMFR	44.625	37.214	35.294	35.950	35.683	39.983	44.685	47.628	52.251
s, Proportion of Births Surviving to Age 15	0.050	0.048	0.051	0.052	0.051	0.052	0.050	0.048	0.042

(continued)

Table 2. *(continued)*

	1875 to 1910	1875	1880	1885	1890	1895	1900	1905	1910
Standard Deviations									
BREASTFEEDING	7.276	6.444	6.775	6.937	6.935	7.079	7.166	7.497	7.722
INFANT MORTALITY	47.856	45.900	48.244	49.714	48.645	49.442	46.926	45.091	39.901
MARRIED SEX RATIO	0.029	0.031	0.028	0.028	0.025	0.024	0.034	0.034	0.030
INCOME	248.587	172.113	178.915	190.209	193.000	226.540	242.263	259.905	262.790
CATHOLIC	36.957	37.506	37.393	37.309	37.112	37.027	36.777	36.510	36.297
SLAV	21.498	21.766	21.726	21.700	21.690	21.464	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
MINING	4.913	4.372	4.793	4.878	4.755	4.678	4.910	5.222	5.600
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	0.082	0.100	0.118
COMMUNICATIONS	0.729	0.476	0.480	0.496	0.515	0.547	0.640	0.759	0.893
URBAN	18.962	17.924	18.021	18.294	18.740	18.968	19.348	19.613	20.007

Source: Table 1.

fertility-controlling behavior until the end of her reproductive years, a point we take to be reached at age 49.

We also suppose that each *Kreis* has an average number of desired surviving children, N^*, which is conditional on the socioeconomic circumstances of the *Kreis* and its inhabitants. (N^* corresponds to the demand for surviving children in the Easterlin-Crimmins framework.) Suppose the probability of a birth surviving to age 15 in this *Kreis* is s (or is believed by the inhabitants to be s).[6] Then the desired number of *births*, as opposed to the desired number of *surviving children*, is N^*/s.

If N^*/s is less than M, then the average couple will have $(M-N^*/s)$ more surviving children than desired, unless fertility is reduced by some means to a lifetime level less than M. Some couples may find fertility-reducing action to be unacceptable; to others it may not even occur as a possibility. Still others may try to limit births, with some succeeding and some failing. Let D denote the proportion of excess births which is avoided, so that $D(M-N^*/s)$ is the number of births averted. D ranges from 0 to 1, and is a measure of the combined effects of the proportions seeking to avert births and the efficiency with which they achieve their goals through contraception, abortion, and abstinence.

Let F measure the fertility outcome, where F is a period measure of the average number of life cycle legitimate births per married woman. We measure F as the general marital fertility rate (GMFR) times the total number of married years (TMY): F = GMFR x TMY.[7] The TMY approximates the average number of fecund years a woman spends married in each *Kreis*, taking into account the time lost between marital disruptions and remarriages. Given the definitions of M, N^*, s, D, and F, the following equation is an identity

$$F = M - (M - N^*/s)D. \qquad (1)$$

Once we let some variables change, however, while assuming that others remain fixed, this equation is no longer an accounting identity but becomes a behavioral model.

We may set this model in motion by imagining a change in one of its parts. Suppose, for example, that child mortality begins to decline, so that survival, s, increases. If M initially exceeds N^*/s, the gap between M and N^*/s will grow, and a fraction, D, of the gap will be averted. Fertility, F, therefore will decline by D times the change in the gap.

Suppose instead that breastfeeding becomes less fashionable or more difficult because of rising female employment, thus leading to a decrease in lactational amenorrhea and a consequent increase in M. In such a case the gap will grow, but in this case fertility will rise by the amount (1-D) times the increment in the gap.

Likewise it may happen that the desired number of surviving children declines, which also increases the gap. In this case, fertility will decline by D times the change in N^* divided by s. Finally, either the readiness to limit births or the efficiency of limitation may increase. In this case, fertility will decline by the amount of the gap times the increment to D.

Examination of Eq. (1) confirms that it contains the interactions stressed earlier. Variations in desired fertility, N^*/s—the focus of structuralist theories of the transition—will affect fertility outcomes only insofar as there is a readiness to limit births, as reflected in D. Variations in natural marital fertility, M, will affect fertility outcomes only insofar as this readiness is incomplete, as reflected in a D less than unity. In the perfect contraceptive society $(D=1)$, variations in natural fertility do not matter at all, so long as M is greater than N^*. The same is true for variations in child survival, s. Variations in the readiness to limit births, D—the focus of diffusionist theories—matter more or less depending on the extent of the gap between the desired number of births and the number of births that people believe they will have in the absence of limitation.

An additional hypothesis can be derived loosely from this line of reasoning: The larger the gap $(M-N^*/s)$ when fertility begins to decline in an area, the more rapid will be the decline. It is expected that the social and information costs of birth limitation would decline very rapidly in a population with a large gap, as the result of rapid diffusion. Such diffusion, however, may encounter cultural and linguistic barriers.

INTERVIEWS WITH COUPLES OF THAT PERIOD

We are fortunate to have some qualitative evidence concerning the extent to which this conceptual framework and model correspond to German couples' modes of thought towards the end of our period of interest. This evidence comes from Max Marcuse (1917), a Berlin physician, who describes interviews with 300 German couples. These couples in no way constitute a random sample; in any event we have not yet undertaken a rigorous analysis of the material. Nonetheless, the interviews afford us a glimpse of the attitudes and motivations regarding fertility in that period, as expressed by the couples themselves.

Some couples do not seem to have fertility targets (N*): "If children come, good; if none come, also good" (Couple 52). "So many come, as come" (Couple 59). "Married people need not themselves after all be careful; why does one marry, then?" (Couple 107). Other couples, however, have fertility targets and strive to attain them through contraceptive behavior. "Up to now without protection, so that sick children do not come, but in the future, rubber or fish-bladder" (Couple 150). Couple 150 wants to wait for the first child or two before using prevention.

In keeping with the model, some couples have goals. Nonetheless, because of reluctance to contracept ($D < 1$), they do nothing to limit fertility even after attaining their goal. For example: "To me it is enough [children]; what can one do, however, when one has married? One must take as many children as one gets. And also, I am not so very much for planning" (Couple 70). "It is very hard with more than two children, but if they are given by dear God, one must be satisfied" (Couple 222). "We do not do that sort of thing [contracept]. Once one marries, one gets children. . . . For the future, we hope that more children do not come, but if they do, then one can do nothing about it" (Couple 34).

The interviews make clear that economic reasons are often important in determining the desired number of children. "The children are needed in farming and are better than foreign workers" (Couple 15). "My wife could have gotten a handsome concierge job, if there were no children" (Couple 18). "One has it too hard with children, and cannot help himself" (Couple 130). Sometimes economic reasons also govern the choice of contraceptive method; Couple 295 wants to practice coitus interruptus in the future because the other remedies are too expensive.

Although quotes such as these can be interpreted in many ways, they appear consistent with the approach taken here.

THE EMPIRICAL SPECIFICATION

So far we have only a general framework linking variables that cannot be observed in our data set. We will proceed as if this were not a problem, and will develop hypotheses about the factors that might have influenced M, N*, and D.

We will begin with M, the average completed fertility of each *Kreis* under natural fertility. Certainly this number will depend on the average number of years a woman is married between ages 15 and 49. Let the average rate of natural marital fertility over this long age span be q, where q is specific to each *Kreis*. Then $M = q(TMY)$. For present purposes we will take TMY as exogenously given. In a more extended analysis, we could model its dependence on other variables.

The annual rate of natural marital fertility, q, however, cannot be observed. Nonetheless we can develop hypotheses about factors that influence this rate. Prolonged breastfeeding should exert a strong negative influence, as should low coital frequency and abstinence. We have breastfeeding data for 36 *Kreise* in 1900, collected by Röse (1905:162–66).[8] We estimate a descriptive regression for these *Kreise* in this year, and use it to impute the variable Breastfeeding, percentage of mothers who have ever breastfed, for all *Kreise* in all years. In addition, deaths of infants will terminate breastfeeding and thereby will increase the conception risk for some women. Accordingly we expect natural marital fertility to be associated positively with the legitimate infant mortality rate variable, Infant Mortality. We also know that natural fertility should be reduced by spousal separation, which we can measure crudely by the ratio of married males to married females in each *Kreis*, denoted Married Sex Ratio. Knodel (1988:285) suggests that natural fertility in Germany at this time may have been affected by nutrition; other authors are generally skeptical about its importance other than in crisis conditions (Bongaarts 1980; Menken, Trussell, and Watkins 1981). We include Income, a measure of income, in an attempt to address this controversial fertility-nutrition link.[9]

More generally, let q = mX, where m is a vector of parameters describing the influence on q of the variables contained in the matrix X.[10] In our case, X contains Breastfeeding, Infant Mortality, Married Sex Ratio, Income, and a vector of unity. Therefore M can be written as

$$M = mX(TMY). \tag{2}$$

Researchers offer a wealth of hypotheses about the factors that influence N*, the number of desired surviving children. Standard economic theories of fertility suggest that income has both positive and negative influences on fertility; the net effect is unclear. Higher income enables couples to afford more children. At the same time, however, it may dispose them to invest more resources in each child and thereby raise the (shadow) price of children (Becker 1981; Willis 1973), thus leading to lower fertility. Insofar as higher income results from higher wages, the price of children may be higher in relation to other activities yielding satisfaction because children are relatively time-intensive. This argument applies most strongly to women, particularly when wage labor is a real option for women. For this reason, researchers are particularly interested in FLFPR, the female labor force participation rate in nontraditional occupations—that is, occupations excluding agricultural labor and domestic service. When examining fertility in relation to female labor force participation, a question of the direction of causation always arises. In the case of Prussia in this period, it appears that variation in female employment was driven by variations in the demand for labor, often because of the location of textile mills.[11]

We believe that school enrollment, proxied by our variable Education, was associated with higher costs of childrearing, and therefore would lead to a reduced demand for numbers of children. Enrollment rates of children may be correlated with their parents' education, and parental education also might lead to a reduced demand for numbers of children, for familiar reasons. In addition, it may have led farmers to mechanize earlier, thus reducing the demand for child labor (Golde 1975).

Many studies have found the occupation of Mining to be associated with high fertility (Haines 1979), perhaps because employment opportunities for wives typically were limited in mining communities, while employment opportunities for male children were abundant.[12]

Children may be viewed as insurance against sickness or destitution; the local availability of commercial Insurance may undermine this function by providing a cheaper and more reliable market substitute. Similarly, children in part may be an investment to provide old-age security; therefore the local availability of Banks may reduce the attractiveness of this kind of investment (Hammer 1986).

Many aspects of Urban areas may raise the direct cost of children and the opportunity costs to their parents. Although it is not clear from Marcuse's interviews that Catholics desired more children than others after controlling for our other influences, it is prudent to allow for this possibility. Similarly, it is appropriate to allow for this possibility among Slavic speakers, who were clustered along the eastern border, and almost all of whom were Catholics.[13] If religion mattered, then it is plausible that it mattered more where institutional religion was stronger, as measured by the number of Church[14] workers per capita. Finally, we include the number of Health workers per capita with the idea that they may have made couples more aware of declines in mortality, and thereby may have caused them to have fewer children.[15]

At the same time, we do not expect some of our variables to influence the demand for surviving children. We exclude infant mortality because its influence is already incorporated when we assume that the number of births desired is N^*/s. There is no apparent reason to include in N^* other variables from the equation for M. We can collect the included variables in Y, and write

$$N^* = nY. \tag{3}$$

The propensity to avert unwanted births, D, should depend on a number of factors such as the extent of knowledge of contraceptive methods, religious and social attitudes towards contraception and abortion, and the availability and costliness of effective means. Our data set contains one set of variables that might affect the spread of new ideas and information, and another that might influence attitudes towards birth limitation.

The variable Communications, which measures the share of local employment in communications and transportation industries, including railway, postal service, and telegraph, should facilitate the diffusion of new ideas and knowledge. We have excluded the Communications variable from the equations for M and N^* because we believe it exerts its major influence on diffusion of knowledge and attitudes towards contraception.

Education, measured by teachers per child age 6 to 13, also may have facilitated the spread of new ideas, at least by increasing literacy, but probably in other ways as well. The variable Health, measured as the proportion of health workers in the labor force, may have raised the level of consciousness and willingness regarding contraception. The variable Urban, the proportion of the *Kreis* population in towns of 2,000 or more, quite likely would have hastened the diffusion of new ideas and information.

Other variables may capture the receptiveness of the population to the idea of birth limitation. Among these, the proportion Catholic occupies a special place. The Catholic Church was officially opposed to contraception. Noonan writes that the "Catholic Church waged war on contraception" during "the period from 1880 to the present" (1966:476). In 1913, the German bishops issued a pastoral letter stating "It is serious sin to will to prevent the increase of the number of children, so that marriage is abused for pleasure alone and its principal purpose is knowingly and willingly frustrated. It is serious sin, very serious sin, with whatever means and in whatever way it occurs" (Noonan 1966:421).

We can go beyond Church dogma to consider the views of German Catholic couples, drawing on the survey reported in Marcuse (1917). Contraceptive practice was widespread; coitus interruptus was reported most widely. Of non-Catholic couples, only 29% said they did not use contraception; of the Catholic couples, 71% did not use contraception.[16] A number of the Catholic couples gave explicitly religious reasons for not contracepting, such as "Never! This is not in accord with our religion!" (Couple 142). "My wife does not do that, she is still one of the Devout" (Couple 296). Remedies other than rinsing out are "prohibited by our religion" (Couple 278). "My wife does not allow it; . . . she is much too Catholic" (Couple 70). In another survey, conducted among 467 married women in the city of Wurzburg in 1914, 36% of Catholic women did not contracept, while 26% of non-Catholic women did not do so (Polano 1917).

The variable Slav, the proportion Slavic-speaking in the *Kreis* population, also might influence the acceptability of birth limitation because the Slavs, who were almost entirely Catholic, lived in an area with little exposure to modernizing influences. The variable Church, the proportion of church workers in the labor force, adds a dimension of intensity to the influence of religion.

At the same time, we have excluded certain variables from the set assumed to influence readiness to avert unwanted births: Income, FLFPR, Mining, Bank, and Insurance. We argue that any effect of Income should operate through other variables already taken into account, such as Communications or Education. Although female employment in nontraditional occupations may have exposed women to a wider range of views and therefore may have promoted diffusion of contraception, it is not clear to us that this should be more true than for employment in traditional occupations. Finally, we see no reason to expect Mining, Bank, or Insurance to be related to willingness to limit births.

A different approach would be to construct a set of variables reflecting the propensity to limit births in surrounding *Kreise* because this propensity would affect both the social acceptability of the practice and the knowledge of methods. The same argument could be made for allowing such influences in the equations for N* and M. Montgomery and Casterline (1993), in their analysis of the transition in Taiwan, introduce "contagion" influences of this sort, as well as terms to capture intertemporal diffusion within each unit. For the time being, however, we will simply let D be a function of Catholic, Slav, Church, Education, Health, Communications, and Urban, and write

$$D = dZ. \tag{4}$$

D, by definition, is limited to the range 0 to 1, and this is not reflected in the linear specification just given. An alternative specification, which suitably constrains the range, is

$$D = 1/(1 + e^{dZ}). \tag{5}$$

As dZ ranges from very large negative values to very large positive values, D ranges from just under 1 to just over 0.

The list of inclusions and exclusions for the natural fertility subequation (M), we believe, will be acceptable to most readers. Our inclusions and exclusions for the demand for children (N*) and the readiness to avert unwanted births (D) may be more controversial. Those who are unconvinced by our specification should note that we also have experimented using the combined set of regressors for both subequations, which we will report later.

Having developed three submodels for each of M, N*, and D, we now can combine them by substituting into Eq. (1):

$$F = mX(TMY) - (mX(TMY) - nY/s)/(1 + e^{dZ}). \tag{6}$$

Of these, the following variables are specific to each *Kreis* and time period, and would be subscripted in a full notation: TMY, s, and all elements of the matrices X, Y, Z.

AN ADDITIONALLY CONSTRAINED MODEL

We have already constrained D to lie between 0 and 1. Similar reasoning can be extended to M. Natural fertility cannot be negative, and a number of studies, following Bongaarts and Potter (1983), have placed upper bounds on it as well. In particular, Bongaarts showed that total natural marital fertility in a number of populations equaled 15 to 17 births per woman. This figure holds as an upper bound for an average woman marrying at age 16 or so. Evidently the average maximal fertility from age 16 to age 49 corresponds to about q = .5 per year of marriage (.5 = 17/(50–16)). Thus .5 appears to be an appropriate upper bound for q, as we have defined it. For populations in which there exists no widespread sterility resulting from sexually transmitted diseases, a value of one-fourth this figure, or .125, seems a reasonable lower bound for natural marital fertility. That would correspond to 4.4 births over the life cycle for a woman marrying at age 15, a safely low figure. In Prussia the average age at first marriage in this period was 25, so these bounds on q would translate into bounds on completed natural fertility of 3.1 to 12.5 children (for the average woman). Therefore it seems reasonable to constrain our estimate of the unobserved q to lie between .125 and .5.

These bounds may be imposed by assuming the following logistic functional form for q:

$$q = (.5e^{mX} + .125)/(1 + e^{mX}). \tag{7}$$

As mX becomes very large in the positive direction, q approaches .5 asymptotically; as mX becomes very large in the negative direction, q approaches .125.

There are no physical, definitional, or biological bounds on the desired number of surviving children. Even negative numbers could be taken to express a strong aversion to any children. Nonetheless, we would view certain numbers as highly implausible. We suggest that values outside the range 1 to 6 are implausible, and constrain the estimates accordingly. Doing so does not mean that no individual couple is permitted to desire no surviving children, or 12 surviving children; it means that the average for the whole *Kreis* is constrained in this way. Also, because the value of s averages around .7, the desired number of births (as opposed to surviving children) is constrained on average to be about 1.4 to 8.6. These constraints can be imposed exactly as for M, as follows:

$$N^* = (6e^{nY} + 1)/(1 + e^{nY}). \tag{8}$$

Our final constrained specification for F is now

$$F = (TMY)(.5e^{mX} + .125)/(1 + e^{mX}) - \{(TMY)(.5e^{mX} + .125)/(1 + e^{mX}) - [((6e^{nY} + 1)/(1 + e^{nY}))/s]\}/(1 + e^{dZ}). \tag{9}$$

Although the functional form of Eq. (9) is far more complicated than that of Eq. (6), it has exactly the same number of right-hand variables and coefficients to be estimated because many coefficients are constrained to be equal.

One constraint perhaps should be included in the model, but we have not incorporated it: when N*/s is greater than M, so that people are having fewer births on average than they would like, then the fertility outcome is M; fertility is not augmented by proception, or negative contraception. In its present form, the model assumes implicitly that proception can occur. (See Montgomery 1987 for a switching regression approach to dealing with this problem in an analysis of an Easterlin-Crimmins-style model with individual data.) This is unlikely to have a noticeable effect on the estimates.

ERROR STRUCTURE

If we take seriously the models described in Eqs. (6) and (9), we cannot simply add an error term to the ends of these equations. The equations actually contain three hypothesized relationships, describing the determinants of M, N*, and D. Errors in the equation must arise through these three relationships. If we add errors to each of these subequations (2, 3, and 5 or 5, 7, and 8), the errors do not simply sum to a single composite error, as they would in a linear model. Instead they interact in a complicated way with one another and with the observed variables. Furthermore, if the original errors are distributed normally, the error in F will not be normal because of the nonlinearities. Although we acknowledge these considerations, we see little choice for the present but to proceed as if a simple additive error were present at the end of Eqs. (6) and (9), which we interpret as specification error.

For the same reasons, we cannot introduce and estimate the usual kind of fixed-effects error model, such as is used in Galloway et al. (1993, 1994). First, we actually should introduce an error into each of the subequations for M, N*, and D; these would not add to a single fixed effect, as in the linear model. To introduce three fixed effects for each *Kreis* would use up 1,221 (=3 x 407) degrees of freedom, and estimation would in any case be beyond the capabilities of our software. With linear models, fixed-effect errors can be purged by subtracting the area-specific mean value from the dependent variable and from each regressor. That cannot be done here, however, because in Eq. (6) or (9), the change in F does not equal the nonlinear function of the changes in the regressors.

Although we cannot estimate a full fixed-effects model, we can estimate the model with fixed effects for large regional groupings of the *Kreise*, where each of the three subequations has its own region-specific fixed effect. We wish to focus on the causes of fertility change rather than on the causes of persistent differences in levels. We hope to isolate the component of variance in the sample arising from changes in fertility over time within *Kreise* (the "within" component of variance); inclusion of regional dummies is a step in this direction. We experimented to determine the maximum number of such regions that our software could estimate, and found that it was nine. We formed these nine regions by combining some of the 14 provinces of Prussia (Galloway 1991:35) . The nine dummies, each with a coefficient in each of the three subequations, lead to estimation of 27 (=3x9) additional coefficients.[17] We estimated this model for Eq. (6), but it proved impossible for the additionally constrained model of Eq. (9). The estimated regional fixed effects indicate whether each region had natural fertility, desired surviving children, or had a propensity to avert unwanted births at a level persistently higher or lower than would have been predicted on the basis of the values of all the included explanatory variables.

HOW IS ESTIMATION POSSIBLE?

Because we observe none of M, N*, and D, one reasonably might ask how we identify the model, and in what sense we can claim to measure M, N*, and D and to distinguish statistically among causal influences on them. Identification is achieved primarily through the imposed nonlinear structure of the model, which implies that some interactions of M, N*, and D are included and others are excluded. We achieve it secondarily through the inclusion and exclusion of particular variables in the subequations for M, N*, and D. In principle, identification could be achieved solely on the basis of the nonlinearities in the model specification, even if all variables were included in each subequation. In practice, however, this would be inefficient and perhaps impossible.

It is important to establish that our results do not depend on minor or arbitrary aspects of the specification. To this end, we have estimated a number of alternative specifications. First, we have varied the functional form by estimating both the version of Eq. (6) and of Eq. (9). Second, we have estimated with and without regional fixed effects. Third, we have estimated the model not only with our preferred list of variables for the subequations for N* and D, but also with an identical list of variables for N* and D. This last version allows us to assess the degree to which our identification of N* and D, and the importance of the various influences acting on them, depend on the specific variable restrictions assumed, or on the functional form. Table 3 shows the lists of variables for our preferred specification and for the sensitivity test.

Table 3. Variables Included in and Excluded from Subequations

Variable	M, Completed Natural Marital Fertility (X)	N*, Demand for Surviving Children (Y)	D, Propensity to Avert Unwanted Births (Z)
Proportion Married	*	—	—
Age at Marriage	*	—	—
BREASTFEEDING	*	—	—
INFANT MORTALITY	*	—	—
MARRIED SEX RATIO	*	—	—
INCOME	*	*	—(*)
FLFPR	—	*	—(*)
MINING	—	*	—(*)
BANK	—	*	—(*)
INSURANCE	—	*	—(*)
URBAN	—	*	*
CATHOLIC	—	*	*
SLAV	—	*	*
CHURCH	—	*	*
HEALTH	—	*	*
EDUCATION	—	*	*
COMMUNICATIONS	—	—(*)	*

Note: Variables included are indicated by an asterisk (*); those excluded, by dashes (—). The preferred specification, on which the reported estimates and the tables and figures are based, is given by the first entry in each column. The second entry, in parentheses, indicates a second specification used to assess the sensitivity of the results to the inclusions and exclusions.

ESTIMATION

Using nonlinear least squares, we have estimated three different versions of the model: Eq. (6), Eq. (9), and Eq. (6) with nine regional dummies, each occurring in each subcomponent of the model.[18] (An additional sensitivity test will be described later.) In Eq. (6), M and N* are determined by linear relationships, while D is constrained nonlinearly between 0 and 1. In Eq. (9), M, N*, and D are all constrained nonlinearly.

Table 4 presents the results of these nonlinear regressions. In Eqs. (6) and (9) it can be seen that the coefficient estimates are very similar: all the signs are identical, and most of the magnitudes differ little except the constant in the M component. We find some interesting differences in signs and coefficients in the fixed-effects model of Eq. (6), which we will discuss later. R^2 is the same in Eqs. (6) and (9): .66, increasing to .75 with the addition of the nine regional dummies. It is encouraging that imposition of the additional constraints in Eq. (9) did not lead to loss of explanatory power.

We will first discuss the signs and significance of the coefficient estimates in relation to hypothesized relations; in a later section we will interpret their magnitudes. Overall we found the fixed-effects estimates to be least satisfactory; we will discuss them separately.

First let us consider Eqs. (6) and (9). The natural fertility component (M) includes four variables (the additional variables for singulate mean age at marriage and for proportions married are reflected in accounting identities but are useful in identifying other variables through interactions). Coefficients for both Breastfeeding and Infant Mortality have signs contrary to hypothesis, generally significant.[19] Married Sex Ratio, the ratio of married

Table 4. Regression Results

	Expected Sign	Eq. (6) Estimated Coefficient	Eq. (6) t-statistic	Eq. (9) Estimated Coefficient	Eq. (9) t-statistic	Eq. (6) with 9 Region Dummies Estimated Coefficient	Eq. (6) with 9 Region Dummies t-statistic
Vector m							
Constant		0.130954	2.84	−1.651320	−3.05		
BREASTFEEDING	−	0.000744	2.24	0.004142	1.01	0.001010	5.49
INFANT MORTALITY	+	−0.000470	−7.33	−0.005383	−6.83	−0.000215	−4.91
MARRIED SEX RATIO	+	0.156077	3.96	1.618900	3.62	0.324254	7.91
INCOME	+	0.000054	4.14	0.000773	4.52	−0.000001	−0.17
Region Dummy 1						−0.068605	−1.73
Region Dummy 2						−0.046629	−1.20
Region Dummy 3						−0.086985	−2.18
Region Dummy 4						−0.075584	−1.94
Region Dummy 5						−0.011139	−0.33
Region Dummy 6						−0.123848	−2.84
Region Dummy 7						−0.076258	−1.88
Region Dummy 8						−0.114992	−2.01
Region Dummy 9						−0.058526	−1.47
Vector n							
Constant		3.660820	38.73	0.221363	2.61		
CATHOLIC	+	0.005984	8.69	0.005085	8.61	0.005076	10.86
SLAV	+	0.012919	15.52	0.010543	15.07	0.012380	18.97
CHURCH	+	0.166831	1.60	0.125378	1.37	−0.288391	−4.25
EDUCATION	−	0.144877	4.50	0.144293	4.97	−0.114020	−7.04
HEALTH	−	−0.711783	−5.26	−0.540126	−4.46	−0.184129	−2.38
FLFPR	−	−0.027428	−9.47	−0.027443	−9.62	−0.017767	−11.16
INCOME	−	−0.000503	−5.71	−0.000551	−6.32	−0.000104	−2.04
MINING	+	0.029396	9.45	0.027091	10.40	0.021829	10.90
BANK	−	0.075557	0.61	0.039503	0.34	−0.349061	−3.53
INSURANCE	−	0.045312	0.32	0.068167	0.50	−0.070940	−0.66
URBAN	−	−0.003700	−3.60	−0.002745	−3.08	−0.000685	−1.08
Region Dummy 1						3.855200	66.04
Region Dummy 2						3.909810	58.85

(continued)

Table 4. *(continued)*

	Expected Sign	Eq. (6) Estimated Coefficient	Eq. (6) t-statistic	Eq. (9) Estimated Coefficient	Eq. (9) t-statistic	Eq. (6) with 9 Region Dummies Estimated Coefficient	Eq. (6) with 9 Region Dummies t-statistic
Region Dummy 3						3.504100	64.37
Region Dummy 4						3.673320	64.99
Region Dummy 5						3.770120	62.19
Region Dummy 6						4.231530	76.81
Region Dummy 7						4.591800	59.68
Region Dummy 8						4.174590	75.54
Region Dummy 9						4.162330	60.67
Vector d							
Constant		1.161050	6.36	1.028260	5.77		
CATHOLIC	+	0.013719	9.68	0.013196	10.18	0.055135	9.24
SLAV	+	−0.008231	−3.00	−0.010552	−3.94	−0.035294	−6.47
CHURCH	+	−0.161587	−0.63	−0.085880	−0.36	2.301570	4.13
EDUCATION	−	−1.297190	−13.78	−1.215280	−13.84	−1.823960	−8.22
HEALTH	−	−0.301691	−0.94	−0.371928	−1.24	−17.147700	−8.87
COMMUNICATIONS	−	−0.069524	−2.00	−0.052008	−1.63	−0.116759	−1.15
URBAN	−	0.017121	8.98	0.015924	9.16	0.038176	7.48
Region Dummy 1						3.836180	7.57
Region Dummy 2						2.242510	5.32
Region Dummy 3						0.427295	1.01
Region Dummy 4						3.192830	5.97
Region Dummy 5						1.909060	5.15
Region Dummy 6						0.203418	0.10
Region Dummy 7						2.854830	5.84
Region Dummy 8						−0.884378	−0.50
Region Dummy 9						1.100530	2.71
Observations		3,256		3,256		3,256	
R-Squared		0.661		0.664		0.752	

males to married females, has the hypothesized positive effect, as does Income, intended as a proxy for nutrition; both are highly significant.

The "demand for surviving children" component (N*) contains 11 explanatory variables, of which the coefficients of eight differ significantly from 0. Of these eight, all but one have the hypothesized signs. Coefficients on Insurance and Bank are insignificant; this finding is disappointing and somewhat puzzling because both were highly significant and had the theoretically expected sign in the earlier linear analyses (Galloway et al. 1993, 1994). Indeed, these variables explained substantial portions of the fertility decline.

In the "readiness to avert unwanted births" component, a negative sign on the coefficient for a variable indicates that it is associated *positively* with readiness because dZ is in the denominator. Among the coefficients, Slav, Church, and Urban have unexpected and (except for Church) significant signs. Coefficients of the remaining variables, Catholic, Education, Communications, and Health, all have the predicted signs; all but that for Health differ significantly from 0.

In the model based on Eq. (6) and including nine regional dummies, the coefficients for the M component are of the "wrong" sign in three out of four cases. Coefficients in the other subcomponents agree more closely with hypotheses, however. In the demand subequation (N*), only one of the 11 coefficients (Church) has a sign contrary to hypothesis; both Insurance and Bank emerge with negative effects, as hypothesized. In the "readiness to avert" subequation (D), all but two coefficients are of the hypothesized sign; Church now has a positive effect, as predicted. The estimated regional effects indicate a range of two children per woman from the lowest region to the highest, net of all included factors. For the demand equation, they indicate a range of one child.

In the decomposition that follows, many of the variables with unexpected signs in these three models will be shown to be unimportant.

INTERPRETATION OF THE ESTIMATES

Because of the complex nonlinear structure of the model, it is difficult to interpret the estimated coefficients directly; thus we provide ancillary calculations. We will investigate the estimates in three stages. First, we will examine the effects of the individual variables overall and on each analytic component; second, we will derive the estimates of the analytic components M, N*, N*/s, and D; third, we will consider the relative importance of changes in each of these components for explaining the fertility decline.

The discussion in this section is based on our preferred estimates, those of Eq. (9). The results are almost identical for Eq. (6), but often are different for Eq. (6) with regional dummies.

Table 5 shows the predicted level and the change in the national total marital fertility when one variable takes on its actual national average value in 1875 and in 1910, while all other variables are held constant at their national sample means. Effects operating through each relevant component are evaluated separately.

Actual fertility declined from 5.7 to 4.7 children per woman, on average (Table 2). Predicted fertility declined by less, from 5.6 to 4.9 (Table 6). Table 5, for example, shows that the tiny increase in the average of Married Sex Ratio, the ratio of married men to married women, led to a tiny increase of less than .01 birth in completed marital fertility. Income had the greatest effect on natural fertility, increasing the number of births by .14. Breastfeeding and Infant Mortality have the "wrong" effects, but their contributions are smaller than that of Income.

The .50 increase in total married years, TMY, led to an increase of .05 births per married woman. The increase in s, survival to age 15, caused a small fertility decline of .15

Table 5. Predicted Fertility (F) When One Variable Takes Values of 1875 and 1910, and All Others Are at Sample Means

Variable	1875	1910	Change 1875 to 1910
Vector m			
BREASTFEEDING	5.313	5.301	−0.012
INFANT MORTALITY	5.284	5.378	0.094
MARRIED SEX RATIO	5.302	5.308	0.006
INCOME	5.224	5.362	0.138
Vector n			
CATHOLIC	5.301	5.310	0.009
SLAV	5.305	5.305	0.000
CHURCH	5.306	5.310	0.005
EDUCATION	5.243	5.362	0.119
HEALTH	5.342	5.241	−0.101
FLFPR	5.438	5.193	−0.245
INCOME	5.429	5.217	−0.212
MINING	5.296	5.321	0.025
BANK	5.304	5.308	0.004
INSURANCE	5.303	5.309	0.005
URBAN	5.315	5.294	−0.021
Vector d			
CATHOLIC	5.301	5.310	0.009
SLAV	5.305	5.305	−0.000
CHURCH	5.305	5.304	−0.001
EDUCATION	5.507	5.148	−0.358
HEALTH	5.314	5.289	−0.025
COMMUNICATIONS	5.315	5.289	−0.026
URBAN	5.285	5.328	0.043
TMY	5.290	5.340	0.050
s	5.339	5.192	−0.147

Sources: Table 2 and Eq. (9) in Table 4.

birth.[20] All of these variables are "supply" variables in the Easterlin-Crimmins framework. Evidently these supply-side changes were not very important in the national fertility decline, although they may well have been influential for explaining differences between *Kreise* and changes over time in individual *Kreise*.

Female labor force participation rate, real income, and concentration of health workers are the dominant influences in the decline in the desired number of surviving children; together they account for a decline of .56 child. Although the sign of Education is opposite to our expectation in the N* equation, its overall net effect on marital fertility, found by adding in the effect through D, is as expected: the rise in Education led to a substantial fertility decline of about .24 birth. As for readiness to avert births, Education is by far the most important factor; it accounts for a decline of .36 birth, more than any other variable in any subcomponent.

Table 6 exhibits the implied estimates, or simulations, along with standard errors of the analytic components over this period, as estimated in Eq. (9). One should keep in mind that none of these components is observed directly, and that these calculated values are the result of imposing a very tight structure on the analysis. We are surprised that these numbers

Table 6. Estimated Analytic Components of Fertility

	1875 to 1910	1875	1880	1885	1890	1895	1900	1905	1910
Estimates (per married woman)									
M, Natural Fertility	6.758	6.387	6.487	6.513	6.536	6.717	7.031	7.101	7.298
	0.159	*0.116*	*0.129*	*0.140*	*0.143*	*0.164*	*0.198*	*0.199*	*0.211*
sM, Supply of Surviving Children	4.685	4.382	4.461	4.453	4.495	4.627	4.873	4.976	5.242
	0.111	*0.080*	*0.089*	*0.096*	*0.098*	*0.113*	*0.137*	*0.139*	*0.151*
N*, Desired Surviving Children	3.237	3.461	3.376	3.307	3.308	3.223	3.095	3.084	3.052
	0.053	*0.054*	*0.055*	*0.055*	*0.051*	*0.052*	*0.057*	*0.054*	*0.053*
N*/s, Desired Births	4.670	5.045	4.910	4.837	4.809	4.679	4.465	4.400	4.249
	0.077	*0.079*	*0.080*	*0.081*	*0.075*	*0.075*	*0.083*	*0.077*	*0.073*
D, Proportion of Unwanted Births Which Is Avoided	0.696	0.602	0.614	0.644	0.685	0.723	0.740	0.756	0.773
	0.022	*0.026*	*0.026*	*0.024*	*0.023*	*0.021*	*0.020*	*0.019*	*0.019*
M-(N*/s), Unwanted Births	2.088	1.343	1.577	1.677	1.726	2.038	2.566	2.701	3.049
	0.215	*0.182*	*0.193*	*0.204*	*0.201*	*0.220*	*0.255*	*0.250*	*0.255*
D(M-(N*/s)), Unwanted Births Averted	1.453	0.808	0.968	1.080	1.183	1.473	1.899	2.043	2.358
	0.162	*0.117*	*0.131*	*0.143*	*0.147*	*0.169*	*0.202*	*0.202*	*0.213*
(1-D)(M-(N*/s)), Unwanted Births Born	0.636	0.534	0.609	0.596	0.543	0.565	0.667	0.658	0.692
	0.074	*0.078*	*0.079*	*0.078*	*0.071*	*0.071*	*0.079*	*0.075*	*0.075*
sF, Surviving Children	3.678	3.827	3.795	3.714	3.681	3.612	3.557	3.545	3.549
	0.010	*0.012*	*0.011*	*0.010*	*0.011*	*0.011*	*0.013*	*0.012*	*0.014*
F, Fertility	5.305	5.579	5.519	5.433	5.353	5.244	5.132	5.058	4.941
	0.015	*0.017*	*0.016*	*0.015*	*0.015*	*0.016*	*0.018*	*0.017*	*0.020*
F, Actual Fertility	5.310	5.706	5.555	5.420	5.372	5.391	5.321	5.015	4.701

Notes: Entries are predicted values evaluated at the sample means for each period

Standard errors (in italics) are calculated in the usual way for linear combinations of estimated coefficients.

See text for precise definitions.

Sources: Table 2 and Eq. (9) in Table 4.

appear to be so reasonable. We calculate that completed natural marital fertility increased from 6.4 to 7.3 children per married woman. For comparison we computed the total marital fertility from age 25 from two sets of reconstitution studies. From Flinn's (1981:111) presentation of data from three German villages for the period 1780–1820, we calculate 7.2 births. From Knodel's (1988:373) study of 14 Prussian parishes for 1750–1774, we calculate 6.8 births.[21] At these early dates it was unlikely that birth limitation was practiced widely, so these numbers should be roughly comparable to our measure of completed natural marital fertility—provided that breastfeeding practices in these few small study populations at the end of the eighteenth century were similar to those in all of Prussia at the end of the nineteenth. On this assumption, the figures of 6.8 to 7.2 that emerge from these studies compare extremely well with our estimated range of 6.4 to 7.3.

The desired number of surviving children, N*, is estimated to decline from 3.5 to 3.1 over the 35-year period, or by .4. These numbers refer to surviving children, not to births. The implied desired number of births can be obtained by dividing N* by s, the proportion of births surviving to age 15. When this is done, the desired number declines from about 5.0 in 1875 to about 4.2 in 1910, or by about .8. When the level and the change in survival are taken into account, the amount of decline doubles. Combining these changes in M and N*/s, we note that the gap between natural fertility and desired births increased from 1.3 children in 1875 to 3.0 children in 1910. Of this increase by 1.7, .4 was due to the decline in N*, another .4 was due to declining mortality, and the remaining .9 was due to increased natural fertility. Thus changes in supply (M and s) were very important.

The readiness to limit unwanted births is estimated initially at .60 and increases to .77 in 1910. Combining these estimates with the estimated gap, we can infer that in 1875, .8 unwanted births were averted and .5 unwanted births occurred. In 1910, 2.4 unwanted births were averted, nearly three times as many as in 1875, while .7 unwanted births occurred. Thus the tendency of unwanted births to increase, because of declining desired numbers and increased supply, was not quite offset by an increase in readiness to limit potential unwanted births.

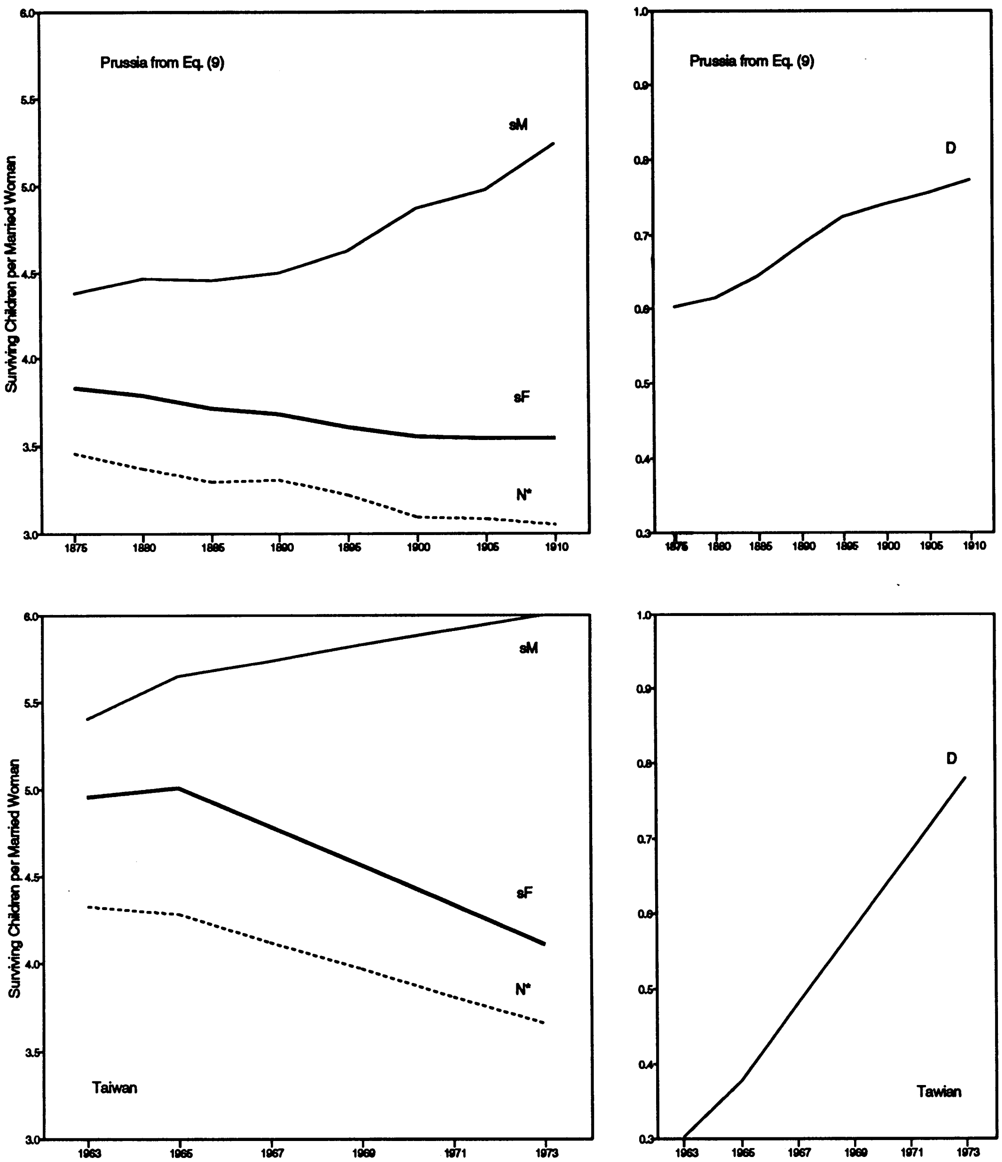
We plot the estimated analytic components of fertility in the top panel of Figure 1. The bottom panel plots the estimates of the same conceptual variables for Taiwan, but N* and D are estimated directly through surveys (Easterlin and Crimmins 1985:136). To facilitate comparison we use Easterlin and Crimmins' definitions of supply (sM), demand (N*), and number of surviving children (sF). The plotted Taiwan data begin around the onset of secular fertility decline, as do the Prussian data. Easterlin and Crimmins present Taiwan data only through 1973.

The two panels show striking similarities. The supply of surviving children increases greatly in both cases, and the desired number of surviving children declines in both. The readiness to limit unwanted births increases in both, but far more strongly in Taiwan, as we might expect under the influence of an active family planning program and the growth in commercial availability of contraceptives. In both cases, the main effect of this growing readiness is to prevent an increase in unwanted births that otherwise would have occurred, rather than to reduce the number of unwanted births. Note that the Taiwan plot, though similar, covers only 10 years, while the Prussian graphs show 35. This difference reflects the relative rapidity of the fertility decline observed in contemporary less developed countries in comparison with historical European historical fertility decline.

The combined effect of all these changes leads to a predicted decline in fertility from 5.6 to 4.9, or by .7 birth; the rate actually declined from 5.7 to 4.7, or by 1.0 birth. Put differently, the estimated Eq. (9) accounts for about 64% of the average fertility decline. By contrast, the linear model without fixed effects estimated in Galloway et al. (1994) accounts for 55% of the decline in the GMFR. Eq. (6) with dummies accounts for about 73% of the fertility decline. The linear model in Galloway et al. (1994) with fixed effects added also is more effective, accounting for 84% of the decline.

If the nonlinear model has an advantage, it lies less in its ability to account for the fertility decline than in its ability to explain in a coherent and organized fashion how and why it happened. Table 7 shows simulated changes in fertility due to M, N*, N*/s, and D. When the effect of change in one is assessed, the values of the others are held fixed at the 1875 levels. In a linear model, the sums of these predicted changes would sum to the total predicted change, or −.614, −.639, and −.727, for Eqs. (6), (9), and (6) with nine dummies. Here, however, the individual effects interact in the way explained earlier. The decline in the desired number of births, for example, has a greater effect when readiness to avert births is higher than when it is lower; and the effect of an increase in natural fertility is less when this is so. Consequently the contributions of M, N*/s, and D in Table 7 sum to only −.347 rather than −.639 (using Eq. (9) as an example); the remainder is due to their interaction.

The simulations in Table 7 are plotted in Figure 2 for Eqs. (6), (9), and (6) with dummies. According to Eq. (9), for example, an increase in M would have led to a rise in F by .363 child; a decline in N*/s would have led to a decline in F by .479 child; and a rise in the readiness to avert births, D, would have led to a decline of .230 child. In this accounting, then, changes in the desired number of births are about twice as important as changes in the readiness to avert births. Eq. (6) leads to the same conclusion. In Eq. (6) with



Sources: Prussia: Table 6. Taiwan: Calculated with data from Eastern and Crimmins (1985:136).

Figure 1. Estimated Analytic Components of Fertility

regional dummies, however, changes in the desired number of births are more than five times as important as the increased readiness to contracept. In all cases, the decline in demand dominates the increase in readiness to contracept, but evidently the relative magnitudes are not robust to model specification.

A SENSITIVITY TEST

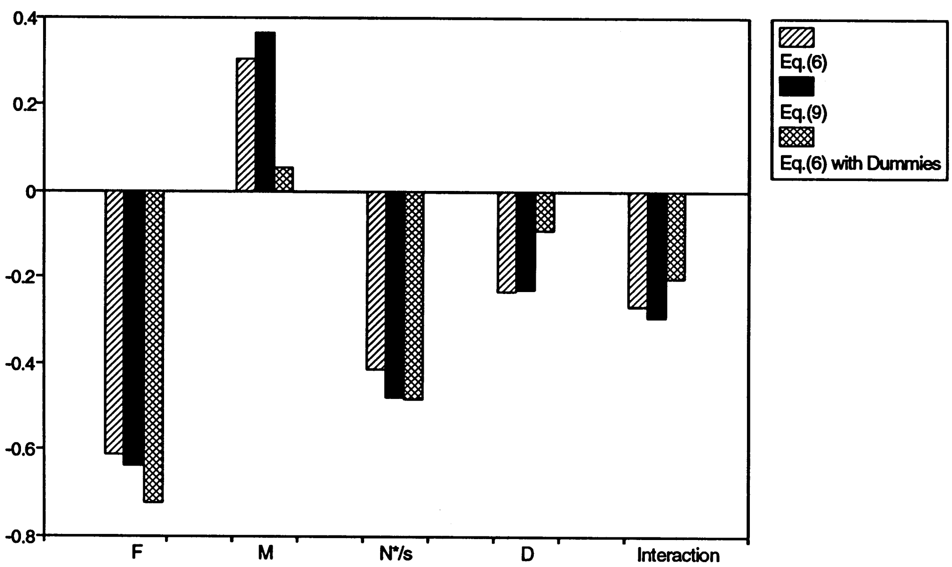
As mentioned earlier, we also estimated a version of Eq. (9) in which the same set of regressors is used for the N* and the D subequations. This procedure permits us to appraise

Table 7. Interpreting the Importance of the Analytic Components of Fertility Decline

Variable	Eq. (6) 1875	Eq. (6) 1910	Eq. (6) Change 1875 to 1910	Eq. (9) 1875	Eq. (9) 1910	Eq. (9) Change 1875 to 1910	Eq. (6) with Dummies 1875	Eq. (6) with Dummies 1910	Eq. (6) Dummies Change 1875 to 1910
Estimate of F	5.581	4.967	−0.614	5.579	4.941	−0.639	5.620	4.893	−0.727
M	5.581	5.886	0.305	5.579	5.942	0.363	5.620	5.673	0.053
N*	5.581	5.286	−0.295	5.579	5.220	−0.359	5.620	5.309	−0.310
N*/s	5.581	5.165	−0.416	5.579	5.100	−0.479	5.620	5.137	−0.483
D	5.581	5.346	−0.235	5.579	5.349	−0.230	5.620	5.527	−0.093
Interaction			−0.267			−0.292			−0.205

Notes: In the estimate for 1910, all components are held constant at their 1875 predicted value except the listed component. The predicted value in 1910 is used for this listed component.
Sources: Tables 2 and 4.

the extent to which our results depend on the specific choice of variables for the N* and the D subequations. The inclusions and exclusions in the preferred model and in this experiment were shown in Table 3. The results for the newly included variables are as follows: Communications is estimated to have a significantly negative effect on N*. Income and FLFPR both have significant effects on readiness to avert births, but in the "wrong" direction; that is, they discourage contraception. Mining and Banking have insignificant effects, while Insurance is found to significantly increase the propensity to avert births. Whatever one makes of this collection of results, it is reassuring to note that there is little change in the qualitative interpretation emerging from the estimation: we estimate very similar levels and trends for M (the average value from 1875 to 1910 is 6.9 in the new specification versus 6.8 in the original specification), N* (3.3 versus 3.2); and D (.76 versus



Source: Table 7.

Figure 2. Estimated Analytic Components of Fertility Decline, 1875 to 1910

.70). The greatest change is that D increases less sharply in this modified specification (by .07 in 1875 versus .17 in 1910); therefore changes in the readiness to contracept play a smaller role in accounting for the transition than do changes in natural fertility, mortality, and the desired number of surviving children. In this respect, the results resemble those from Eq. (6) with fixed effects. This experiment shows that the broad results do not depend on the details of choice of regressors in the subequations, and suggests that identification is achieved largely through the nonlinear structure of the framework relating M, N*, s, and D.

SUMMARY AND CONCLUSION

The analysis undertaken here is experimental. The formal model is new, although it derives from the well-known framework of Easterlin and Crimmins (1985). Our Prussian data set, although unusually rich, does not contain direct measures of the key analytic components: natural marital fertility, desired number of surviving children, and readiness to avert births. We estimated these components and the variables affecting them by imposing a tight structure on the specification. In the case of natural marital fertility we were able to make rough comparisons with historical family reconstitution studies, which suggested that our estimates were surprisingly good. For desired number of children and readiness to avert, however, we lack historical information, and have no way to establish whether the indirect estimates presented here are reasonably close to the truth.

We were unable to resist taking our results literally and drawing out their detailed implications, despite the obvious risks in doing so. In Eqs. (6) and (9), we attribute twice as much responsibility for the fertility decline to a desire for fewer births than to an increased readiness to avert undesired births. This ratio jumps to five times as much in the fixed-effects model. An increase in natural marital fertility tended to raise fertility; an increase in survival prospects tended to lower it. Although the number of unwanted births averted tripled over the period, the number of unwanted births occurring still rose slightly, by .1 or .2. If we take these results at face value (admittedly a risky step), they contradict Cleland and Wilson's (1987) claim that demand-side changes were not important in the demographic transition.

Of the explanatory variables we considered, the most important in accounting for the decline in average fertility in Prussia were female employment in nontraditional occupations (−.245), prevalence of teachers (−.239), concentrations of health workers (−.126), and real income (−.074).[22] The estimated strong role of increased survival in reducing the desired number of births was largely offset by its estimated perverse effect in raising natural fertility.

Although the estimates in this paper present some puzzles, we find the overall performance of this experimental model quite promising. The results suggest that structural socioeconomic change can explain much of the fertility transition. The structural change exerted its influence primarily by reducing the desired number of children and, to a lesser extent, by increasing the willingness and ability of the population to implement their desires through limiting births. These two aspects of behavior interacted to bring about a decline greater than the sum of their individual contributions.

NOTES

[1] For example, the average growth rate for the European population from 1600 to 1800 was only .0025 (Livi-Bacci 1992:31), corresponding to an average NRR of about 1.1.

[2] By "programmatic variables" we mean variables related to the existence and efficiency of family planning programs.

[3] We estimate that fertility began its long-term decline in Prussia around 1890. Knodel (1974:58–62) estimates that long-term fertility decline in Germany as a whole began around 1895.

[4] A *Kreis* is a small Prussian administrative unit, similar to a census tract but larger. The average population of a *Kreis* is about 60,000. Some *Kreise* subdivide over time. Where necessary, we have grouped *Kreise* together to form one unit so as to achieve consistent administrative borders over the sample period.

[5] Knodel (1974) and Richards (1977) analyzed fertility in 71 large districts in Germany, of which 34 were in Prussia. (Recall that we are examining 407 areas in Prussia.) Knodel found that fertility was associated positively with proportion Catholic, infant mortality, percent dependent on primary industry, and illiteracy among military recruits. Fertility was associated negatively with high ratios of savings accounts and slightly negatively with his measure of female employment outside agriculture (Knodel 1974:260–61). Many of the variables used by Knodel were analyzed for only one or two points in time. Using a method similar to ours (in Galloway et al. 1993, 1994) but with far fewer units of analysis and independent variables, Richards found that "industrialization, urbanization, religious composition, migration, infant mortality and marriage patterns satisfactorily explain the fertility decline once regional differences have been taken into account" (1977:403).

[6] Selection of age 15 is rather arbitrary, but any choice between 15 and 25 or 30 would yield very similar results.

[7] The GMFR is calculated as the annual number of legitimate births in the *Kreis* divided by the number of married women between ages 15 and 49. The TMY is the average number of married years spent by females between ages 15 and 49 in each *Kreis*. The TMY can be calculated for the 36 *Regierungsbezirke*, larger geographic units containing the *Kreise*, by summing the proportions of women in each age group who are currently married. Such data do not exist for the individual *Kreise*, but we have *Kreis*-level data on married females age 15–49 as a proportion of all women age 15–49. We first estimate a regression for *Regierungsbezirke* of TMY on this proportion and on the singulate mean age of marriage. Then we use this regression, with the *Kreis*-level proportion and the *Regierungsbezirke*-level singulate mean age, to predict the TMY. The TMY includes years of low average fecundity, such as 45–49; this should not matter because these years also are included in the denominator of the GMFR.

[8] Röse (1905) published data on average duration of breastfeeding and percentage of children ever breastfed for 34 cities and 113 districts in Germany, Switzerland, and Sweden. The data were collected by Röse and many other dentists. The purpose of the study was to assess the impact of differences in breastfeeding practices on children's dental health and on the physical fitness of military recruits. Röse also examined differences in breastfeeding practices by locality (region, city, suburb, rural area). We have restricted our use of his data to places in Prussia.

[9] Behrman and Deolalikar (1988) have shown that income is not always associated positively with nutrition.

[10] In analyses of individual data (see Easterlin and Crimmins 1985; Rosenzweig and Schultz 1985) it is often assumed that couples evaluate their own natural fertility by observing their own birth outcomes at an early stage of their union. The aggregate-level counterpart is to estimate natural fertility based on marital fertility at ages 20–24 (Coale and Trussell 1978), but that is not feasible with our data set because we do not have age-specific fertility at the *Kreis* level.

[11] The employment rates for unmarried women are correlated quite highly with those for married women. This finding encourages us to believe that low fertility was not causing some areas to have higher female employment, rather than the reverse causation (Galloway et al. 1993, 1994).

[12] We found that mining towns were associated with somewhat higher levels of male child employment (Galloway et al. 1993).

[13] Golde suggests that lower fertility among Protestants is a consequence of higher levels of literacy among Protestants in the preindustrial era, which enabled them to mechanize earlier. This led in turn to a lower labor value of children (Golde 1975). As a consequence, Catholics would have higher fertility. The same argument probably would hold for the Slavic-speaking population, who have the highest rates of illiteracy in nineteenth-century Prussia. We might already have picked up such effects with our educational variable—but not necessarily.

[14] This category includes those whose primary occupation involves church and religious activities.

[15] Health workers include doctors, nurses, midwives, veterinarians, and associated administrative and service employees.

[16] Of 300 couples interviewed, both spouses were Catholic in 24 cases.

[17] We experimented with a variety of specifications, including Eq. (6) with 36 *Regierungsbezirk* dummmies and Eq. (9) with the nine regional dummies. Estimation of these models failed.

[18] Estimation placed substantial demands on our software, particularly when regional fixed effects were included. We experimented with Gauss, MicroTSP, Stata, and 386-TSP. The last of these proved most satisfactory for our purposes.

[19] We note that the association between Infant Mortality and fertility is statistically insignificant in our pooled regression analysis of 407 *Kreise*, but shifts strongly to the hypothesized positive association in the fixed-effects model (Galloway et al. 1994). Breastfeeding is an imputed variable, and may capture only poorly the actual variations in breastfeeding practices.

[20] That is, it increased the supply of surviving children, which in turn led people to desire fewer births. When the extent of readiness to avert births is taken into account, the net result was to reduce fertility by .147 child.

[21] From both Flinn and Knodel, we have marital fertility rates for women marrying at ages 25–29; we summed these rates from ages 25 to the last ages given (40–44 for Flinn and 45–49 for Knodel) and multiplied by 5. Knodel also found that natural fertility increased over time in his sample of German villages (Knodel 1988:285).

[22] We calculated these by summing all the effects occurring for each variable in Table 5. Declining mortality has two effects. First, in our estimates it perversely raises fertility by .094, operating through natural fertility; second, it reduces fertility by .147, operating through the increased survival of children, s. The net effect is −.053.

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