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## Institutions and Demographic Responses to Shocks: Württemberg, 1634-1870


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# Institutions and Demographic Responses to Shocks: Württemberg, 1634-1870

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## Abstract

Simple Malthusian models remain an important tool for understanding pre-modern demographic systems and their connection to the economy. But most recent literature has lost sight of the institutional context for demographic behavior that lay at the heart of Malthus's own analysis. This paper estimates a short-run version of a Malthusian model for two Württemberg communities from 1646 to 1870. Württemberg differed institutionally from the northwest European societies analyzed in previous studies. The impact of institutional differences shows clearly in differing demographic reactions to economic shocks. Mortality was less sensitive to shocks than one would expect, while nuptiality was especially sensitive.

**JEL codes**: N33, J10

**Keywords**: Malthusian models, mortality, fertility, nuptiality, guilds

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## Tables, Figures, and Appendices

Malthusian ideas now lie at the heart of discussions of population and its relationship to the economy. In their *Population History of England* (1981), Wrigley and Schofield argued that Malthus's preventive check worked particularly strongly in early-modern England, especially in comparison with France, and helps explain the English economy's earlier and more robust development. A more recent line of research, usually called "unified growth theory," starts from economic models of long-run growth, and tries to integrate population into that picture. This literature uses the term "Malthusian" in a much looser sense, but most versions focus on changing demographic behavior as the key to sustained economic growth.[1]

Social institutions have hitherto been largely absent from these discussions – a surprising gap given their importance for Malthus himself and in modern microeconomic theories of demographic behaviour. This paper brings institutions back into the story, focusing on how they regulated economic decisions, demographic behavior, and the relationship between the two. The society we study here – the south German territory of Württemberg – gave local communities, occupational guilds, and the state much stronger power to regulate residence, occupation, and marriage than was the case in England, France, or other societies of the northwest Atlantic seaboard. We see the demographic implications of these institutions in the models reported below. Institutions form a central research agenda in economic history today, but they seem to have gone missing from the literature on historical population and its relationship to the economy. Malthus of course grounded his hopes for long-term economic growth in changing institutions, especially in reducing the incentive for the poor to undertake "early and improvident" marriages. By

[1] The unified growth literature tries to understand long-run growth by integrating endogenous population into economic models of growth. The most visible figure is Oded Galor. See, for example, Galor and Weil (2000).

re-asserting the role of institutions in demographic behavior, we hope to nudge the literature toward a broader and more useful understanding of this central issue in long-run economic growth.

This literature now contains contributions on many different regions of Europe and indeed around the world. We focus here on the way the people of Wildberg and Ebhausen, two small communities in Württemberg, responded to price shocks in the period 1646-1870. Württemberg had a different kind of institutional organization than most European regions studied thus far. For one thing, its state institutions were militarily hyperactive but fiscally inefficient, repeatedly involving the country in expensive and disastrous wars from the seventeenth to the nineteenth century. It secured domestic support for these ventures by enforcing the powers and privileges of local corporative institutions, particularly guilds and local communities.[2] Much has been written about guilds recently, and there is a small literature on how guilds and related institutions affect demographic behavior.[3] Communal institutions have also attracted growing attention in the literature on demography, economic development, and "social capital".[4] Our results challenge some of what is in the literature, and support the view that these institutions in fact constrained demographic and economic opportunities for many people.

This paper is part of a larger project on long-run demographic and economic development in this part of Germany. The next step is to use family reconstitution methods to study the determinants of marriage, fertility and mortality in three Württemberg communities – these two and one other. Because we have individual-level

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[2] Wilson (1995); Vann (1984); Ogilvie (1997, 1999).
[3] Braun (1978); Hardwick (1998); Hermann (2005); Lee (1999); Ogilvie (1997, 2003); Taylor (1994).
[4] Fertig (2000); Ogilvie (1997, 2003, 2004); Dennison and Ogilvie (2007); Rosero-Bixby, Collado and Seligson (2005); Rosero-Bixby and Casterline (1994); Montgomery and Casterline (1996); Bongaarts and Watkins (1996).

data, we will be able to address some questions that must remain open here. And because we can link the demographic information to a wide array of variables that describe wealth, occupation, office-holding, etc., we will be able to advance the relevant historical demography literature considerably.[5] This paper, however, explores a crucial initial issue: how this central European demographic system, regulated institutionally by the state, occupational guilds, and local communities, responded to economic shocks. Family reconstitution techniques, with all their strengths, cannot address this question completely because their findings relate to the "reconstitutable minority". The approaches used in this paper, by contrast, capture the demographic responses of the whole population. This is especially important given that many European societies – including the German society analysed here – institutionally prevented certain groups from marrying, excluding them from appearing as adults in a family reconstitution. We use techniques here that capture this otherwise invisible section of the population.[6]

The next section describes the Malthusian model and its relationship to the short-term models we estimate and report below. Section 2 turns to the demographic and economic background, that is, Wildberg and Ebhausen, their social institutions, and their place in the regional economy. We next describe the underlying data sources and providing a summary overview of the demographic series for Wildberg and Ebhausen in

[5] These family reconstitution studies, linked to socioeconomic data from other historical sources, are being undertaken in the context of a project entitled "Economy, Gender, and Social Capital in the German Demographic Transition", supported by the Leverhulme Trust (F/09 722/A); for further details, see http://www.hpss.geog.cam.ac.uk/research/projects/germandemography/.

[6] A recent literature uses family-reconstitution techniques to ask how specific life-course events respond to economic shocks. See Bengtsson and Dribe (2006) for an example dealing with fertility. Breschi, Fornasin, and Gonano (2005) use published official demographic data to study the impact of price shocks on mortality at different ages in Tuscany. This method, where it is feasible, has the virtue of working with the demographic behavior of the entire population. We intend to pursue approaches similar to Bengtsson and Dribe with our family reconstitutions, bearing in mind the limitation of the "reconstitutable minority" that underlies such work.

this period. Section 4 describes our econometric methods, and Section 5 reports our results.

## 1. **The Malthusian Model**

Economists and others employ the term "Malthusian" too broadly, often using it when what they really mean is a poor economy, or one in which mortality seems to them especially high. We find it most useful to stick to what Malthus argued. The model consists of three equations. The first says that births are a function of the real wage. The second says that deaths are also a function of the real wage. The third says that the real wage is a negative function of the number of people using a given stock of capital and natural resources. Our focus in this paper is to estimate the central elasticities in the first two equations: the effects of real wage shocks on births and on deaths.

Figure 1 reproduces a summary of the Malthusian model originally devised by Ron Lee. On the right-hand side, we see the expectation that as the real wage increases, births increase and deaths decrease. The equilibrium population growth rate, zero, occurs at the real wage that equates births to deaths. The left-hand side shows two marginal product of labor schedules. The lower schedule produces that equilibrium growth rate – zero growth – for a population of size $N_0$. This equilibrium illustrates the role of economic productivity in the Malthusian model: the marginal product of labor schedule does not determine the real wage, which is instead determined by the demographic schedules on the right-hand diagram; rather, it determines the size of population consistent with zero population growth. The second, higher marginal product of labor schedule illustrates the effect of an economic shock in this model. Suppose unusually good weather raises productivity above its normal level. Population size is fixed in the short run, so the effect of better productivity is to raise the real wage. At that higher real wage, however, demographic behavior is out of equilibrium: we expect to see a higher birth rate and a lower death rate. This simple comparative-static thought experiment illustrates the identification strategy used in this paper.

Two observations are needed to avoid some of the confusion that has been introduced into the literature. First, the dependence of births on the real wage is mediated, according to Malthus, by marriage. This link reflects what later historians called the "Western European Marriage Pattern," which is based on the social (and sometimes legal) expectation that couples will not marry until they can afford to support themselves and any children.[7] This expectation implies that age at marriage and the chance of marrying at all depend on the real wage. In the simplest Malthusian model there is no fertility control within marriage; ages at marriage and proportions who marry fully determine fertility (at least stochastically). This central assumption is testable, and part of our modeling amounts to tests of that assumption. Second, there is no sense in which a Malthusian model is inconsistent with technological change or necessarily implies a poor population. All it requires is that, as in Figure 1, the equilibrium real wage be a function of demographic decisions. The third equation assumes only that the marginal product of labor is declining for a given stock of capital and a given state of know-how. There is nothing "Malthusian" about this feature of the model; it is central to most neoclassical models of economic growth.

[7] Hajnal (1965, 1982) describes the Western European Marriage Pattern and how it affects population dynamics.

Nobody would be surprised to learn that a shock to incomes raised death rates or reduced fertility. What makes the model interesting is knowing how strong these effects are, and how the strength of each effect varies across societies and time-periods. This was Malthus' own approach in the *Second Essay*. Throughout this paper we use the English and French cases as points of comparison for our two Württemberg communities.

Much of the interest in formal Malthusian models since *The Population History of England* reflects some complex issues inherent in the model. The model we have described contains only endogenous variables. Lee (1985) and others stressed the difficulty of identifying this model using long-run data. But Lee also observed that in the short run, the model is easily identified. In a period of say three or four years, one can treat population size as approximately fixed. This implies that any shocks to the real wage are due to movement *of* the marginal product of labor schedule, as illustrated in Figure 1, and not movement *along* the schedule.[8]

Focus on the short run neatly deals with another serious issue in the Malthusian model. The long-term dynamics of human populations imply that over a generation or more, there will be movements in births and deaths that are echoes of earlier population movements rather than a behavioral response to current shocks. Suppose, for example, that there was a spike in fertility 25 years ago. Today, without any change in individual behavior, there will be another spike in fertility, simply because there is now a large

[8] Earlier papers in this literature all employ the same or similar econometric techniques. But in some cases (for example, Galloway (1988); Hammel and Galloway (2000); Bengtsson and Dribe (2005); Breschi, Fornasin, and Gonano (2005)) the authors interpret their results as demonstrating the way populations react to economic stress. Reactions to stress in fact identify the parameters of the Malthusian model. Bengtsson and Dribe (2005) push the analysis further, arguing that the way populations react to shocks can help the historian understand mechanisms of savings and credit, as well as formal and informal social-welfare systems. We agree.

cohort of young women entering their child-bearing years.[9] Once again, the short-run analysis allows us to avoid this problem.

## 2. The Württemberg Communities of Wildberg and Ebhausen

The demographic data we analyze come from the communities of Wildberg and Ebhausen in the Württemberg Black Forest. The Duchy (after 1806 Kingdom) of Württemberg was a middle-sized state in southwestern Germany – what has been called a "German territory of the second rank" (Vann 1984, p. 36). It had about half a million inhabitants in 1600, sustained serious population lossess in the Thirty Years War (1618-1648), but recovered again to 320,000 by 1700, 640,000 by 1797, 1.7 million by 1849, and just above 2 million in 1900 (Boelcke 1987, pp. 93-6, 165, 215). For most of its history, Wildberg was the capital of one of Württemberg's 45-60 districts, administering itself and 10-12 villages, one of which was Ebhausen. Although Wildberg had the legal status of a town, it was very small, with a population of about 1500 in 1625, 1100 in 1650, 1300 in 1700, 1500 in 1750, 1700 in 1800, and 1800 in 1850, falling again to 1300 by 1900. Ebhausen, as a village, started out much smaller but grew faster, with a population of about 200 in 1650, 350 in 1700, 650 in 1750, 1000 in 1800, and 1600 in 1850 (nearly equalling Wildberg), but then falling back to 1200 by 1900. The relative size and growth trajectories of our two communities can be seen in Figure 2.

[9] We in fact have access to population totals, but do not use them in this paper, in order to maintain the parallel to other literature. Papers that use a long-run version of a Malthusian model must "filter" the data to distinguish between extraneous changes such as echo effects and the underlying trends. Lee and Anderson (2002) use a state-space representation of the Malthusian system with Wrigley and Schofield's English data. They find estimates of the preventative and positive check much more similar to the short-run estimates reported in Galloway (1988), Lee (1981), Weir (1984), and others on non-English societies. Reher and Ortega Osona (2000)'s analysis of England, northern Italy, and northern Castile relies on techniques that require less econometric structure, but impose *a priori* the relevant time-span for the relevant relationships.

Germany was the battlefield of Europe in the seventeenth and eighteenth centuries, and the territory of Württemberg was no exception. It was repeatedly devastated by warfare, partly inflicted exogenously but also exacerbated by its institutional structure, which enabled its rulers to alternate between conspicuous consumption and destructive military ventures – often both at once – as during the Thirty Years War (1618-1648), the War of the Grand Alliance (1688-1697) (during which Württemberg was repeatedly invaded by the French), the Seven Years War (1756-63), the French Revolutionary Wars (during which Württemberg fought on both sides), the Seven Weeks War (1866), and the Franco-Prussian War (1870-1). The one constant characteristic of Württemberg's rulers was their extravagance and consequent willingness to sell monopolies and other economic "privileges" to powerful interest-groups in return for fiscal favours (Ogilvie 1999; Vann 1984; Wilson (1995)).

Württemberg, like most of the German south, was economically undynamic between the late sixteeenth century and the mid-twentieth. The country's agriculture was unproductive and continued to be carried out on small, fragmented holdings under the communal regulation of the old three-field crop rotation system until the agrarian reforms after 1879. Württemberg industrialized late even by German standards, with factories first appearing in the 1830s but not becoming widespread until long after 1850. But Württemberg did have a long history of dense rural crafts and export-oriented proto-industries and in 1800 was accounted to have one of the highest densities of industrial occupations per capita of any German state (Reininghaus 1990, p. 9). Alongside a general pattern of by-employed craftsmen-farmers, there were also two regions of much denser export-oriented textile proto-industry, the Urach linen region in the east of the country and the Calw-Wildberg worsted region in the west (Medick 1996; Ogilvie 1997).

The community of Wildberg itself saw the rise of export-oriented worsted production in the 1580s, and from about 1600 until about 1800 was the most important single centre of the worsted proto-industry in the country, with 120-140 independent weavers, comprising some 40 percent of its household heads. The village of Ebhausen moved into proto-industry much later, with only 25 weavers in 1670 and 50 by 1730, by which time they comprised about 37 percent of household heads. The worsted proto-industry also offered employment to some 75 percent of the unmarried women and widows of Wildberg (and later Ebhausen) as piece-rate spinners. But agriculture was also important in both communities, with about 40 percent of households in Wildberg and 80 percent in Ebhausen at least partly dependent on farming their own land (usually alongside worsted-weaving or a craft workshop) in 1736. This was reflected in a strongly "arable" pattern of marriage seasonality in both communities (more accentuated in Ebhausen than Wildberg), which lasted into the nineteenth century (Ogilvie 1997, ch. 8). The worsted proto-industry was hard hit in the 1790's by the French Revolutionary Wars and in 1797 the monopolistic association of worsted merchants was dissolved. The economies of Wildberg and Ebhausen gradually reverted to agriculture and locally oriented crafts and services in the first half of the nineteenth century. Even the establishment in the later nineteenth century of a few small-scale and short-lived "factories" (wool-spinning, heckle-making, saw-milling, oil-milling, fulling, brick-making) failed fully to re-industrialize the local economy.[10]

Like many other western European economies, by 1600 Württemberg was quite market-oriented (Sabean 1990; Ogilvie 1997). Proto-industrial worsted- and linen-weavers exported their wares throughout Europe and imported raw materials in bulk from outside the region. Grain and other foodstuffs were widely sold to provision townspeople, proto-industrial producers, landless labourers, and the rural land-poor. Labour markets encompassed servants, day-labourers, spinners, and a whole array of miscellaneous workers. Land changed hands between kin and non-kin at a rapid rate. On rural credit markets, borrowers offered mortgages, collateral, and interest-payments to a wide array of lenders.

On the other hand, in Württemberg all these market transactions were circumscribed by powerful non-market institutions. We have already mentioned the Württemberg state, which was strong enough to involve the territory repeatedly in unnecessary military ventures, but too weak to finance them without granting expensive monopolies and institutional privileges to rent-seeking interest-groups (Vann 1984; Ogilvie 1992, 1999). This entrenched the powers of two other institutions – guilds and local communities – which were much stronger here than, for instance, in the Netherlands, England, Scotland, or France. Guilds in Württemberg, as in many areas of central and southern Europe, did not break down after the medieval period but instead became stronger by securing state enforcement. They regulated rural as well as urban producers and existed not in just traditional crafts but also in proto-industries,

[10] For more detail on the economic history of Wildberg, Ebhausen, and the immediate region, see Ogilvie (1997, 2003); Troeltsch (1897); Mantel (1974); Klaß (1987); Königliches Statistisch-topographisches Bureau (1862).

shopkeeping, merchant trading, and a vast range of other secondary and tertiary occupations (Hoffmann 1905; Raiser 1978). Worsted textile production in proto-industrial communities such as Wildberg (and later Ebhausen) was regulated by strong regional weavers' guilds, which regulated prices, output quotas, techniques, labour relations, and the prices paid to suppliers such as the army of unguilded female spinners, and which were not abolished until 1864 (Ogilvie 1997; Ogilvie 2003; Flik 1990). On the export end, the worsted proto-industry was monopolized by a powerful, guild-like association of merchant-dyers established in 1650, which until 1797 successfully enforced its legal right to compel all local weavers to sell exclusively to its members and excluded all competitors from the worsted trade (Troeltsch 1897; Staudenmeyer 1972; Ogilvie 1997).

Community institutions in Württemberg also reinforced their control over local life by offering fiscal and political support to the state in return for enforcement of their regulations. Each village or town exercised intense surveillance and regulation over marriage, sexuality, migration, inheritance, citizenship, settlement, agricultural technology, markets, residence, education, diligence, leisure, and consumption (Grube 1954; Ogilvie 1997; Sabean 1990). Demographic behaviour in particular was closely monitored and controlled. People were not allowed to marry unless they could satisfy their community council that they could support themselves, whether by inheriting some land, achieving guild mastership, or otherwise obtaining a niche in a not very rapidly growing economy (Sabean 1990; Ogilvie 1997; Ogilvie 2003). Permission to marry and settle was often denied to men and women who were regarded by their communities as "economically and morally weak", according to a set of increasingly formal marriage regulations that after 1800 began to be enforced by the state, under the rubric of the "politische Ehekonsens" (political control of marriage) (Matz 1980; Ehmer 1991; Guinnane 1996; Ogilvie 1995). This, together with the scarcity of legal "niches" for achieving economic independence, created incentives for massive emigration from Württemberg in the eighteenth and nineteenth centuries, to both America and eastern Europe (Bassler 1974, Hippel 1984). Not until the later nineteenth century did the economic and demographic regulation exercised by local communal institutions begin to break down (Sabean 1990). Guilds were not abolished in Württemberg until 1864 (Ogilvie 1997). Marriage restrictions began to liberalize only in 1862 and were abolished only with German unification in 1870 (Matz 1980; Ehmer 1991).

This was a society, therefore, in which people's economic and demographic decisions were affected by both market and non-market factors. On the one hand, hardly anyone in Württemberg was not exposed to the influences of the market, since few farmed enough land to subsist from. Nearly everyone had to sell agricultural output, craft wares, proto-industrial goods, or simply their own labour to survive. This was true for women as well as men – eighteenth-century Wildberg and Ebhausen show very high levels of female labour force participation and market orientation, even among married women (Ogilvie 2003, 2004). For these reasons, every inhabitant of Württemberg from the seventeenth century on would have experienced the influence of prices in every decision she or he took.

On the other hand, both economic and demographic decisions were regulated by powerful non-market "social networks" – guilds and local communities – whose powers were enforced by the Württemberg state. The state not only exacerbated the vulnerability of the population to price fluctuations, whether through war-induced scarcity, monetary devaluation, high taxation, or forbidding the construction of railways until the 1850s (the railway reached Wildberg as late as 1870 (Scharf 1995)). It also reinforced the powers of local communities and guilds, which themselves both constrained and amplified people's responses to prices, as well as affecting the underlying formation of these prices. Such institutionalized social networks had a much more direct effect on economic and demographic behavior in Württemberg than in England or France, although probably quite similarly to many economies in central, southern and eastern Europe before the modern era (Ogilvie 1997, 1999, 2006). This makes it particularly interesting to explore the operation of Malthusian positive and preventive checks in an institutional environment more typical of the European continent than the advanced economies of the north Atlantic seaboard that have been the focus in most existing literature.

### 3. Births, Deaths, and Marriages

The sources for our demographic data are the parish registers and church visitation records for the communities of Wildberg and Ebhausen between 1558 and 1870.[11] After the Reformation, Württemberg became an officially Lutheran state, which it remained until 1806 when the Napoleonic territorial reorganization of Germany brought a number of Catholic territories into the new kingdom. Until then, Württemberg was religiously homogeneous and (at least outwardly) remarkably pious, aided by the efforts of a dedicated Lutheran church administration, powerful local church courts (established 1646) which monitored religious observance, and community courts which typically refused settlement rights to non-Lutherans (while tolerating servants and itinerant

[11] For a full discussion of these demographic sources, see Appendix B.

laborers from Catholic and Calvinist territories) (Ehmer 1999; Fritz 1993; Holtz 1996). Even after 1806, the Lutheran territories of "Old Württemberg" remained socially distinct from the kingdom's new Catholic territories, and the number of non-Lutherans living in historically Lutheran areas of the country remained tiny. As late as 1895, only 2.4 percent of the population of Wildberg and 0.5 percent of the population of Ebhausen was non-Lutheran. We know this because the numbers of non-Lutherans were carefully ennumerated in the annual church visitation of each community. Their marriages, baptisms and burials were also often recorded in the Lutheran parish registers since it was usually prohibitively difficult for them to travel to a community with a Catholic church.

The annual counts of demographic events that we use in our analysis are extracted from the baptism, marriage, and burial registers for Wildberg and Ebhausen. The Württemberg Lutheran church began keeping registers of marriages and baptisms in 1558 and added registers of burials around 1610. But not all communities kept registers carefully from the beginning or were able to conserve them to the present day. Thus Wildberg has surviving marriage registers from 1558 on, burials from 1615 on, but baptisms only from 1646 on because the first register was destroyed in the Thirty Years War. Ebhausen has marriages inconsistently from 1559 to 1561, but consistently only from 1604 on, burials from 1571 on, and baptisms from 1559 on.

Although any registration system can be evaded given sufficient motivation, Württemberg communal institutions and local church courts exercised sufficiently close surveillance over the inhabitants of the small communities they controlled that the costs of evasion were very high (Ogilvie 1997; Sabean 1990). There is reason to be confident that the data extracted from these sources reflect the actual demographic situation.

Figure 2 presents the populations of these two communities for all years this measure is available. We plot three series – one each for Wildberg and Ebhausen, and a third that combines Ebhausen with several nearby sub-parishes of the Ebhausen church. (These dependent hamlets do not appear in our counts of baptisms, burials, and marriages for Ebhausen.) Table 1 presents basic information on the annual numbers of demographic events in the three sub-periods we analyze, whose selection we explain below. These are all untransformed series, that is, simply the counts of births, deaths, and marriages. Our estimates all use transformed series, that is, percent deviations from a moving average, for the reasons discussed below. The series all run through 1914, but start at different times because of the different dates at which marriage, baptism and burial registers were kept (or survive) for each community. This implies that in the analysis below the number of observations for the first sub-period will depend on which demographic variables we use in the analysis. We have annual grain prices for the entire period.[12]

**4. Econometric Methods**

The literature contains several careful studies investigating Malthusian models in pre-industrial Europe. Lee (1981) pioneered the basic approach, and both Weir (1984) and Galloway (1988) use nearly identical econometric methods. We focus on Weir's study as a comparison, because his approach allows us to see some population responses we could not if we adopted Galloway's nearly equivalent approach. Weir and others

[12] Both demographic series and price series are for calendar years. Some studies try to match demographic series to harvest year, but this approach neglects the role of buffer stocks of grain. In any case, one function of the lags is to pick up any mismatch between the price year and the demographic year.

convert all variables to percent deviations from an 11-year moving average.[13] This removes any trends from the data, and has the convenient feature that the resulting regression coefficients are elasticities. These scholars all used very parsimonious models in which they regressed a demographic series (for example, annual number of births) on current prices and three lags of prices. Their approaches differed slightly in one respect. Most models of this type estimated without lags of the dependent variable exhibit serial correlation. Galloway corrected for serial correlation using a Cochrane-Orcutt procedure. Weir used two lagged values of the dependent variable. The two approaches have similar implications for the estimated price coefficients, but Weir's allows us to study how "shocks" to an exogenous variable affected the dependent variable.[14]

[13] Thus the models estimated are similar to an autoregressive moving-average (ARMA) model. We experimented with simply estimating ARMA models on the untransformed series. Our results were similar to those reported here, so we focus on the models most easily compared to Weir's and Galloway's. The Durbin-Watson statistic for each regression model discussed below suggests that the model successfully dealt with the problem of serial correlation. We performed, but do not report, standard tests (the Dickey-Fuller and Philips-Perron) for unit roots in the series. None of the transformed demographic events series has a unit root, as one would expect.

[14] Galloway (1988, Appendix Table I) reports a fourth lag; this is to conform to Lee's models. As Weir notes, the fourth price lag is rarely statistically significant. It was not significant in any of our models. In our regressions we adjust mortality to reflect primarily non-infant mortality as does Weir (1984, note 26): Adjusted deaths = Deaths – IMR*(s*Births + (1-s)*$Births_{t-1}$) where IMR is the infant mortality rate and s is a separation factor for the proportion of all infant deaths that occur in the calendar year of birth. We take *s* to be .764, as does Weir, and for IMR use the decadal value of the infant mortality rate implied by the first wave of the Wildberg family reconstitutions. For decades earlier than the 1640s (when the Wildberg family reconstitution starts) we use .323 as the value of IMR. Our results are not sensitive to the values of *s*, and, in fact, results obtained without the mortality adjustment are qualitatively similar to those reported below. We also estimated the models reported here in a SUR framework. SUR can be, in principle, more efficient than OLS, but in our models the gains in efficiency were small. We also experimented with Newey-West standard errors and with approaches that are more robust than OLS against serial correlation and various forms of conditional heteroscedasticity, but obtained similar results. Here we report and use only the Huber-White "robust" standard errors. The most common way to interpret a VAR model, using impulse-response functions (IRF), assumes that all the variables in the system are endogenous. Rye prices here are not endogenous; neither Wildberg nor Ebhausen was large enough to affect grain markets elsewhere. The VAR approach is more appropriate for analyzing a country, as in Nicolini (2007). Some recent efforts estimate Malthusian models using VAR models (for example, Nicolini's study). A VAR model corresponds to estimating each equation separately by OLS; the only advantage to the VAR approach is possible gains in efficiency by estimating the equations in a SUR framework.

Most earlier research in this literature has used changes in nominal grain prices as the measure of, or proxy for, economic shocks.[15] We follow this practice, and for the same reasons. There are two ways to think of this approach. First, food costs dominated household spending until the late nineteenth century in most societies. Thus for most households short-run changes in grain prices are a good proxy for variations in the real wage. Second, what we require, formally, is a variable that reflects shifts in the marginal product of labor, as in Figure 1. Grain prices certainly reflect such shifts in the short run. We acknowledge, however, that grain price shocks would not affect everyone in a community in precisely the same way. Some households were either net sellers of grain or could be at the right relative prices. A net seller of grain would welcome a positive shock to grain prices. This helps explain some differences between our two communities.

Ideally we would have grain prices for Wildberg and Ebhausen themselves. We have located nothing like this, and so must use data for other places as proxies for the "true" local price series. We have, for several cities in southern and western Germany, reports of the wholesale prices of major grains. The series used here is based on the price of rye in Augsburg until the early nineteenth century, and the price of rye in Vienna thereafter. So long as the weather and other shocks faced in these markets are similar to those in Wildberg and Ebhausen, the series should work well. In addition, as explained in Appendix A, we can show that prices throughout this region are very strongly correlated, implying that the series we use would be highly correlated with prices in our communities. All the prices reported here have been converted to Gulden per hectoliter.

[15] Appendix A describes our sources for grain prices, and how we decided which price series to use.

## 5. Mortality, Nuptiality, and Fertility

Given the structure of the models we estimate, the regression results themselves are not terribly meaningful.[16] It is more instructive to use the results to compute a cumulative elasticity of prices, as in Tables 2-4. The elasticities report a simple thought experiment: if we increased prices by x percent, what would be the impact on mortality, nuptiality, and fertility?[17] The elasticities cannot be read off the regression model directly, because of the lagged dependent variables. To see this, consider a specific example. In 1805, our rye price rose nearly 67 percent over its long-run average price. In 1805, that shock has only a direct effect on, for example, mortality. But in 1806 there are two price effects: the new price for 1806, a 10 percent increase; and the effect of the 1805 price shock working through the lagged value of the dependent variable. For the same reason, the standard error of a given elasticity does not correspond to the standard error of any given regression coefficient.[18] Throughout this section, an elasticity is called "statistically significant" if the 95 percent confidence interval that includes the elasticity does not include zero. In Tables 2-4, we mark such elasticities with a star (*).

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[16] Appendix Table C.1 presents the full regression results. Appendix Table C.2 reports tests of linear restrictions that various groups of variables are zero. Our specification choices are constrained by the need to parallel Weir's models in order to use his results as a comparison. Many of our individual regressions have t-statistics that are below conventional confidence levels. This does not necessarily correspond to the significance of a given elasticity, as shown by the simulations discussed below. For the purposes of our analysis it is more informative to examine the F-statistic associated with a "block" of variables, such as all the price effects in a given regression. These statistics imply that the coefficients for the crucial effects, prices, are generally significant. Note that we would *expect* the effects in the fertility models to be small or zero.

[17] We cannot improve on Weir's (1984, p. 38) visual model of these elasticities: suppose the outcome variable follows a straight-line trend. Imagine the response to the price shock as a deviation from that trend. The cumulative elasticity represents the area between the (counter-factual) straight-line trend and the outcome variable as affected by the price shock. The units are in fractions of the value of the outcome variable in an average year. Thus an elasticity of -.500 implies that over the four-year period, the price shock reduced total marriages (for example) by an amount equal to half of all marriages that would occur in an average year.

[18] The details of this calculation are in Appendix A.

We estimate separate models for the periods 1638-1687, 1688-1795, and 1796-1870.[19] The first period is actually somewhat shorter, as the moving-average transformation of the series loses some years at the start of our data. The periods were chosen to correspond to major events or changes in the history of the region. In 1688, as already discussed, French troops invaded Württemberg, causing a noticeable demographic break, first in mortality and then in nuptiality and fertilty. The second break-point, 1795, was chosen because of the war with France and the collapse of the worsted proto-industry, the mainstay of the local economy. The end point of 1870 was chosen because it was the year that Württemberg joined a unified Germany, the political controls on permission to marry were abolished, and the railway reached the Wildberg-Ebhausen region; only a few years earlier, in 1864, the Württemberg guilds had been abolished. We have also examined shorter sub-periods to insure against misspecification associated with forcing two different regimes into the same model.

*Mortality*

We begin with mortality. The mortality model has two lagged values of the dependent variable as well as the current value of prices and three lags of prices. The Malthusian logic implies that these impacts be positive: an increase in prices should increase mortality. In the seventeenth century, we find no statistically significant impact of price shocks on mortality in either of our communities. This apparently perverse finding can be explained by institutional features – the disastrous warfare into which the state repeatedly dragged the Württemberg population during the seventeenth century. Ebhausen was burnt to ashes in the 1630s and Wildberg lost at least one third of its

[19] The start-year 1651 is used in all analyses for Wildberg.

inhabitants. In both communities, a non-trivial share of the population farmed their own land and thus benefited from higher rye prices. It is therefore not surprising that we observe no positive check in the seventeenth century: mortality was high, but responded to warfare and the post-war recovery, not to yearly price fluctuations.

By the early eighteenth century, both communities had recovered demographically from the Thirty Years War. Agriculture had become less important again, and proto-industry more important, especially in Ebhausen. It is therefore not surprising that we find large and often statistically significant effects of price shocks on mortality in the eighteenth century, in both Wildberg and Ebhausen. In the eighteenth century, for example, a 10 percent increase in grain prices would raise death rates by almost 5 percent.

In the period 1795-1870, the relationship between prices and mortality essentially disappears, as we would expect. With rising incomes and more diversified food supplies, shocks to any food price should not have the same impact on mortality.

How does the positive check in these Württemberg communities compare to Weir's findings for England and France? Weir's periods do not correspond to ours, so comparisons cannot be exact. But the comparisons are still instructive. In what Weir calls the "black" seventeenth century (1670-1739), a grain price shock had a cumulative, four-year elasticity of .310 in England and.502 in France (Weir 1984, Table 6). By comparison, Wildberg at .085 was much lower than England, while Ebhausen at .790 was even larger than France. But neither elasticity for Württemberg is statistically significant. Evidently the institutional features that drew Württemberg into repeated disastrous wars and invasions made the seventeenth century even "blacker" in Württemberg than in

England or France, completely obliterating the expected link between prices and demographic behavior.[20]

In Weir's study, for the period 1790-1829, the parallel figures for England and France are .424 and .037 (Weir 1984, Table 5). Our results imply that the relationship between price shocks and mortality essentially disappears in Wildberg and Ebhausen during the course of the nineteenth century.[21]

The most interesting comparison arises in the eighteenth century, when we find a significant positive check in Wildberg and Ebhausen. This is no surprise. But relative to expectations, the check in our communities is small: we would expect the positive check to be stronger in our communities than in England or France. After all, England and France are entire countries (which implies much more room for adjustment to any shock) and were significantly wealthier and more developed than Württemberg (which would imply greater resistance to any economic shock). Instead, the positive check in our communities, at.438 for Wildberg and .488 for Ebhausen, is larger than Weir's estimate cumulative four-year elasticity for England (.037) in the period 1790-1829, but about the same as the alogous figure for France (.424).

Institutional influences can help us explain this apparently surprising finding. Württemberg communities, as already discussed, exercised very strict controls over who could live locally. Anyone who did not hold "Bürgerrecht" (citizenship in that community) was only tolerated on a temporary basis as a "Beisitzer" (a "bye-settler" who

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[20] On the more more disastrous and institutionally rooted character of the seventeenth-century crisis in German-speaking central Europe than in England or France, see Ogilvie (1992).

[21] For the period 1740-1789, Weir finds that a price shock *reduced* mortality in both France and England. This is a perverse result that apparently disappears if weather variables are introduced into the model. Thus our comparison here is to the next period reports in his Table 5, which is 1790-1829. If we estimate our models for precisely this period, 1790-1829, we find four-year cumulative elasticities of .292 for Wildberg and .210 for Ebhausen.

was obliged to apply annually for permission to go on living in the community). Men with this status usually carried out the most menial labouring jobs – herding cattle or day-labouring – and could be ejected from the community in hard times (Ogilvie 1997). Württemberg communities also exercised strict controls over independent unmarried women, whom they pejoratively called "Eigenbrötlerinnen" – literally "own-breaders" – and subjected to continual harrassment and threats of expulsion (Ogilvie 1990, 2003). When an adverse economic shock occurred, the first response of any Württemberg community was to eject non-citizens, both in order to reduce competition for local producers and consumers, and to lighten the burden on the communal welfare system (Ogilvie 1997, 60-72). A vivid illustration of this response to perceived scarcity can be seen from a case in late seventeenth-century Wildberg. At the annual community assembly in 1660, at which every man with "citizenship" was asked if he had anything to report to the rest of the commune, one Wildberg citizen complained that "there are some *Eigenbrötlerinnen* here, who should be sent away; in the market everything is grabbed away by them, and no citizen can get anything any more". This inspired the community to conduct "a house-to-house visitation to see what *Eigenbrötlerinnen* there are here, whereupon [the matter] shall be ventilated in the community court".[22] In another example, from 1711, a linen-weaver from Calw who had lived in Wildberg for the preceding 19 years but was now too old to support himself was sent back to his "citizenship" in Calw.[23] Analysis of local court records documents how frequently the communities of Wildberg and Ebhausen did in practice expel and exclude non-citizens when times got hard or established

[22] Hauptstaatsarchiv Stuttgart A573 Bü. 91, fol. 8r-v, 29.10.1660: "Es habe für Aigenbröthlerin. hier solten thaills abgeschafft werden, werde vff dem Marckht alles von Ihnen hinweg gerissen, könne kein burger nichts mehr bekommen"; "Nechster tagen solle von hauß zue hauß Visitirt werden, waß sich für aigbröthlerin alhier befinden alßdan gerichtlich erörtert werd."
[23] Pfarrarchiv Wildberg, Kirchenkonventsprotokolle, Vol. IV, fol. 284v, 25.09.1711.

citizens perceived outsiders as threatening their economic well-being (Ogilvie 1990, 1997, 2003). This attitude was summed up by the Ebhausen communal church court in 1736 when it responded to a state inquiry about the adequacy of its welfare system by reporting that “if no more outsiders come in, then we are indeed in a position to provide for our own poor”.[24]

An institutional environment with these characteristics might indeed give rise to a situation in which the mortality response to an adverse price shock, despite Württemberg’s comparative poverty and underdevelopment, could be milder than in England or France. Admittedly, a small number of marginal non-citizens might be more likely to die – but as vagrants they would tend to die without being recorded or would survive by migrating to less hard-hit localities.[25] And as a result of their ejection, the established community citizens left behind would have fewer hungry mouths to feed (whether through their own earnings or through the communal welfare system) and would weather the price shock with lower mortality. By shifting the mortality impact of a price shock onto a small group of already impoverished migrants, the Württemberg institutional regime might well have weakened the positive check among the majority population of established locals. Württemberg communities, that is, could export part of the effect of an economic shock.[26]

[24] Pfarrarchiv Ebhausen, Kirchenkonventsprotokolle, Vol. III, fol. 198r, 6.8.1736: “wann Keine frembde mehr kommen, sind wir schon im stand unsere eigene arme zu versorg. ”.

[25] A few deaths of vagrants are recorded in the Wildberg and Ebhausen burial registers, but the literature concludes that most such people slipped through the registration system. Those ejected by small communities typically ended up in larger urban centres where they could more easily escape surveillance and avoid ejection. On this, see, e.g. Jütte (1994).

[26] Hammel and Galloway (2000) study the positive check in the northern Balkans at the end of the eighteenth century and the beginning of the nineteenth. The econometric approach they use is similar to that in Galloway (1988). This is one of the few such studies of the positive check, to our knowledge, that links the positive check and changes in its magnitude to detailed historical and institutional conditions.

*Nuptiality*

Our models for nuptiality include two lagged values of the dependent variable as well as mortality and three lags of mortality and the same price variables as in the mortality model. The elasticities of nuptiality with respect to price shocks are reported in Table 3. The Malthusian model predicts that an increase in prices will reduce nuptiality, which is confirmed in our models for the seventeenth and eighteenth centuries. Eighteenth-century Wildberg had an especially powerful preventive check: a ten percent increase in grain prices reduces marriages by nearly 7 percent after four years.

Weir's basic finding was that Wrigley and Schofield had mischaracterized the relative power of the preventive check in England and France. Weir found that it was, contrary to their view, stronger in France. The preventive check was even stronger in eighteenth-century Württemberg, as Figure 3 reports. This comparison selects the Weir sub-period in which the preventive check was apparently strongest. The preventive check was even stronger in Wildberg in the eighteenth century. The preventive check in Ebhausen was not nearly so strong in the eighteenth century – perhaps because the village was still quite small and niches remained available in proto-industrial worsted-weaving there up to about 1730 (Ogilvie 1997, pp. 131-9). But the preventive check in eighteenth-century Ebhausen was still stronger than in England in the period 1740-1789, and nearly as strong as in France. The preventive check loses much of its force in our communities during the nineteenth century, although in Wildberg the values remain about the same as in England in the same period.[27]

[27] This comparisons are sharper if we use Weir's shorter periods. For the period 1740-1789, for example, the four-year cumulative elasticity of prices with respect to marriages in Wildberg is -.782. For France in the same period, Weir estimates an elasticity of -.608, and for England, -.113. The comparable figure for Ebhausen is -.204.

The exceptional strength of the preventive check in Wildberg, and to a lesser extent in Ebhausen, runs against some widely held views, according to which the Western European Marriage Pattern was particularly strongly rooted in the northwest corner of Europe (England, the Low Countries, and northern France).[28] It also casts light on the underlying causes of this marriage pattern, some of which consisted of informal cultural expectations while others consisted of formal institutional rules. Traditionally, the Western European pattern of late marriage and high lifetime celibacy is regarded as having been primarily cultural in origin, driven by the informal *expectation* that one did not marry unless one could support oneself independently, but not enforced by much (or any) formal institutional coercion. This informal cultural expectation also prevailed in Württemberg, but was intensified, as discussed above, by a system of formal institutional rules enforced by community councils, church courts, and guilds, which regulated permission to settle, marry, form an independent household, and practise an occupation independently, and did so in the perceived interest of established male citizens. Over the course of the eighteenth century, these traditional institutional practices were increasingly backed up by state regulations formalizing communal control over marriage and settlement, and imposing additional restrictions on the marriage of certain sub-groups such as paupers and soldiers. By the early nineteenth century this had turned into the notorious "politische Ehekonsens", a draconian system of demographic regulation practised by states in alliance with local communities across broad swathes of central Europe until c. 1870 (Guinnane 1996; Ogilvie 1995; Matz 1980; Ehmer 1991).

The human cost was high: by 1800, 22 per cent of Wildberg women were lifetime celibates, emigration rates were high, and illegitimate births were proliferating, bringing

[28] Hajnal (1965, 1982); Macfarlane (1978); Laslett (1988); De Moor and Van Zanden (2005).

in their wake very high levels of infant mortality by European standards. The women who failed to marry were forbidden by communities and guilds to engage in many independent economic occupations. Excluded from guilded crafts, commerce, and most services (other than prostitution), they were pushed into spinning (at piece-rates set at artificially low levels by weaving guilds) and day-labouring (at wages fixed by male community councils), and most eked out a wretched living on the margins of Württemberg's corporate communities (Ogilvie 2003; 2004). But this institutionally enforced Central European variant of the Western European Marriage Pattern evidently gave rise to extremely strong preventive checks, and thus a population whose nuptiality and fertility reacted very sensitively – perhaps even *over*-reacted – to fluctuations in prices.

Why did the strong negative effect of prices on nuptiality weaken in the nineteenth century, when the "political control of marriages" is supposed to have been most intense? The institutional framework may offer an explanation for this finding. Communal controls on citizenship, settlement, marriage and work, combined with guild controls on occupational mobility, combined to cause huge emigration from Württemberg to North America and eastern Europe, which reached its highpoint in the nineteenth century (Hippel 1984). An adverse economic shock was likely to cause a surge in emigration by the economically weak, leaving behind the economically strong. Until the liberalization and ultimate abolition of the Württemberg political controls on permission to marry (which did not occur until 1862-1870), the economically weak members of communities were precisely those most likely to be denied permission to marry (Matz 1980; Ehmer 1991; Ogilvie 2003). An adverse economic shock in the high-emigration environment of the nineteenth century was likely, therefore, to cause the non-marrying poor to emigrate, leaving more niches to encourage marriages among the middling and better-off members of the community. The weakening of the impact of prices on nuptiality in the nineteenth century may therefore – paradoxically – be an artefact of the strengthening of the institutional restrictions on marriage which encouraged emigration among those strata most likely to be hard hit by a price shock.

*Mortality and Nuptiality*

To consider another feature of the institutional environment in Wildberg and Ebhausen, we must briefly step away from the pure Malthusian model. Weir and others in this literature control, in their nuptiality models, for the effect of mortality. The idea is that a mortality spike might affect marriages in the near future by reducing the number of possible mates available, or by creating a larger number of widows and widowers seeking to remarry. The *direct* effect of mortality on nuptiality has not, however, received much attention in interpreting these models. Figure 4 shows the simulated impact of a mortality shock on nuptiality for Wildberg and the similar period from Weir's estimates for France and England. (The figure reports elasticities for Wildberg only; similar computations for Ebhausen show that the effect there is similar but smaller than in Wildberg). These hypothetical shocks to mortality hold prices constant, so they are somewhat artificial. Most events that would lead to mortality shocks, such as war or crop failure, would also affect prices. The elasticities are much, much larger than the price elasticities. They imply for the eighteenth century that a ten percent increase in the death rate in Wildberg would cause an eight percent total increase in marriages over a four-year period. The ninety-five percent confidence interval for the Wildberg elasticities (not reported) lie above the French estimate after the first year; we cannot compute the error bands for Weir's elasticities because we lack the variance-covariance matrix of the estimates, but the Wildberg elasticities are clearly much larger than those in France or Enland in this period.

This result is fully consistent with the institutional framework governing family formation and economic activity in rural Württemberg. Marriage was only possible if one could *both* support oneself *and* convince one's community council and one's guild that one could do so. This required inheriting some land (implying that someone had to die) and, since only a few people still lived exclusively from farming their own land, also inheriting a craft workshop from one's father or the capital to set up a new workshop. Furthermore, one had to persuade the local guild chapter that regulated one's craft or other occupation that an additional workshop would not constitute "unfair" competition against existing masters, as can be seen from communal court minutes and petitions of those refused permission to marry or settle locally on precisely such grounds. One young man who in the seventeenth century promised marriage to an Ebhausen girl, "on condition that if he be admitted here as a [community] citizen he will get wedded to her", was "rejected by the bailiff and community court [on the grounds that] the craft is over-filled and the citizenry altogether too large".[29]

[29] Hauptstaatsarchiv Stuttgart A573 Bü. 124, fol. 61r, 23.4.1625: "solch. mas. verheürath, dz wann er, bürg.lich alhie einkomme, er hochzeit mit ihro hallten wölle"; "werde er vonn s: vnnd gericht abgewis., daß handtwerkh seye übersezt vnd die burgerschafft allzugroß". Schofield (2003, p. 57) contrasts the English demographic system, "which operated through the mechanisms of the wage-economy," to an economy based on the filling of niches, "in which people have to wait for dead men's shoes before they can enter upon a holding."

This left day-laboring as the main occupation not reliant on inheriting or obtaining guild mastership or both. But community councils were chary of permitting marriage to people who could only support themselves through day-laboring (Matz 1980; Ogilvie 1997, 2003). Although it was sometimes inevitable, communities sought to restrain the practice, and the central state increasingly provided them with legislative instruments to help them enforce these marriage restrictions against poor people. Thus, for instance, in 1743 the Ebhausen church court refused permission to Jerg Rauschenberger from Monhardt (an isolated hamlet near Ebhausen) to marry the daughter of an Ebhausen citizen, on the grounds that "all circumstances show absolutely clearly that both Godly commandments and temporal ordinances permit no marriage here ... Rauschenberger is not a community citizen and neither can nor will be accepted as such, and the latest instructions from the district authorities relating to the many princely decrees and to the princely marriage ordinance totally prohibit recognition of such marriages any longer, and on both sides [bride's and groom's] there is nothing present but pure poverty".[30] Under such circumstances, it is unsurprising that marriage in Württemberg emerges as being so strongly dependent on mortality, which alone could free up "niches" and create incentives for one's community to permit a new household to be formed.

### *Fertility*

Finally, we turn to the estimates of how fertility responded to price shocks. The models reported here can be thought of as either tests of the key assumption underlying

[30] Pfarrarchiv Ebhausen, Kirchenkonventsprotokolle, Vol. IV, fol. 10v, 26.4.1743: "da nun alle umbstand so clar u: deütl:, daß das gottl.: gepoten, u: die weltl: ordnung hierin keine Ehe Erlaubt, dazu noch gekomm., daß .... d. rausch.berger kein burger, auch zu keinen burger könn. noch woll. angenomm. werd., u: das lestere oberammtl.: außschreiben welches sich auff frstl.: vile Rescript, u: Eheordnung. beziehet, durchauß v.bietet keine solche Ehen Mehr zu erkenn., u: beederseits eine pure armuth Vorhand.".

Malthusian models – that fertility is regulated by marriage, not by fertility decisions within marriage – or as a crude effort to look for the beginnings of the fertility transition. At a simple level, the fertility of a natural fertility population should not react to price shocks. One can think of qualifications, of course. In a badly-nourished population, a severe shock might be enough to reduce the fecundability of women, and thus reduce fertility without any intentional fertility control. That is, the price shocks modeled here might affect the determinants of natural fertility as well as provide incentives to control fertility.[31]

The fertility models again include two lagged values of the dependent variable, the usual price variables, and the current and three lagged values of mortality. One would expect fertility in such a population to be a function of nuptiality, but recent marriages will account for a small fraction of all fertile couples. In any case, adding nuptiality terms to the model does not alter the results presented here.

Table 4 reports the elasticities of fertility with respect to rye prices. On the one hand, the estimates for the periods up to 1795 confirm the basic assumptions of the Malthusian model: fertility does not respond significantly to price shocks in most cases.[32] The regulation of births works through the regulation of marriage. The nineteenth century

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[31] The next step in our research is to use family reconstitutions for Wildberg, Ebhausen, and a third village, Auingen, to examine the determinants of fertility. Thus we are not relying on this exercise to examine the fertility transition *per se*. For the purposes of the present analysis, we prefer to remain agnostic on the precise interpretation of the reaction of marital fertility, measured this way, to price shocks. A recent paper using couple-level data from Sweden for the period 1766-1864 interprets the reaction of fertility to price shocks as deliberate contraception (Bengtsson and Dribe (2006)). We are sympathetic to that view, and plan to pursue a similar analysis with our family-reconstitution data. An alternative interpretation would be that the response of marital fertility to price shocks reflects variations in the level of natural fertility. Such variations might reflect the impact of prices on nutrition, spousal separation, or coital frequency. The latter interpretation is plausible but debated. Among others, Menken, Trussell, and Watkins (1981) doubt that plausible nutritional changes could affect the biological determinants of fecundity enough to produce significant changes in fertility.

[32] The fertility series here is constructed from legitimate births, as it should be for our argument. Re-estimating these models including illegitimate births shows that extra-marital fertility behaved in a very similar way.

holds some surprises that will provide the basis for our future work based on the family-reconstitution data for these communities. Wildberg fertility exhibits significant, negative responses to a price shock for the period 1796-1870. To place these in context, the largest such elasticities Weir reports, for England and France in the period 1790-1829, range up to -.208. For France in the period 1830-1869, when we know from other sources that a fertility transition was well underway, Weir's largest estimates are -.122 (Weir 1984, Table 4). So the fertility responses we find for Wildberg are relatively strong. Wildberg thus shows some evidence of possible fertility control in the period 1795-1870, before the demographic transition is supposed to have taken off in Germany. These econometric findings are very suggestive, but this kind of aggregative analysis is not sufficient to demonstrate that fertility control was really taking place. We will address this issue in greater detail with the family reconstitution approach, which supports fine-grained tests of departures from natural fertility.

*How Did Wildberg and Ebhausen Differ?*

Overall, Wildberg and Ebhausen responded to price shocks very similarly, but occasionally their reactions diverged. Why might this have been? Formal econometric testing suggests that in some instances where the Wildberg and Ebhausen models appear to diverge, it is really just a matter of imprecise estimates for one or the other community; that is, we usually cannot reject the null hypothesis of "no model difference" for the two places. In other cases, the divergence is explicable in terms of economic differences between the two communities – Wildberg was more urban, more industrial, more wealthy, and more economically stagnant; Ebhausen was more rural, more agricultural, poorer, and began its proto-industrial expansion nearly a century later.

There are no instances in which the positive check is significant in one community and not in the other. The elasticities also tend to have similar magnitudes for the communities. The only exception is the seventeenth century, when the positive check in Ebhausen is somewhat erratic, but much larger than in Wildberg (although not statistically significant). Wildberg had a far more industrial economy and Ebhausen a far more agricultural one. As late as 1736, despite the continual growth of proto-industry in Ebhausen, around 80 percent of its households lived partly from farming their own land, compared to only 40 percent of households in Wildberg. There are two, offsetting effects at work here. On the one hand, one would expect the more highly industrialized community of Wildberg to have been more vulnerable to a price shock because it contained more households that were net purchasers of food, and hence to show a stronger positive check than the more agricultural community of Ebhausen where more households benefited from rising grain prices by being net sellers, rather than buyers, of grain. On the other hand, Wildberg's income base was more diversified, and this case the benefits of diversification prevailed. The positive check converges in the two communities in the eighteenth and nineteenth centuries, not surprisingly since Ebhausen was becoming more highly industrial, and hence more similar to Wildberg

Nuptiality also responds somewhat differently in the two communities. In the seventeenth century, the preventive check is stronger in Ebhausen, although not significant. In the eighteenth century it is much stronger in Wildberg, and this time statistically significant. In the third period (1796-1870), the elasticities are essentially the same between Wildberg and Ebhausen, and very small. Wildberg nuptiality remained more vulnerable to shocks in the eighteenth century. This is not surprising, since its economy was still more industrial than that of Ebhausen.

Fertility responds in a basically similar way in both communities. In the first and second periods, the signs are always the same between the two communities, the magnitudes are always very similar (and very small). In the third period, Wildberg shows signs of limiting fertility in the face of price shocks. Ebhausen's response is slightly smaller in absolute value and shows the same sign, so there is no contradiction between the results for the two communities, except for the fact that highly urban and long-industrialized Wildberg *may* be showing some early signs of fertility control in the 75 years before 1870, whereas more rural and still more agricultural Ebhausen was not.

## 6. Conclusions

This paper uses a now-standard methodology to model the impact of short-run fluctuations in prices on mortality, nuptiality, and fertility in two Württemberg communities from the seventeenth to the early twentieth century. We confirm, as have many before us, the existence of a positive check and a preventive check in the eighteenth century. We also confirm the basic assumption of the Malthusian model of fertility: births are largely regulated by variables affecting marriage rates rather than by the limitation of fertility within marriage. At one level, therefore, our study provides one more confirmation of the basic contours of this Malthusian model.

But in many ways our results differ from those found for other European regions, and in ways that signal the need to pay close attention to the way local institutions governed economic life. Unfortunately most studies of this sort have not paid much attention to the institutional context or have only remarked on institutions to explain some uncomfortable finding. We know that in this part of Germany, local communities, occupational guilds, and the state had unusually well-developed powers over the right to marry, to carry on an occupation, and even to live in a given place. Those powers imply specific departures from the findings for England or France in the same periods. Our analysis confirms the demographic importance of these institutional features of the Württemberg environment, and form a warning to those who would ignore them in other contexts.

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**Table 1: Descriptive Statistics for Untransformed Demographic Events Series**

Wildberg:

| | 1651-1687* | 1688-1795 | 1796-1870 |
|---|---|---|---|
| Baptisms | 52 | 55.8 | 61.8 |
| (excluding | 85 | 72 | 99 |
| stillbirths) | 35 | 36 | 41 |
| | | | |
| Marriages | 12.8 | 12.7 | 17.5 |
| | 19 | 24 | 34 |
| | 7 | 4 | 6 |
| | | | |
| Burials | 41.7 | 51 | 60.1 |
| excluding | 86 | 185 | 117 |
| stillbirths and | 17 | 13 | 39 |
| peri-natal | | | |
| deaths | | | |

Ebhausen:

| | 1634-1687 | 1688-1795 | 1796-1870 |
|---|---|---|---|
| Baptisms | 14.1 | 23.1 | 55.8 |
| (excluding | 28 | 64 | 84 |
| stillbirths) | 0 | 1 | 31 |
| | | | |
| Marriages | 3.2 | 32.2 | 14.6 |
| | 12 | 60 | 27 |
| | 0 | 8 | 3 |
| | | | |
| Burials | 6.7 | 6.8 | 42.7 |
| excluding | 24 | 19 | 72 |
| stillbirths and | 0 | 0 | 17 |
| peri-natal | | | |
| deaths | | | |

*Note*: Figures are the mean, maximum, and minimum of the untransformed annual series. These are *not* crude rates. First period for Wildberg is actually 1651-1688

**Table 2: Cumulative Elasticities of Mortality with Respect to a Price Shock**

| Years since shock | 1634-1688 | | 1689-1795 | | 1796-1870 | |
|---|---|---|---|---|---|---|
| | Wildberg | Ebhsen | Wildberg | Ebhsen | Wildberg | Ebhsen |
| 0 | -0.346 | -0.679 | 0.124 | -0.087 | 0.008 | -0.020 |
| 1 | 0.136 | 0.553 | *0.550 | *0.578 | 0.074 | -0.008 |
| 2 | 0.316 | -0.008 | *0.980 | *0.686 | -0.029 | -0.054 |
| 3 | 0.092 | 0.657 | 0.450 | 0.443 | 0.163 | 0.074 |
| 4 | 0.085 | 0.790 | 0.438 | 0.488 | 0.169 | 0.060 |

*Source*: computed from the regression models; full regression results are available on request.

*Note*: * means that a 95-percent confidence interval for this statistic does not include zero. First period for Wildberg is 1651-1688

**Table 3: Cumulative Elasticities of Nuptiality with Respect to a Price Shock**

| | 1634-1688 | | 1689-1795 | | 1796-1870 | |
|---|---|---|---|---|---|---|
| Years since shock | Wildberg | Ebhausen | Wildberg | Ebhausen | Wildberg | Ebhausen |
| 0 | -0.080 | 0.402 | -0.071 | -0.322 | -0.012 | 0.215 |
| 1 | -0.220 | -0.825 | *-0.447 | -0.117 | 0.036 | -0.187 |
| 2 | -0.034 | 0.825 | *-0.574 | 0.077 | -0.043 | -0.099 |
| 3 | -0.141 | 0.083 | *-0.750 | -0.203 | 0.136 | 0.000 |
| 4 | -0.178 | -0.201 | *-0.699 | -0.230 | 0.132 | -0.003 |

*Source*: Computed from the regression models; full regression results are available on request.

*Notes*:

These elasticities are net of mortality.

First period for Wildberg is 1651-1688

* means that a 95-percent confidence interval for this statistic does not include zero.

**Table 4: Cumulative Elasticities of Fertility with Respect to a Price Shock**

| Years since shock | 1634-1688 | | 1689-1795 | | 1796-1870 | |
|---|---|---|---|---|---|---|
| | Wildberg | Ebhausen | Wildberg | Ebhausen | Wildberg | Ebhausen |
| 0 | 0.051 | -0.108 | 0.020 | -0.072 | -0.006 | 0.104 |
| 1 | *-0.232 | -0.086 | -0.027 | -0.036 | *-0.142 | -0.078 |
| 2 | -0.007 | 0.002 | -0.096 | -0.096 | *-0.123 | -0.124 |
| 3 | -0.153 | -0.219 | -0.066 | -0.115 | *-0.165 | -0.051 |
| 4 | -0.068 | -0.171 | -0.056 | -0.099 | *-0.165 | -0.061 |

*Source*: Computed from the regression models; full regression results are available on request.

*Notes*:

These elasticities are net of mortality.

The first period for Wildberg is 1651-1688

* means that a 95-percent confidence interval for this statistic does not include zero.

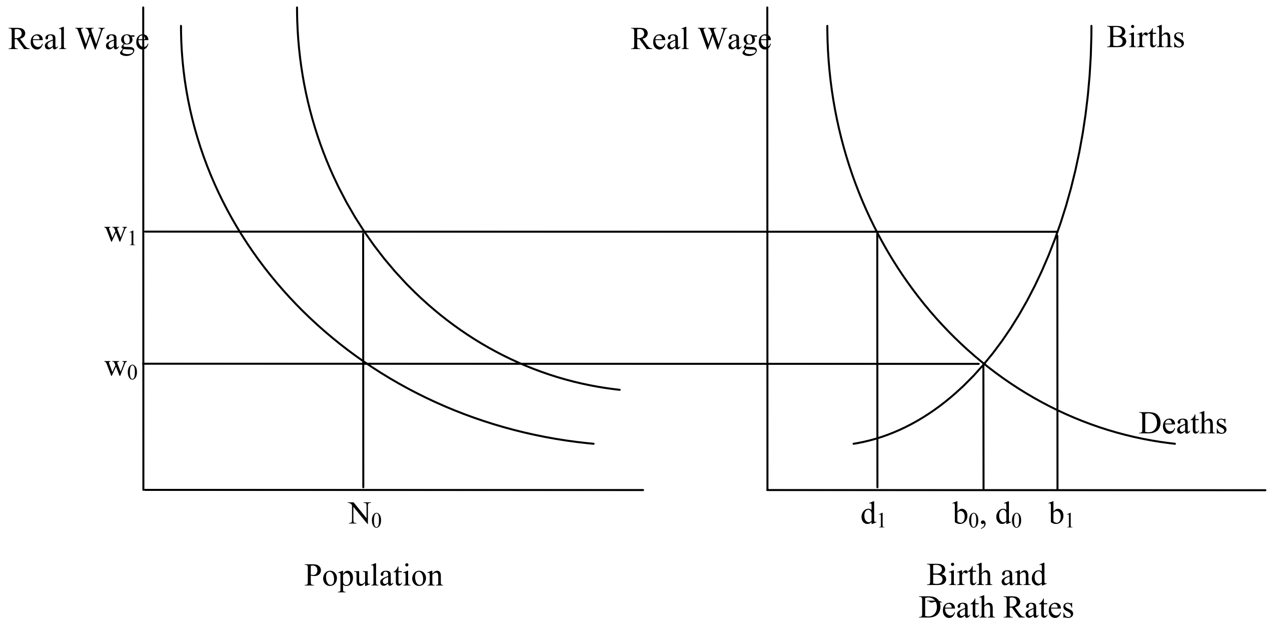



Figure 1: A Schematic Representation of the Malthusian Model

Figure 2: Populations of Wildberg and Ebhausen

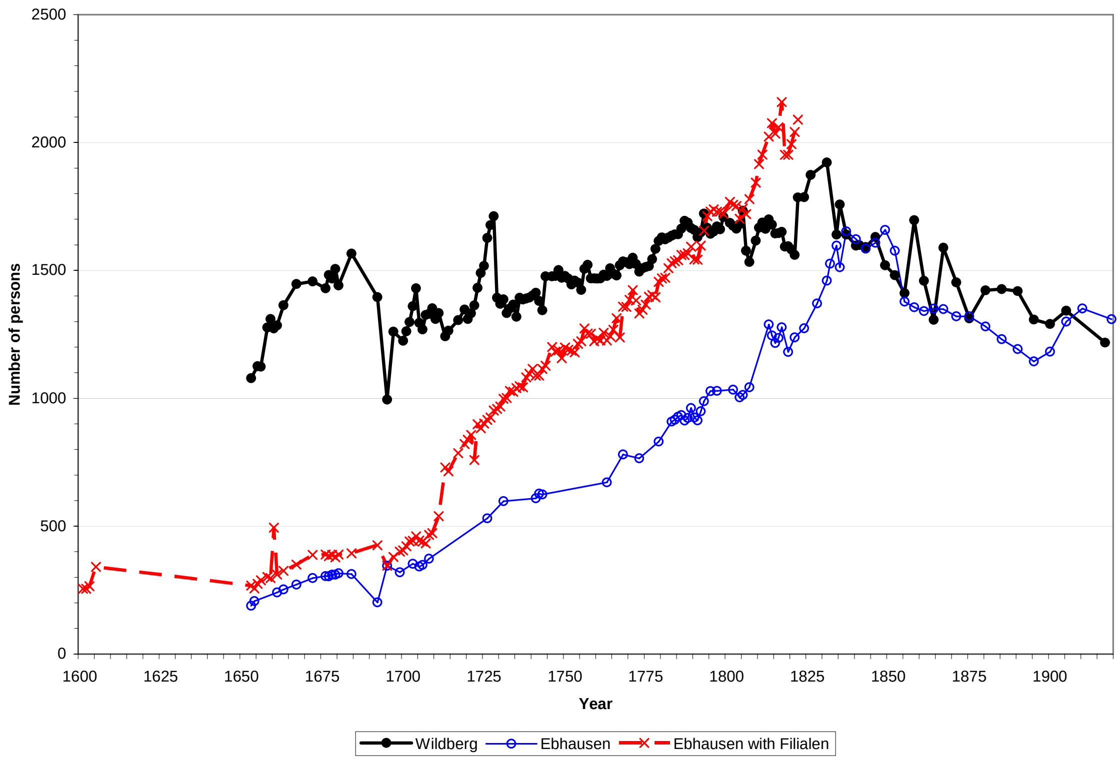
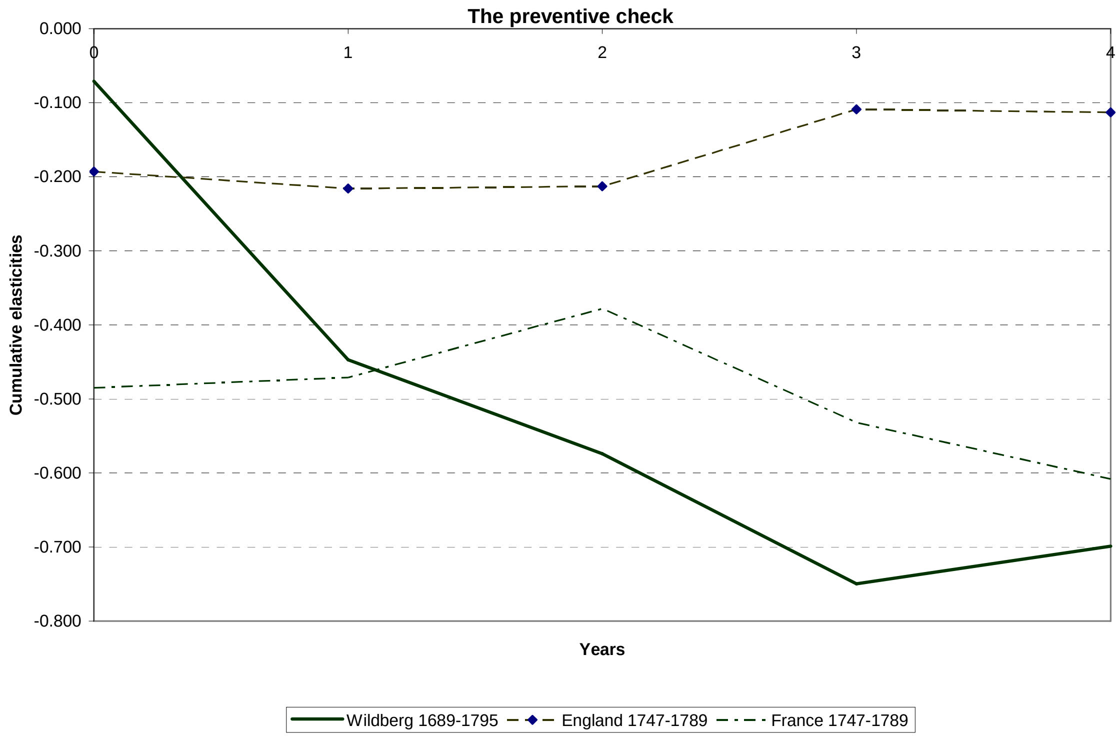
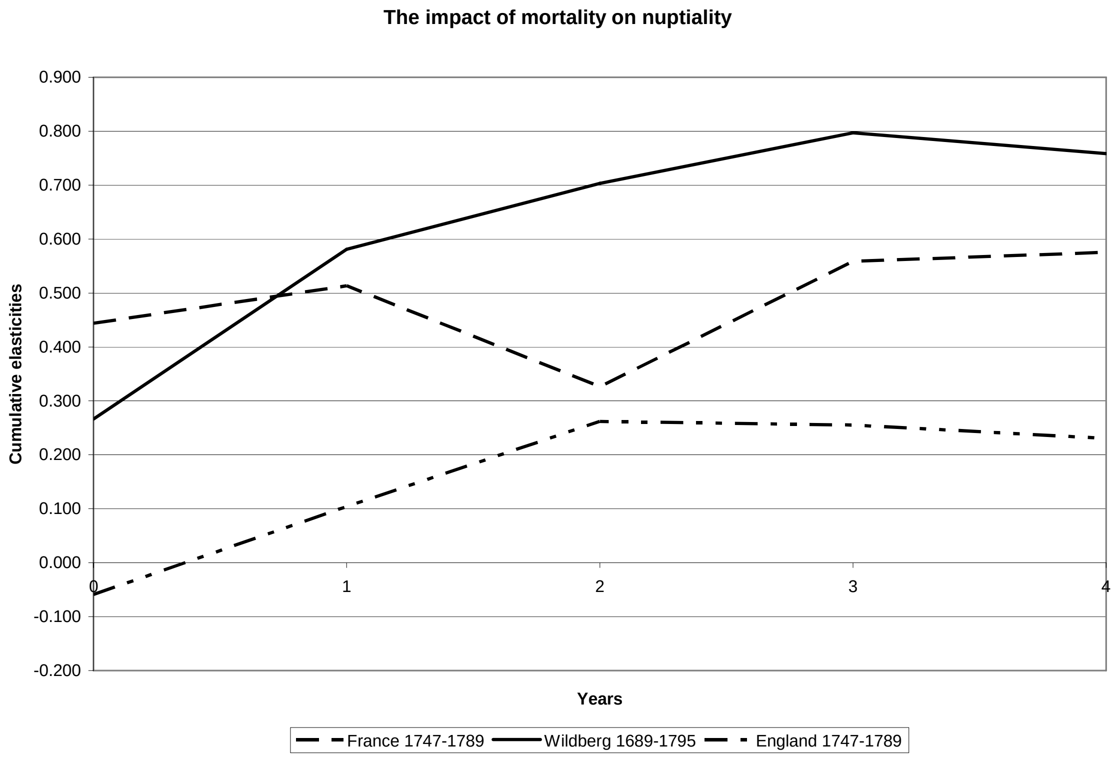


Figure 3: Comparisons of the Sensitivity of Nuptiality to Price Shocks




Source: Wildberg, from Table 3. England and France, Weir (1984, Table 4).

Figure 4: The Impact of Mortality Shocks on Nuptiality




*Sources*: France and England computed from Weir (1984, Appendix Table 1A); Wildberg, computed from regressions reported in Appendix Table C.1.

## Appendix A: Explanation of Standard Errors and Construction of Price Series

### *Estimation of Standard Errors*

The standard errors of the elasticities discussed in the text cannot be read directly off the regression results. We constructed the standard errors by bootstrap, as follows. We created 1000 replications of a normally distributed random variable with mean $\beta^*$ and variance-covariance matrix VC($\beta^*$), where $\beta^*$ is the vector of estimated OLS coefficients and VC($\beta^*$) is their estimated variance-covariance matrix. We then constructed our elasticity statistics $\varepsilon$ algebraically from these 1000 replications. The 95 percent confidence intervals were constructed by finding the $2.5^{th}$ and $97.5^{th}$ percentile of these $\varepsilon$'s. We used the Huber-White variance-covariance matrix that underlies the t-statistics reported in Appendix Table C.1. We experimented with the Newey-West variance-covariance matrix, which is in principle robust against serial correlation. These did not affect the significance levels reported in Tables 3-4.

### *Price Series Used in Estimation*

There are two specific limitations to our price data. First, none deals with a market in the region of Wildberg and Ebhausen. Appendix Table A.1 lists the various grain price series we were able to locate, and additional details for the series we actually use. The series from an area closest to Wildberg and Ebhausen is the series we are calling "Württemberg" (which is claimed to be for the entire country, although the author is not clear about his sources). The others are for cities at some distance. Distance *per se* is not a huge problem. First, most price shocks reflect supply shocks that were in turn caused by weather. To the extent Frankfurt and the Wildberg-Ebhausen region share similar weather patterns, the price information from Frankfurt should be closely correlated with that from Wildberg. Second, in the pre-railroad age (i.e. in the Wildberg-Ebhausen region up to 1870), access to water routes made some distances economically shorter than others. Shiue (2005) has shown for the nineteenth century that cities on the same river are economically much closer to one another than those on different rivers. If this is true in our period then Ausgburg is much further away than is Frankfurt or even Cologne, because the river of the Wildberg-Ebhausen region (the Nagold) drains to the Rhine. A more serious problem is that prices generated by a large market such as Frankfurt may not reflect the full range of price shocks experienced by people in the Wildberg-Ebhausen region; in a well-functioning market, price shocks are profit opportunities that are arbitraged away.

One way to address this concern is to ask how closely the various grain-price series are correlated with *each other*. This does not tell us, really, whether our hypothetical price series for the Wildberg-Ebhausen region would be correlated with Frankfurt, but if Frankfurt and Augsburg are correlated with each other, then it gives us greater confidence that the variations in prices are not driven by idiosyncratic shocks. Focusing for the moment on rye prices (for which our series are most complete, and which was the basic bread-grain in most parts of pre-industrial Germany) we find extremely high correlations across markets. The Württemberg price series has a zero-order correlation of at least .55 with all other rye prices, in the years for which the series overlap. Its correlation with the series we use most in this version of the analysis (rye in Augsburg) is about .82. To take a more focused case, for the 5 price series we could use in the analysis of the sub-period 1646-1805, the period when we have the greatest heterogeneity in location and grain for the price data, the lowest pairwise correlation is .67.

All of the results presented in the text use a single series derived from two underlying sources. Prior to 1821, it is the price of rye in Augsburg; after this date, it is the price of rye in Vienna. The Augsburg series have a few missing values which are interpolated using the predicted values from an AR(3) model. Both series are expressed as gulden per hectoliter. Given the correlations noted above, we are confident that this series is up to the task at hand. But for additional confidence we undertook two types of robustness checks. For individual sub-periods we sometimes have several choices of price series. Where possible, we re-estimated our models using alternative price series. In none of the cases can we identify significantly different results associated with a different series. More systematically, we also used principal-component methods to combine series, then using the first principal component instead of a single price series. Again, this approach yields answers that are substantially the same as those reported in the text.

Our ongoing research project on Württemberg household inventories (http://www.econ.cam.ac.uk/faculty/ogilvie/ESRC-project-English.pdf) promises to yield local price series for grain stocks as well as many other items of daily consumption. A previous analysis by Maisch (1992) (Table 3.1.3.1.c) reports prices for spelt (a variety of wheat) extracted from personal inventories in three Württemberg villages quite close to our project communities, in 25 selected years 1712-1808. Our calculations show that Maisch's grain prices from inventories are strongly and significantly correlated across the three villages (lowest pairwise correlation 0.76) *and* with Augsburg market prices from Elsas (1936) (lowest correlation 0.67). This strong correlation in grain prices among these Württemberg villages, and between these Württemberg villages and market prices recorded elsewhere, provides reassuring support for our use of German price series from outside the immediate proximity of our project communities.

## Appendix Table A.1: Grain Price Series

| City/Place | Crop | Years | Source |
|---|---|---|---|
| Frankfurt am Main | Roggen | 1550-1820 | Elsas M. J., 1940. *Umriss einer Geschichte der Preise und Lohne in Deutschland*, Vol. 2A, pp. 464-511. |
| | Hafer | | |
| | Weizen | | |
| Augsburg | Roggen | | Elsas, M. J., 1936. *Umriss einer Geschichte der Preise und Lohne in Deutschland*, Vol 1, pp. 593-599. |
| | Hafer | | |
| | Gerste | | |
| Württemberg | Kernen | 1550-1628, 1766-1895 | 1550-1628: Helferich, J. A. R. von, 1858. "Württembergische Getreide- und Weinpreise von 1456-1628. Ein Betrag zur Geschichte der Geldentwerthung nach der Entdeckung von Amerika," *Zeitschrift für die gesamte Staatswissenschaft*, 14(2/3): 471-502.<br><br>1766-1895: Königliches Statistisches Landesamt, 1896. "Die Durchschnittspreise von Getreide (Kernen, Gerste, Haber, Dinkel, Weizen, Roggen) in Württemberg in den Jahren 1766-1895," *Württembergische Jahrbücher für Statistik und Landeskunde*, 1896(II): 117-122. |
| | Gerste | 1766-1895 | Königliches Statistisches Landesamt, 1896. " Die Durchschnittspreise von Getreide (Kernen, Gerste, Haber, Dinkel, Weizen, Roggen) in Württemberg in den Jahren 1766-1895," *Württembergische Jahrbücher für Statistik und Landeskunde*, 1896(II): 117-122. |
| | Hafer | | |
| | Dinkel | | |
| | Weizen | 1830, 1852-1895 | |
| | Roggen | 1766-1895 | |
| Speyer | Roggen | 1550-1820 | Elsas, M. J., 1940. *Umriss einer Geschichte der Preise und Lohne in Deutschland*, Vol 2A, pp. 551-555. |
| | Gerste | 1550-1799 | |
| | Hafer | | |
| Würzburg | Roggen | 1550-1799 | Elsas, M. J., 1936. *Umriss einer Geschichte der Preise und Lohne in Deutschland*, Vol 1, pp. 636-640. |
| | Hafer | | |
| | Weizen | | |
| Mainz | Korn | 1730-1789 | Dreyfus, François-Georges, 1960. "Beitrag zu den Preisbewegungen im Oberrheingebiet im 18. Jahrhundert," *Vierteljahresschrift für Sozial- und Wirtschaftsgeschichte*, 47: 245-256 |
| Vienna | Korn | 1691-1913 | Pribram, Alfred Francis, 1938. *Materialien zur Geschichte der Preise und Löhne in Österreich, pp. 371-373* |

## Appendix B: Provenance of Demographic Data

The number of deaths in each year is extracted from the burial registers, which record the date and personal details of each individual buried in Wildberg from 1615 onward and in Ebhausen from 1571 onward.[33] Since the registers record even the deaths of itinerant journeymen, soldiers, Calvinists, and Catholics, there is strong reason to believe that it is an accurate record of local mortality.

The number of marriages in each year is extracted from the marriage registers, which record the date and personal details of all brides and grooms married in Wildberg from 1558 on, and for Ebhausen inconsistently from 1559 to 1561 and consistently from 1604 on.[34] As discussed in the main text, marriage in Württemberg was closely regulated by local community institutions as well as local church courts, and thus it is highly unlikely that any couple was permitted to live in the married state without having their married state officially recorded.[35] When bride and groom were from different communities, they had the choice of which community to marry in, and this might have led to the registering of some marriages in Wildberg for couples who did not intend to settle there and vice versa. This might have meant that they were responding to the economic and demographic constraints prevailing in some neighbouring community rather than Wildberg. However, there was an incentive to celebrate one's marriage in the community where one intended to settle, as a way of establishing oneself within the social networks of the local community.[36] Furthermore, as long as social practices regarding where marriages were celebrated did not change significantly over time (and there is no evidence they did), the minor degree of over- or under-registration of weddings of couples of mixed community origin should not bias the number of marriages recorded in Wildberg from year to year.[37]

The number of births in each year is extracted from the baptism registers, which record the date and personal details of all infants born, along with information about their parents, for Wildberg from 1646 on and for Ebhausen from 1558 on.[38] The baptism

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[33] Wildberg burials are registered in Pfarrarchiv Wildberg, Kirchenbücher, Bd. 6 (Toten 1615-1670), Bd. 11 (Toten 1671-1771), Bd. 12 (Toten 1772-1807), Bd. 13 (Toten 1808-1832), Bd. 14 (Toten 1832-1854), Bd. 15 (Toten 1855-1888) ; Bd. 23 (1889-1942). Ebhausen burials are registered in Pfarrarchiv Ebhausen (microfilms in Landeskirchliches Archiv Stuttgart), Bd. 1 (Toten 1571-1674), Bd. 3 (Toten 1674-1740), Bd. 4 (Toten 1740-1807), Bd. 13 (Toten 1808-1846), Bd. 14 (Toten 1847-1875); unnumbered volume (1876-1914).

[34] Wildberg marriages are registered in Pfarrarchiv Wildberg, Kirchenbücher, Bd. 6 (Ehen 1558-1745), Bd. 7 (Ehen 1739-1808), Bd. 8 (Ehen 1808-1845), Bd. 9 (Ehen 1846-1872), Bd. 10 (Ehen 1873-1968). Ebhausen marriages are registered in Pfarrarchiv Ebhausen (microfilms in Landeskirchliches Archiv Stuttgart), Bd. 1 (Ehen 1559-1561, 1604-1674), Bd. 3 (Ehen 1674-1740), Bd. 4 (Ehen 1740-1807), Bd. 11 (Ehen 1808-1846), Bd. 12 (Ehen 1847-1898) ; unnumbered volume (1899-1914).

[35] For examples of these sorts of controls of vital registration in action in early modern Ebhausen and Wildberg, see Ogilvie (2003), esp. ch. 2.

[36] As shown by the fact that significantly fewer men than women married into Wildberg from outside; on this see Mantel (1974), p. 144 (Table A4).

[37] On figures for marriages into and out of Wildberg from 1559 to 1750, see Mantel (1974), esp. Table A4.

[38] Wildberg baptisms are registered in Pfarrarchiv Wildberg, Kirchenbücher, Bd. 1 (Taufen 1646-1771), Bd. 2 (Taufen 1772-1807), Bd. 3 (Taufen 1808-1829), Bd. 4 (Taufen 1830-1854), Bd. 5 (Taufen 1855-1884); Bd. 9 (Taufen 1885-1926). Ebhausen baptisms are registered in Pfarrarchiv Ebhausen (microfilms in Landeskirchliches Archiv Stuttgart), Bd. 1 (Taufen 1559-1674), Bd. 2 (Taufen 1871-1875), Bd. 3 (Taufen 1674-1740), Bd. 4 (Taufen 1740-1792), Bd. 5 (Taufen 1793-1807), Bd. 6 (Taufen 1808-1836), Bd. 7

registers record the dates and place of both birth and baptism (seldom more than a few days apart before the nineteenth century), and even include the baptisms of children born non-Lutheran parents, especially around 1870 when Wildberg hosted a large temporary population of Catholic railway workers. The only local births that may be missing are those of Catholic couples who incurred the costs of traveling to a community with a Catholic church in order to baptise their children; but since there was seldom more than a single Catholic household in Wildberg at any date during the period under analysis, it is unlikely that this had any significant effect on our figures. The baptism registers record illegitimate births carefully, since illegitimacy was a matter of deep concern to both church (for moral reasons) and community (for economic reasons) and midwives were obliged to swear an oath to report all births (Ogilvie 1986, 2003). These facts suggest strongly that the baptisms registers contain an accurate record of local fertility.

The population counts we use are extracted from the reports on the periodic inspections ("visitations") of the Wildberg and Ebhausen parish churches, which took place periodically from 1584 onward and close to annually between 1653 and 1821. After 1822, these were replaced by population counts undertaken by the state authorities every 3-9 years.[39]

(Taufen 1837-1870), Bd. 8 (Taufen 1871-1897), Bd. 9 (Taufen 1842-1852), Bd. 10 (Taufen 1857-1871); unnumbered volume (1872-1914).

[39] The archival sources for the population counts are: Landeskirchliches Archiv Stuttgart, Synodusprotokolle (1584-1822); Hauptstaatsarchiv Stuttgart, A 281 Kirchenvisitationsakten (1563, 1599, 1601-1806); Staatsarchiv Ludwigsburg E 258 III Nr. 7699, Oberamt Nagold (1834-1917); Staatsarchiv Ludwigsburg E 258 III Nr. 98, Oberamt Calw (Ebhausen) (1834-1917). Population counts for our communities were also extracted from the following published sources: Königl. Statistisch-Topographischen Bureau, ed., *Königlich-Württembergisches Hof- und Staats-Handbuch*. Stuttgart (counts for 1821, 1824, 1828, 1831, 1835); Philipp Wilhelm Gottlieb Hausleutner, *Schwäbisches Archiv*. Stuttgart, 1790 (counts for 1622, 1634, 1639, 1645 (communicant and catechist numbers only); Königl. statist.-topograph. Bureau, ed. [author: Eduard Paulus], *Beschreibung des Oberamts Nagold: mit drei Tabellen, einer Karte des Oberamts und drei Ansichten*, Stuttgart, 1862, pp. 150, 252.

**Appendix Table C.1: Regression results**

Wildberg nuptiality

| | (1)<br>1651-1688 | (2)<br>1689-1795 | (3)<br>1796-1870 |
|---|---|---|---|
| L. Marriages | 0.189 | -0.135 | -0.074 |
| | (1.07) | (1.34) | (0.68) |
| L2. Marriages | -0.090 | -0.213 | -0.115 |
| | (0.61) | (2.11)* | (1.12) |
| Deaths | -0.038 | 0.267 | -0.169 |
| | (0.30) | (3.68)** | (1.60) |
| L. Deaths | -0.146 | 0.350 | -0.174 |
| | (1.68) | (5.06)** | (1.73) |
| L2. Deaths | -0.099 | 0.222 | -0.284 |
| | (1.02) | (3.12)** | (1.90) |
| L3. Deaths | 0.090 | 0.177 | -0.263 |
| | (0.94) | (2.90)** | (2.38)* |
| Rye prices | -0.080 | -0.071 | -0.012 |
| | (0.36) | (0.65) | (0.10) |
| L. Rye prices | -0.126 | -0.386 | 0.047 |
| | (0.58) | (3.34)** | (0.35) |
| L2. Rye prices | 0.206 | -0.193 | -0.077 |
| | (1.12) | (1.35) | (0.49) |
| L3. Rye prices | -0.155 | -0.273 | 0.179 |
| | (1.23) | (2.37)* | (1.43) |
| Constant | 0.352 | -1.474 | -0.089 |
| | (0.09) | (0.55) | (0.03) |
| Observations | 38 | 107 | 75 |
| R-squared | 0.32 | 0.36 | 0.17 |

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Mortality adjusted for infant deaths; see text. L1, L2, etc, are lags of variables

Ebhausen nuptiality

| | (1) | (2) | (3) |
|---|---|---|---|
| | 1634-1688 | 1689-1795 | 1796-1870 |
| L. Marriages | -0.201 | -0.024 | -0.128 |
| | (1.41) | (0.23) | (1.12) |
| L2. Marriages | -0.263 | -0.176 | 0.102 |
| | (1.34) | (1.78) | (0.96) |
| Deaths | 0.070 | -0.078 | 0.089 |
| | (0.72) | (0.96) | (1.22) |
| L. | 0.026 | -0.134 | -0.021 |
| | (0.27) | (1.59) | (0.28) |
| L2. | 0.069 | 0.074 | -0.177 |
| | (1.15) | (0.86) | (1.99) |
| L3. | 0.150 | -0.023 | -0.128 |
| | (2.17)* | (0.31) | (1.61) |
| Rye prices | 0.402 | -0.322 | 0.215 |
| | (1.00) | (1.68) | (1.40) |
| L. Rye prices | -1.146 | 0.198 | -0.374 |
| | (1.55) | (0.95) | (1.92) |
| L2. Rye prices | 1.510 | 0.142 | 0.014 |
| | (1.88) | (0.85) | (0.07) |
| L3. Rye prices | -0.733 | -0.239 | 0.151 |
| | (2.06)* | (1.48) | (0.90) |
| Constant | 2.877 | -0.083 | -1.238 |
| | (0.26) | (0.02) | (0.31) |
| Observations | 51 | 107 | 75 |
| R-squared | 0.27 | 0.11 | 0.20 |

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Mortality adjusted for infant deaths; see text. L1, L2, etc, are lags of variables

Wildberg fertility

| | (1) | (2) | (3) |
|---|---|---|---|
| | 1651-1688 | 1689-1795 | 1796-1870 |
| L. Marriages | -0.135 | -0.262 | -0.064 |
| | (0.78) | (2.97)** | (0.49) |
| L2. Marriages | 0.288 | -0.265 | -0.149 |
| | (2.00) | (3.22)** | (1.20) |
| Deaths | -0.088 | -0.066 | 0.039 |
| | (1.70) | (2.12)* | (0.92) |
| L. Deaths | 0.013 | -0.034 | 0.061 |
| | (0.20) | (1.62) | (1.70) |
| L2. Deaths | -0.007 | -0.025 | 0.049 |
| | (0.08) | (0.94) | (0.94) |
| L3. Deaths | -0.022 | -0.020 | 0.080 |
| | (0.27) | (0.84) | (1.65) |
| Rye prices | 0.051 | 0.020 | -0.006 |
| | (0.46) | (0.42) | (0.16) |
| L. Rye prices | -0.277 | -0.042 | -0.136 |
| | (1.72) | (0.75) | (2.73)** |
| L2. Rye prices | 0.172 | -0.076 | 0.009 |
| | (1.21) | (1.51) | (0.17) |
| L3. Rye prices | -0.034 | -0.001 | -0.060 |
| | (0.37) | (0.02) | (1.27) |
| Constant | 1.124 | -0.530 | -0.734 |
| | (0.49) | (0.48) | (0.56) |
| Observations | 36 | 107 | 75 |
| R-squared | 0.35 | 0.27 | 0.19 |

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Mortality adjusted for infant deaths; see text. L1, L2, etc, are lags of variables

Ebhausen fertility

| | (1) | (2) | (3) |
|---|---|---|---|
| | 1634-1688 | 1689-1795 | 1796-1870 |
| L. | -0.262 | -0.194 | -0.109 |
| | (1.45) | (1.86) | (0.78) |
| L2. | -0.118 | -0.211 | 0.038 |
| | (0.44) | (2.04)* | (0.30) |
| Deaths | -0.084 | -0.093 | 0.010 |
| | (1.51) | (3.23)** | (0.27) |
| L. Deaths | -0.030 | -0.046 | 0.117 |
| | (0.57) | (1.68) | (3.57)** |
| L2. Deaths | 0.036 | -0.035 | -0.029 |
| | (0.75) | (1.08) | (0.60) |
| L3. Deaths | 0.045 | -0.015 | -0.016 |
| | (1.02) | (0.63) | (0.36) |
| Rye prices | -0.108 | -0.072 | 0.104 |
| | (0.91) | (1.17) | (1.77) |
| L. Rye prices | -0.007 | 0.022 | -0.171 |
| | (0.03) | (0.25) | (2.06)* |
| L2. Rye prices | 0.081 | -0.068 | -0.069 |
| | (0.37) | (0.91) | (0.94) |
| L3. Rye prices | -0.195 | -0.023 | 0.074 |
| | (1.48) | (0.40) | (1.28) |
| Constant | -0.755 | -1.231 | -0.447 |
| | (0.18) | (0.82) | (0.27) |
| Observations | 32 | 107 | 75 |
| R-squared | 0.25 | 0.24 | 0.38 |

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Mortality adjusted for infant deaths; see text. L1, L2, etc, are lags of variables

Wildberg mortality

| | (1) | (2) | (3) |
|---|---|---|---|
| | 1651-1688 | 1689-1795 | 1796-1870 |
| L. Deaths | -0.241 | -0.051 | -0.135 |
| | (2.03) | (0.56) | (1.31) |
| L2. Deaths | -0.339 | -0.089 | -0.311 |
| | (3.18)** | (1.01) | (2.53)* |
| Rye prices | -0.346 | 0.124 | 0.008 |
| | (1.53) | (0.62) | (0.07) |
| L. Rye prices | 0.399 | 0.433 | 0.068 |
| | (1.15) | (2.24)* | (0.40) |
| L2. Rye prices | 0.179 | 0.462 | -0.092 |
| | (0.51) | (2.74)** | (0.58) |
| L3. Rye prices | -0.018 | -0.470 | 0.199 |
| | (0.09) | (3.32)** | (1.59) |
| Constant | 0.570 | 0.636 | 1.199 |
| | (0.09) | (0.15) | (0.31) |
| Observations | 38 | 107 | 75 |
| R-squared | 0.42 | 0.29 | 0.11 |

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Mortality adjusted for infant deaths; see text. L1, L2, etc, are lags of variables

Ebhausen mortality

| | (1) | (2) | (3) |
|---|---|---|---|
| | 1634-1688 | 1689-1795 | 1796-1870 |
| L. Marriages | 0.022 | -0.213 | -0.202 |
| | (0.14) | (2.40)* | (2.25)* |
| L2. Marriages | -0.211 | -0.064 | -0.242 |
| | (1.42) | (0.67) | (1.61) |
| Rye prices | -0.679 | -0.087 | -0.020 |
| | (1.19) | (0.32) | (0.10) |
| L. Rye prices | 1.247 | 0.646 | 0.008 |
| | (1.34) | (2.85)** | (0.03) |
| L2. Rye prices | -0.732 | 0.244 | -0.049 |
| | (0.74) | (0.84) | (0.21) |
| L3. Rye prices | 0.938 | -0.177 | 0.122 |
| | (0.77) | (0.74) | (0.74) |
| Constant | -3.726 | -1.997 | 0.237 |
| | (0.21) | (0.36) | (0.04) |
| Observations | 52 | 107 | 75 |
| R-squared | 0.15 | 0.16 | 0.09 |

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

Mortality adjusted for infant deaths; see text. L1, L2, etc, are lags of variables

Appendix Table C.2: Goodness-of-fit of the regression models

| | 1634-1688 | | 1689-1795 | | 1796-1870 | |
|---|---|---|---|---|---|---|
| | Wildberg | Ebhausen | Wildberg | Ebhausen | Wildberg | Ebhausen |
| Nuptiality model | | | | | | |
| All regression coefficients zero | 1.590 | 3.500 | 6.170 | 1.680 | 1.950 | 2.190 |
| | (0.163) | (0.002) | (0.00) | (0.097) | (0.055) | (0.029) |
| Lags of dependent variable are zero | 0.740 | 1.400 | 2.990 | 1.590 | 0.900 | 1.290 |
| | (0.487) | (0.259) | (0.055) | (0.201) | (0.410) | (0.282) |
| Mortality impacts are zero | 1.470 | 1.520 | 9.740 | 1.370 | 1.960 | 1.740 |
| | (0.239) | (0.214) | (0.00) | (0.251) | (0.111) | (0.152) |
| Price impacts are zero | 1.000 | 1.260 | 8.450 | 1.130 | 0.710 | 2.560 |
| | (0.422) | (0.301) | (0.00) | (0.346) | (0.590) | (0.047) |
| Fertility model | | | | | | |
| All regression coefficients zero | 2.330 | 2.360 | 5.310 | 3.100 | 3.200 | 4.820 |
| | (0.042) | (0.047) | (0.00) | (0.002) | (0.002) | (0.00) |
| Lags of dependent variable are zero | 2.050 | 1.070 | 9.060 | 3.540 | 0.720 | 0.350 |
| | (0.149) | (0.362) | (0.00) | (0.033) | (0.491) | (0.706) |
| Mortality impacts are zero | 0.850 | 1.590 | 1.820 | 3.530 | 1.210 | 4.270 |
| | (0.509) | (0.214) | (0.131) | (0.010) | (0.315) | (0.004) |
| Price impacts are zero | 1.960 | 0.850 | 1.350 | 0.870 | 4.930 | 4.580 |
| | (0.131) | (0.511) | (0.258) | (0.487) | (0.002) | (0.003) |
| Mortality model | | | | | | |
| All regression coefficients zero | 7.960 | 1.040 | 9.870 | 2.910 | 2.410 | 1.180 |
| | (0.00) | (0.413) | (0.00) | (0.012) | (0.036) | (0.328) |
| Lags of dependent variable are zero | 6.810 | 1.930 | 0.780 | 2.890 | 4.240 | 2.760 |
| | (0.003) | (0.156) | (0.463) | (0.060) | (0.018) | (0.071) |
| Price impacts are zero | 2.930 | 0.590 | 13.320 | 3.780 | 0.830 | 0.210 |
| | (0.036) | (0.669) | (0.00) | (0.007) | (0.510) | (0.929) |

Figures are F-statistics associated with given null hypothesis, computed from the regressions reported in Table C.1. Rejection probability in parentheses. The first period for Wildberg is 1651-1688.