Essays on Economic Determinants of Population Dynamics

Inaugural-Dissertation
zur Erlangung des Grades
Doctor oeconomiae publicae
an der Ludwig-Maximilians-Universität München

vorgelegt von
Fabian Siuda

Essays on
Economic Determinants of
Population Dynamics

Inaugural-Dissertation
zur Erlangung des Grades
Doctor oeconomiae publicae (Dr. oec. publ.)
an der Ludwig-Maximilians-Universität München

2020

vorgelegt von

Fabian Siuda

Referent: Prof. Helmut Rainer, Ph.D.

Korreferent: Prof. Dr. Uwe Sunde

Promotionsabschlussberatung: 22. Juli 2020

Tag der mündlichen Prüfung: 7. Juli 2020

Gutachter: Helmut Rainer, Uwe Sunde, Andreas Peichl

Acknowledgments

I would like to thank Helmut Rainer, my primary research supervisor, for his patient advice, continuous support and enthusiastic encouragement during my time at the ifo Center for Labor and Demographic Economics. I am deeply indebted to Uwe Sunde, who is not only co-author of my first paper and second member of my thesis committee but also the person who got me interested in academic research and pursuing a PhD. Furthermore, I would like to thank David De La Croix for a fruitful discussion of my research ideas, posting as third member of my examination committee and for providing a letter of recommendation for the academic job market. I would also like to thank Jeremy Greenwood for inviting me to the University of Pennsylvania for my research visit and providing valuable feedback for my research.

My special thanks goes to my family and friends, who have supported me unconditionally throughout the last couple of years during my PhD. Next, I would like to thank all my colleagues who have become friends over the last years and without whom the dissertation as well as the job market would not have been possible. I am very grateful for all insights and feedback I have received during conference and seminar presentation, as well as during one-on-one and group meetings where my research was discussed.

Lastly, I thank the Leibniz Supercomputing Centre of the Bavarian Academy of Science and Humanities (LRZ) and their staff for helpful feedback and support. Data access and support has been provided by the Research Data Centre of the Statistical Offices of the federal states in Munich. Financial support has been granted by the Leibniz Association for the Project “Economic Uncertainty and the Family (EcUFam)” and is gratefully acknowledged.

Munich, March 2020
Fabian Siuda

Contents

List of Figures

List of Tables

Chapter 1

Opening Remarks

1.1 Introduction

The interaction of economics and population dynamics is complex and often bi-directional in nature. On the one hand, population dynamics influence the economy for example through consumption and labor supply. On the other hand, economic circumstances influence population dynamics for example though partnership and fertility decisions. Germany, as well as many other developed countries, experienced fertility rates below replacement for a substantial time now. In Germany, since the 1980's, fertility rates have consistently been below 1.5 children per mother. Even though there is a current slight increase in the number of children, total fertility rates in Germany are sill far below the replacement rate.

Looking at the bigger picture, the low fertility rates observed today are a rather new phenomenon. Back in medieval times and throughout most of history, women in Germany and in many other European countries often had a substantially larger number children. These high fertility rates were accompanied with low living standards and low levels of economic growth and development. During those times, individuals and societies were trapped in a Malthusian Regime, where it was optimal for individuals to get as many children as they could afford. This phenomenon was put to an end by the demographic transition, where individuals deliberately reduced their fertility, invested more in the human capital of their children and thus contributed to the onset of sustained growth (Galor and Weil, 2000; Galor, 2011).

In Germany, from the beginning of the 20th century until now, interrupted by war-time distortions, the total fertility rate of women in Germany has fallen to the low rates observed today. Two factors are behind these low fertility rates: A low number of children per mother and an increasingly large fraction of women who never become mothers. While Germany is not the only country facing this issue (Baudin et al., 2015, 2020; Myong et al., 2018), understanding this issue in the context of Germany is important as it largely contributes to the low fertility rates observed in the country today. While there already exists a long literature on fertility, most of the work so far has ignored the rise in childlessness observed in many countries around the world. The decision to become a mother, the decision on how many children to have and when to have them as well as the decision on marriage formation are linked and partly determined by economic factors and policies.

The underlying mechanisms that determine fertility and partnership formation decisions are partially determined by labor market situations. Early works on the economics behind partnership formation include the seminal works by Becker (1973, 1974). Modern partnership formation models stress possibility of specialization within the household and the importance of the insurance motive within marriage. Social policies that aim at reforming the labor market may have unanticipated consequences for marriage formation and fertility, which affect population dynamics in the long run.

1.2 Outline of the Thesis

My dissertation consists of three independent studies on the interaction of economics and population dynamics. All chapters have a separate introduction which includes a literature review. The notation in each chapter is self-contained. Selected additional results can be found in the appendices of the respective chapters.

Chapter 2 is joint work with Uwe Sunde. It provides an empirical investigation of the hypothesis that population shocks such as the outbreak of the Black Death affected the timing of the onset of the demographic transition. The empirical analysis uses disaggregate data from Germany and exploits geographic variation in the exposure to medieval plague shocks. The findings document that areas with greater exposure to plague outbreaks exhibited an earlier onset of the demographic transition. Additional analyses confirm this finding using data from France. The results are consistent with the predictions of the unified growth literature and provide novel insights into the largely unexplored empirical determinants of the timing of the transition from stagnation to growth.

Chapter 3 develops and estimates a dynamic structural model of fertility with endogenous marriage formation, linking the timing of fertility to its intensive (number of children) and extensive (having children) margin. The model features rational, forward-looking agents who make decisions on marriage and fertility, and are exposed to declining fecundity rates over time. In every period, agents face a trade-off between work and child-rearing, and across time there is a trade-off between having children early or late in life.

I identify the model parameters using four distinct facts of the 2008 and 2012 German Microcensus: (i) fertility until age 30 decreases with education for married and single women, (ii) fertility after age 30 increases with education for married and single women, (iii) childlessness increases with women's education, (iv) marriage rates decrease with education for women and increase with education for men. I obtain three main insights. First, postponement of childbirth combined with the natural decline of fecundity over time can explain up to 15% of childlessness, depending on education. Second, by estimating the model separately for East and West Germany, I find that institutions and economic conditions matter: the two major factors for childlessness in West Germany are postponement of childbirth and high opportunity costs of children due to lack of public childcare. By contrast, in East Germany, social sterility plays a larger role. Finally, using the estimated model parameters for counterfactual analysis, I evaluate consequences of reoccurring labor market interruptions and policies aimed at reconciling work and family life.

Chapter 4 is joint work with Bastian Schulz. In this paper, we empirically investigate how labor market institutions shape economic incentives to get or remain married, using the example of the unemployment insurance system. The underlying thought is that marriage and divorce decisions are influenced by the institutional environment in which they are made To identify institutional effects on marriage and divorce decisions, we exploit a reform of household-level means testing in Germany that altered said incentives. Means-testing exemption amounts were sharply reduced in January 2003 and this increased the extent to which spouses have to insure each other against unemployment. We argue that the extent to which (potential) spouses were affected by this reform varies with individuals' migration background. Using the universes of marriages and divorces in Germany between 1997 and 2013, we find that increased means-testing made the formation of interethnic marriages significantly less attractive. At the same time, it increased marital stability: interethnic marriages formed after the reform are more stable than interethnic marriages marriages formed before the reform.

Chapter 2

Disease and Demographic Development: The Legacy of the Plague

This chapter is joint work with Uwe Sunde from the University of Munich.

2.1 Introduction

One of the key questions in economics concerns the reasons for development differences across countries and regions. In view of the non-monotonic dynamics of long-run development, as maintained by unified growth theories, the answer to this question is closely related to the reasons for differences in the timing of the take-off in economic and demographic development. The timing of the demographic transition plays a central role in this context since it is widely viewed as a prerequisite of economic development. According to the canonical view, the demographic transition begins with a reduction in mortality that is followed, with some delay, by a decline in fertility. This marks the onset of the fertility transition, which represents the key turning point for population dynamics, education, and the transition to sustained growth. In particular, the deliberate reduction in fertility allowed for intensified child rearing, increased human capital investment, and ultimately a sustained increase in incomes per capita as consequence of continuing productivity improvements (Galor and Weil, 2000; Galor, 2011). Consequently, the transition from a Malthusian population regime with slowly increasing population density and living standards to a Modern Growth regime with a sustained growth in incomes that is accompanied by a decline in fertility constitutes the central building block of the mechanisms underlying unified growth theory. While there is widespread agreement about the role of the fertility transition for the economic take-off and ample evidence regarding the mechanics of these transitions, there is relatively little empirical work in economics that has investigated the determinants of the timing of the fertility transition.[1]

This paper contributes to the literature by investigating the empirical determinants of the timing of the fertility transition. The empirical approach is motivated by the conjecture that mortality shocks might have triggered adjustment mechanisms that led to shifts in the Malthusian equilibrium with the consequence of higher population density (Voigtländer and Voth, 2013b,a), which ultimately provided the ground for the transition from (Post-)Malthusian stagnation to a modern growth regime (Galor and Weil, 2000). Evidence on this conjecture is scant, however.

---

[1] For simplicity and since the distinction is inconsequential for the purpose of this paper, the terms "fertility transition" and "demographic transition" are used as synonyms in the remainder of the paper.

A first set of regressions of the timing of the onset of the fertility transition in cities or regions in Germany on the number of plague outbreaks indeed provides evidence that cities that experienced more frequent plague-related population shocks also experienced an earlier fertility transition. To rule out spurious results, the analysis controls for an extensive set of additional variables that potentially affect the timing of the fertility transition. While the extensive specification of the empirical model makes it unlikely that the finding is driven by third factors, historical data on plague outbreaks are fraught with error. The empirical strategy used to address this problem is based on variation in the spread of repeated outbreaks of plagues in Europe during the Middle Ages and the resulting variation in the exposure of cities or regions to plague shocks. Regardless of whether outbreaks of the plague after the 1348 outbreak of the Black Death occurred spontaneously from reservoirs in Europe or from repeated reintroductions from Asia, outbreaks spread inland along medieval travel routes. From maritime harbors, where they were recognized first, plague epidemics spread concentrically and with an intensity that decreased in travel distance to the entry ports. This motivates an identification strategy that builds on the insight that cities that were closer to these harbors were affected more by outbreaks of the plague. A second set of results based on reduced form estimates reveal that greater exposure to plague outbreaks as proxied by lower travel time to the nearest entry port is associated with a significantly earlier onset of the demographic transition. The third step of the analysis applies an instrumental variables approach that uses travel time to the nearest entry port as instrument for the number of plague outbreaks. The corresponding estimation results reveal instrument relevance and confirm the finding that cities that experienced more plague shocks showed an earlier onset of the demographic transition.

Several robustness checks confirm this finding. The results are robust to controlling for other characteristics, including access to medieval and modern trade routes that have been conjectured to be relevant predictors of the demographic transition, as well as accounting for additional historical and geographic information. In particular, by accounting for access to maritime trade routes, access to the hanseatic trade network, and trade networks during the 19th century, the analysis disentangles the role of population shocks related to medieval plague exposure from effects that are exclusively related to trade or other mechanisms, such as the demand for human capital, that affect the timing of the transition but are not related to population shocks. Additional analyses reveal that this pattern is also found for France, providing additional support for the external validity of the results. Taken together, the empirical results support the hypothesis that the fertility decline in the context of the demographic transition occurred earlier in cities and regions that were more exposed to the plague and correspondingly experienced more frequent plague-related population shocks.

The paper contributes to the literature in several ways. The results provide empirical support for some of the central predictions of unified growth theory, according to which the demographic transition, which was the prerequisite for long-run development, was fostered by reduced Malthusian population pressure and an increase in the demand for skills (Galor and Weil, 2000; Galor, 2011). Despite the important negative short-run consequences of disease shocks (see, e.g., Shankha et al., 2010; Bhattacharya and Chakraborty, 2017) and the set-backs in long-run development caused by repeated epidemic shocks (Lagerlöf, 2003), the evidence shown here suggests that frequent exposure to diseases might indeed have induced transitions to Malthusian steady states with higher population density as response to major population shocks and as consequence of behavioral responses that foster development in the long-run. The findings thereby provide empirical support for the implications of the mechanisms proposed by Voigtländer and Voth (2013b), who suggest that exogenous disease shocks like the outbreak of the Black Death might have triggered a transition to a new Malthusian equilibrium with higher wages and population density, with important consequences for long-run development. For instance, plague-related population shocks might have ultimately triggered fertility reduction by fostering female employment and delaying marriage and childbirth (Voigtländer and Voth (2013a), see also Clark (2008)), although this pattern was more prevalent in Northern Europe than in Southern regions like Italy (De Moor and Van Zanden, 2010). The empirical validity of this channel is also a matter of ongoing debate in light of findings that delayed marriage did not affect total fertility (Ortmayr, 1995) and that the plague exhibited a similar age pattern in mortality for men and women, while there are no significant gender-differences in mortality (De Witte, 2010; Curtis and Roosen, 2017; Alfani and Murphy, 2017; Alfani and Bonetti, 2019), implying that the potential comparative advantage underlying this mechanism might have been weaker than previously thought. Alternatively, plague shocks might have led to changes in household composition that favored investments in child quality. If larger households were more affected by plague shocks than smaller households, as suggested by recent evidence by Alfani and Bonetti (2019), and had a greater propensity toward child quality and more resources to spend on each child, a quantity-quality argument would imply that this led to a shift in the Malthusian equilibrium and ultimately led to an earlier transition from a Malthusian or post-Malthusian equilibrium to a modern growth regime.[2] While the findings presented in this paper are not suited for disentangling the empirical relevance of the different mechanisms that have been proposed in the literature, they suggest that greater plague exposure was associated with an earlier fertility decline. In this sense, the results also complement recent evidence for England by Crafts and Mills (2017) that is overall consistent with the view that the plague shifted the pre-industrial Malthusian equilibrium and eventually gave rise to a demographic transition that marked the onset of modern growth. Likewise, Dittmar and Meisenzahl (2020) find evidence that plague outbreaks led to the adoption of policies and institutions that were favored by the protestant reformation and that fostered human capital acquisition and greater population growth until the 19th century. While their argument rests on the randomness of the timing outbreaks during a short period, our analysis is based on the overall exposure to plague-related shocks. Our results add to their findings by providing new information about the heterogeneity of the timing of the fertility transition about one century later.

Using spatial variation in the plague-related mortality at the city level, Jebwab et al. (2019) explore the impact of the outbreak of the Black Death 1347-1352 on city growth. They present new evidence for the duration until the populations recovered as well as its determinants and document heterogeneity regarding geographic endowments of cities in terms of land suitability and access to trade networks. On the other hand, recent work by Alfani and Percoco (2019) on Italian cities suggests that the plague epidemic of 1629-30 represented a productivity shock that caused a long-run decline in city growth and urbanization rates. The empirical analysis in this paper provides evidence that complements these findings by documenting that repeated plague outbreaks might in

---

[2] This conjecture is in line with recent evidence reported by Galor and Klemp (2019).

fact have led to an earlier fertility transition once controlling for heterogeneity in other factors.[3] At the same time, the approach focuses on a confined area of comparable geography, demography, and institutional environment in Northern Europe, thereby to a certain extent implicitly accounting for the heterogeneity of the impact of the plague that has been documented by Pamuk (2007) and more recently by Alfani (2013) in the context of Europe. The findings thereby also contribute an explanation for the heterogeneity in fertility dynamics across regions that eventually converged in the context of changes in transportation and migration, as recently documented by Daudin et al. (2019).

Our findings also complement evidence that fertility reductions in Germany and France were linked to increased education (Becker et al., 2010; Becker et al., 2013; Murphy, 2015; De La Croix and Perrin, 2018) consistent with the unified growth perspective of a close link between the fertility transition, education and economic development. This paper adds the exposure to population shocks during the middle ages as a long-run determinant of the relative timing of the transition in different regions. The empirical findings also complement evidence of higher education attainment in predominantly Protestant areas (Becker and Woessmann, 2008, 2009, 2010), while Protestantism was mainly adopted in regions where the return to education was comparably high, related to, e.g., access to major trade routes of the time, which affected the demographic dynamics above and beyond the distance to entry ports of reintroduced plague outbreaks (Cervellati and Sunde, 2016). The results are also consistent with a role of greater life expectancy for long-run development (Cervellati and Sunde, 2013, 2015), because plague outbreaks represent infrequent epidemics that unfold their consequences through population dynamics at the macro level rather than through individual incentives for education attainment. Finally, the use of disaggregate data complements recent evidence for the role of policies, such as the introduction of public health systems, for longevity and development (Strittmatter and Sunde, 2013).

The remainder of the paper is structured as follows. Section 2.2 describes the background of the resurgent outbreaks of the plague in Europe and the resulting hypothesis.

---

[3] Higher disease exposure also exerts greater evolutionary pressure, with important implications for long-run development, see, e.g., Galor and Moav (2002). However, the lack of immune resistance to plague and the short period since the medieval outbreaks makes the evolutionary channel appear less relevant in the present context.

Section 2.3 describes the data and the empirical strategy. Section 2.4 presents the main results. Section 2.5 provides a discussion of the findings.

2.2 Background and Main Hypothesis

2.2.1 The Plague in Medieval Europe: Some Background

The first outbreak of the plague in medieval Europe, the Black Death of 1347, marks one of the largest pandemics in human history. This experience has influenced the social and cultural thinking, unlike any other epidemic disease (and even unlike the earlier outbreak of the "Justinian Plague" in 541), and it is present even in today's consciousness regarding public health (see, e.g., Cantor, 2002; Slack, 2012).

The (bubonic and pneumonic) plague is a zoonotic disease that is caused by the bacterium *Yersinia pestis*. Three different variants of *yersinia pestis* have been shown to be responsible for the major outbreaks of the plague in history, the Justinian plague in 541, the medieval Black Death that began in 1347, and the outbreak in China in 1890, all of which originated in Asia. The disease primarily affects mammals, with more than 200 mammalian species reported to be naturally infected with the pathogen, but rodents are the most important hosts, see Perry and Fetherston (1997).

Transmission of the disease can occur through direct contact or ingestion, but transmission is mostly through fleas, in particular the oriental rat flea (*Xenopsylla cheopis*), which acquire the pathogen from mammals, in particular rodents, through blood meals. The virulence of *yersinia pestis* is temperature-dependent and increases due to the temperature difference between the flea and infected mammals.[4] Usually, the pathogen first spreads to lymph nodes, where it multiplies (causing the swelling known as bubonic plague), but depending on the infected organs, this can also lead to pneumonic plague (which is highly infectious from human to human). In light of the contagiousness and

---

[4] Upon infection with *Yersinia pestis*, the fleas develop a blockage of their esophagus, which leads to repeated attempts to feed. The blockages causes blood sucked from the mammal host to be mixed with *Yersinia pestis* bacilli in the flea's esophagus and ultimately to be re-injected to the host by regurgitation. Within the mammal host, most *Yersinia pestis* cells are initially destroyed by the immune system. However, already after three to five hours at high temperatures in the mammal (with body temperatures at and above 37^{o}C, which is about 15^{o}C higher than in the flea's body), *yersinia pestis* develops resistance to the phagocytes (i.e., the bacterium cannot be detected by the immune system anymore) and leads to an infection in the entire body (sepsis).

fast spread of the epidemic, there has been a debate as to whether the plague had potentially been caused by some other pathogen, possibly a virus. Recent DNA evidence from grave samples confirmed an infection by *yersinia pestis* throughout Europe (see, e.g., the discussion in Campbell, 2016, Section 4.03). Nevertheless, the transmission of plague is not well understood (see, e.g., Alfani and Murphy, 2017, for a survey of the state of the literature). In terms of intensity, recent research points towards substantially higher plague-related mortality than earlier estimates, indicating that the impact of the plague might have even underestimated previously (Benedictow, 2004; Alfani, 2013; Alfani and Murphy, 2017).

The prevalent view regarding repeated outbreaks is that the bacterium had stayed in Europe after the introduction of *Yersinia pestis* in 1347 and reproduced in rodent reservoirs in wildlife or urban environments. From these reservoirs, repeated spontaneous outbreaks were thought to have led to waves of plague in Europe, until the disappearance of the plague during the 19th Century (see, e.g., Davis, 1986; Keeling and Gilligan, 2000). The origins and dynamics of these outbreaks have been an issue of some debate in the literature (see, e.g, Cohn (2008)for a survey). Outbreaks have been shown to depend on the relative abundance of host populations and vector populations (Reijniers et al., 2012).[5] Recently, Schmid et al. (2015) conjectured that instead of persisting in hidden reservoirs in Europe, *Yersinia pestis* was repeatedly reintroduced from Asia following particular climatic conditions that favored the outbreak and spread of the pathogen. Instead of new outbreaks being the result of a transmission from other European cities, they argue that outbreaks were the result of repeated reintroductions of the plague from outbreaks in Central Asia, with the respective entry ports all located at trade points connecting Europe with trading routes to Asia. Building on earlier evidence by Stenseth et al. (2006) and Samia et al. (2011), Schmid et al. (2015) argue that all outbreaks can be related to suitable climatological conditions in Asia for an outbreak more than ten years earlier. In contrast, recent work based on ancient DNA (aDNA) analysis has been able to show that later European outbreaks of plague were caused by strains of *Y. pestis*

---

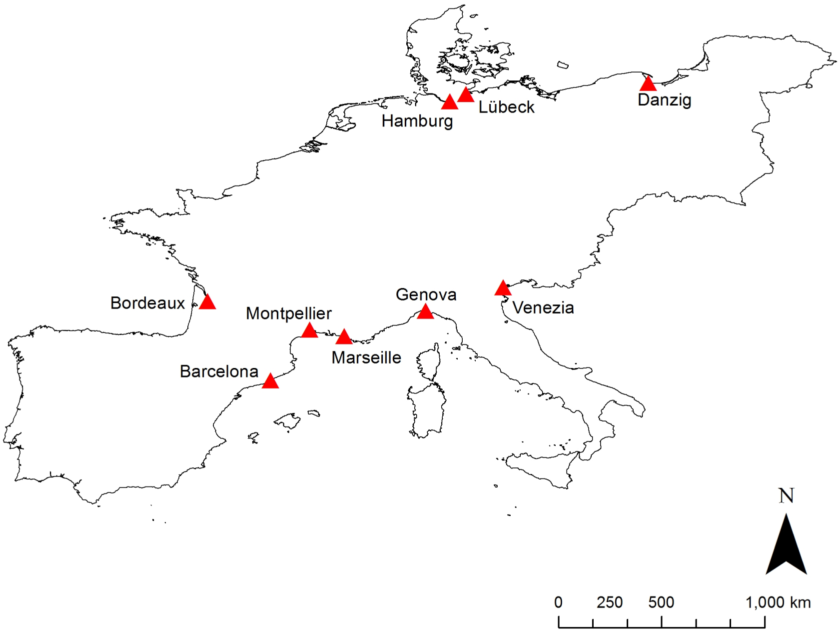
[5] The outbreaks and transmission dynamics have also been shown to heavily depend on climatic conditions, which might have favored a synchronization of host and vector populations, and thereby an increased risk of an outbreak, as documented by evidence from Asia (Stenseth et al., 2006; Kausrud et al., 2007; Cohn, 2008; Samia et al., 2011).

that are related to the strains found in burial cites of victims of the 14th century Black Death (e.g., Bos et al., 2016) report evidence for burial sites of victims of the outbreak of 1722 in Marseille, France, whereas Seifert et al. (2016) report genetic similarities in aDNA of *Y. pestis* strains across different burial sites in Germany that span 300 years, and Spyrou et al. (2016) report similarity of *Y. pestis* strains among plague victims of the Black Death in Barcelona and two subsequent historical outbreaks in Russia and Germany). This evidence supports the view of reoccurrence of the plague in Europe from local reservoirs, although the location of these reservoirs is still debated. While it seems accepted by now that the bacterium can survive and remain active in soil for prolonged periods (e.g., Ayyadurai et al., 2008), recent evidence points at plague foci close to the sea as consequence of the salt tolerance of *Y. pestis* (Malek et al., 2017). This is consistent with the finding that plague outbreaks in Europe can be traced back to outbreaks in the vicinity of ports or to maritime imports from other cities. In fact, outbreaks at the beginning of the chain of maritime transmissions can be isolated as outbreaks for which there was no earlier plague outbreak (within a time span of two years) within a 500km radius on land, or 1000km radius for harbors. Figure 2.1 provides a map of the location and the dates of the respective outbreaks of new waves of the plague.

2.2.2 Empirical Hypothesis

Regardless of the underlying reasons for renewed outbreaks of the plague during the middle ages, new waves of the plague repeatedly spread across Europe, initiating from ports and spreading through overland trade routes and waterways. The spread of the plague was related to human interaction, and the speed of this spread has been estimated to have been several kilometers per day (e.g., Benedictow, 2004). Hence, geographic location to a large extent determined the exposure to plague outbreaks, with cities and regions closer to the ports where the new waves originated facing a higher risk of being hit by a new outbreak. Due to this opaque and irregular pattern, outbreaks of the plague were taken as random events, possibly caused by metaphysical or other forces (Cantor, 2002). As consequence, there was no systematic migration related to the infrequent outbreaks of the plague that would indicate that individuals avoided particular ports and the related trade routes. Moreover, recent work by Skog and Hauska (2013) suggests

Figure 2.1: Plague Reintroductions in Europe



Notes: Red triangles denote plague entry ports in terms of maritime harbors exhibiting plague outbreaks that are not related to nearby land-based or maritime outbreaks, bold face names denote entry ports for plague reintroductions, reproduced from Figure 1 in Schmid et al. (2015). The years next to the cities indicate plague outbreaks that have not been preceded by a plague outbreak on land within a 500 km radius and on harbors within a 1000 km radius for two years prior to the outbreak.

that the spread of the Black Death in Sweden in 1350 is well approximated by travel distances on the medieval road network, and evidence by Dittmar and Meisenzahl (2020) and Yue et al. (2016) indicates that locations close to ports, rivers and trade routes were particularly affected by the diffusion of the plague.[6] Taken together, this suggests that, ceteris paribus, the mortality shocks caused by outbreaks of the plague were more frequent and intense in locations closer to the ports where the new plague waves originated.

In the centuries that followed the outbreak of the Black Death in 1347, plague and other deadly epidemics ravaged throughout the continent and caused millions of casualties. According to Keyser (1941), these deaths were followed by higher birth rates that compensated the population loss in the aftermath of the outbreak. This implies that medieval Europe can be described as being governed by a Malthusian population regime. Voigtländer and Voth (2013b) argue that population shocks like plague epidemics imply large shocks to income per capita, and in the medium run lead to increased urbanization, birth and death rates, and ultimately to a transition from one Malthusian regime to a

---

[6] Conversely, the spread of epidemics like the plague has been used as proxy for relative trade intensities, which is consistent with the approach taken here, see, e.g., Boerner and Severgnini (2014).

another Malthusian regime with higher population density. The loss of lives caused by an epidemic outbreak also led to a temporary scarcity of labor and increased land-labor ratios, favoring more land-intensive production in terms of animal husbandry as compared to the relatively labor-intensive plow agriculture producing crops. According to Voigtländer and Voth (2013a), this and the comparative advantage of women in pastoral farming increased the incentives for female employment, leading to higher marriage ages and lower fertility in the aggregate, and hence a Malthusian equilibrium characterized by better living conditions and greater population density. In a longer perspective, greater population density fostered the demand for skills, while lower fertility, in turn, implied lower opportunity costs for undergoing the demographic transition, from quantity to quality investments in children. This development was accompanied by institutional changes, for instance in inheritance rules, that were triggered by repeated plague outbreaks (see, e.g., Alfani and Di Tullio, 2019) and ultimately constituted the basis for the economic take-off (Galor, 2011). Regardless of the precise mechanisms that were triggered by the population shocks due to epidemics, the consequences and the resulting change in fertility behavior were presumably more prevalent and powerful in the locations hit harder by the plague.

The core hypothesis that follows from this discussion is that greater exposure to the plague might have accelerated the demographic development and ultimately led to an earlier fertility transition. By spreading from city to city, the outbreak of the plague might have had a major impact on many cities. Importantly, however, this impact was likely to be heterogeneous, depending on the location of the city which determined the exposure to the occasional outbreaks of the plague. Hence, cities and regions that were more exposed to these outbreaks faced more frequent and pronounced population shocks and, ceteris paribus, a faster demographic development along the lines outlined before. In particular, the greater exposure to plague outbreaks is expected to be reflected by an earlier onset of the fertility transition.

This paper provides a reduced form analysis of the effect of variation in the exposure to repeated plague outbreaks on the timing of the fertility transition across regions in Germany and France.[7]

---

[7] Since the focus of this paper is on the long-run development implications of population shocks, and for reasons of data availability, this study focuses on variation in the timing of the fertility transition

2.3 Data and Empirical Approach

2.3.1 Data

Fertility Transition Data. The baseline analysis is conducted for Germany. The demographic information central to our analysis is the timing of the fertility transition. The main data source is Knodel (1974), who provides detailed data on the on fertility and age distribution of the population in Germany on a regional level within the boundaries of 1900 (district boundaries from 1901).

Marital fertility rates, which provide the most reliable source of fertility data, are used to calculate the onset of the fertility transition for 237 cities in 56 German regions based on data covering the time from 1871 to 1939. Among a variety of definitions of fertility rates, Knodel (1974) puts most emphasis on the marital fertility instead of total fertility, which also includes illegitimate births since these are more likely to be misreported as result of social pressure. The marital fertility rates take into account different age distributions in different German regions, and thus provide a comparable measure of fertility in terms of the actual number of births during a year relative to the potential fertility.[8] The onset of the fertility transition is defined as the year in which marital fertility reached a threshold.[9] There is some arbitrariness associated with this definition, since it does not measure the onset of the decline in fertility, but the time of reaching a threshold. However, at the same time this definition is transparent and avoids confusion of the onset of the fertility transition with a temporary decline or fluctuations in fertility, e.g., due to a war or German unification. Figure 2.2 provides a map that illustrates the timing of the fertility transition.

As alternative source of demographic data, we use the data set assembled by Galloway (1994, 2007). These data contain detailed information on vital statistics at the level of Prussian regions. To construct a measure of the timing of the fertility transition, we make use of the standard thresholds for fertility and mortality used in demography and

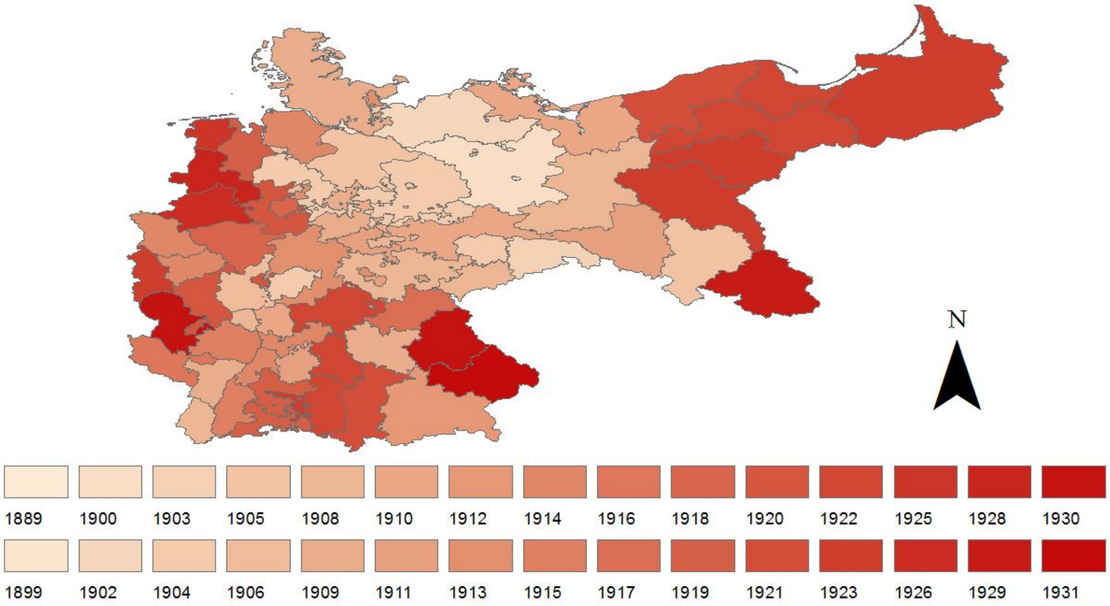
---

across regions in Germany and France and does not investigate the short and medium-run implications of the plague for development in urban versus rural areas, as done, e.g., by Alfani (2013).

[8] The marital fertility is defined as $I_g = B_L/(\sum_i m_i F_i)$ where B_L is the number of legitimate births, m_i is the number of women in the (five-year) age interval i, and F_i is the age-specific natural fertility, proxied by the fertility of a married Hutterite woman in 1921-1930, see also Table A.1 in the Appendix.

[9] Consistent with the interpretation by Knodel (1974), this threshold is taken to be 0.5 in the baseline analysis. In robustness checks, we consider an alternative threshold of 0.6.

Figure 2.2: The Timing of the Fertility Transition in Germany



Notes: Districts colored by the year of the fertility transition (threshold 0.5) according to Knodel (1974).

code the onset of the transition as the year in which the thresholds are surpassed for the first time.[10] To demonstrate the robustness and external validity of the main finding, below we also consider the timing of the fertility transition in France using data from the Princeton European Fertility Project (Coale and Coats-Watkins, 1986).

Travel Distance from Plague Entry Ports. The exposure to plague outbreaks is measured by the geographic travel distance from the initial entry ports depicted in Figure 2.1. These ports are: Danzig (Gdansk), Hamburg and Lübeck, Venice, Genova, Marseille, Montpellier, Bordeaux, and Barcelona. The final dataset is constructed on the basis of about 5.7 million road/river segments with elevation data at both the start and end of each of these line segments. The data covers continental Europe West of, and including, Poland and the Czech Republic. In order to measure the travel times from the harbors to the different cities, we combine data from two sources. The data for the road and river network of Europe is taken from Openstreetmap.org via MapCruzin.com. These data comprise of about 8 million line segments, representing roads and about 2 million

---

[10] The thresholds are a crude birth rate lower than 35 per 1000 and a crude death rate lower than 30 per 1000, see Chesnais (1992) and Cervellati and Sunde (2011). To account for the fact that the mortality transition precedes the fertility transition and to account for measurement error in the Galloway data, we use the average of the two years in which the two thresholds are passed.

line segments representing waterways in all over Europe and parts of western Asia. The dataset includes countries ranging from Portugal to parts of western Russia and Turkey.

The additional data for the elevation is taken from DIVA-GIS. This data is available for each country and provides precise elevation data for a fine raster. The elevation data for the individual countries was merged to create an elevation profile for Western and central continental Europe.[11]

The travel distance is constructed from a road map that is based on contemporaneous road network, adjusted for historic travel times. In order to ensure the validity of this measure, the basic dataset is adjusted as follows. Historically, the existing roads in Europe were continuously developed up to the road network observed today. This has been done mainly by expanding existing roads. The most prominent example for this is probably the "Via Appia" in Italy, an old roman road that is still used today. Obvious deviations are, e.g., the system of motor ways (Autobahn) which was built for a completely different purpose and without historic predecessors. Hence, motor ways and other constructions that were obviously not in place in medieval and early modern times, such as tunnels and canals, were excluded from the dataset. This implies a rather realistic dataset for measuring the distances, especially in areas with mountains such as the Alps.[12]

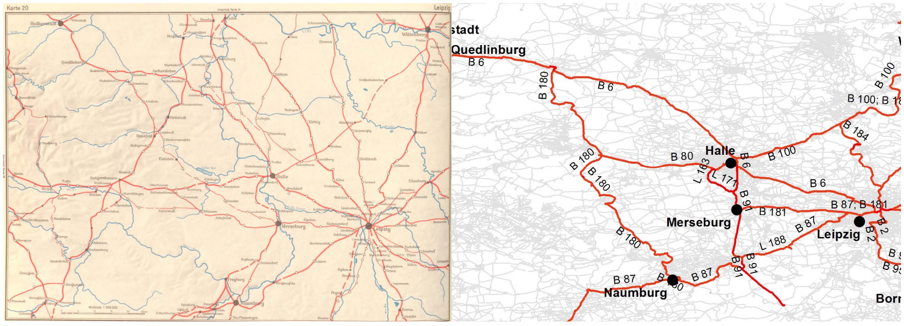
A comparison between maps of the historical road network in Germany during the 19th century and the network obtained by this methodology confirms its validity. To illustrate this, Figure 2.3 provides a direct comparison for the region around Leipzig, Halberstadt and Wittenberg. Panel (a) shows the map of this region with medieval trade routes as depicted in the atlas of hanseatic routes by Bruns and Weczerka (1962). Panel (b) shows the digitized data for roads. All streets that have been used for determining travel distance are shown in grey, the most important hanseatic routes are marked with red (including the modern street labels and numbers). These are the basis for the computation of travel distance in terms of time as discussed below.

---

[11] In order to check the accuracy of the elevation data, the DIVA-GIS elevation data was compared to the elevation data provided by Bosker et al. (2013). The reported elevation difference was in the range of up to four meters. The difference could be a result of a different raster size of the elevation data. Furthermore, the maximal elevation difference of four meters lies well in the range one can expect to be within a certain city.

[12] Furthermore, areas that are not relevant for the empirical analysis, such as Turkey and Russia, were excluded from the data.

Figure 2.3: Comparing Historical and Contemporaneous Road Networks



(a) Historical Road Map (b) Digitized Road Map

Notes: Panel (a) depicts a map of historical hanseatic trade routes reproduced from Bruns and Weczerka (1962). Panel (b) depicts the digitized road map that is used to determine the distances and travel times for the empirical analysis.

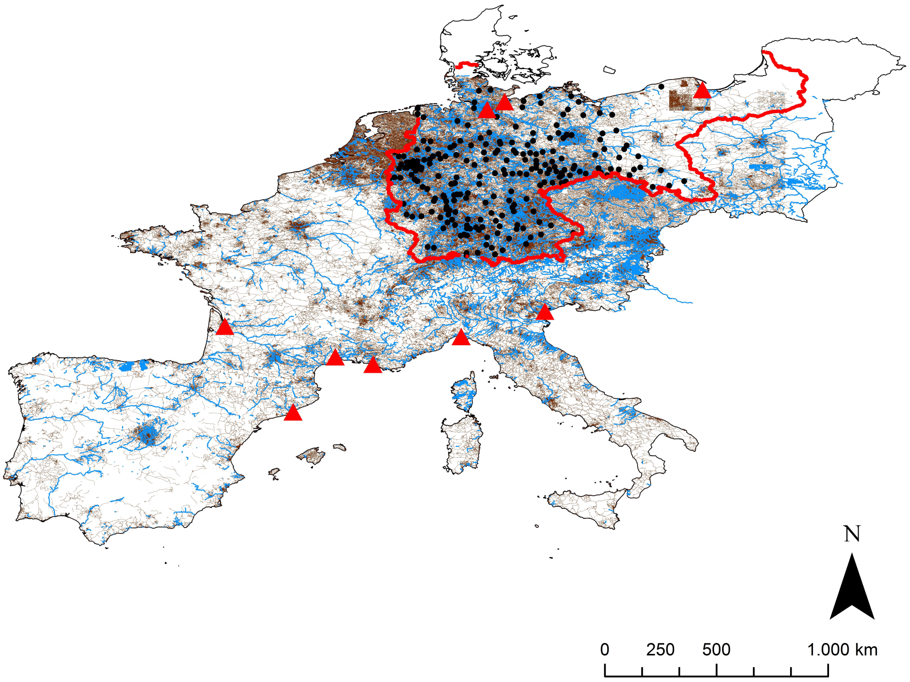
In a second step, the road map was projected into “Europe Equidistant Conic”, a coordinate system that preserves distances between points. This is necessary to avoid distortions due to projecting the three-dimensional world on a two-dimensional map. An equidistant projection does not distort the distances between cities and entry ports, which is crucial for measuring the travel times.[13] Figure 2.4 shows the projected road and river map of Europe. In addition to the road and river network shown in Figure 2.4, the data use about 5.7 million line segments including detailed elevation data. Using elevation data at both ends of these line segments, we computed the absolute difference in elevation over the length of the line segment and calculated the corresponding slope of the line segments (in degrees) as the arctangens of the elevation difference relative to the length of the segment.

Based on the information from the road and river network map and the slopes of the street segments, we calculated the travel time from the individual ports to each city. The travel times depend crucially on the assumptions about travel speeds for the different means of transportation. Transport via ships on rivers used to be substantially faster than traveling by foot. Transport of people and goods over land was mostly performed by horse coaches, which were just little faster than walking. The average speed of travel was around five to seven kilometers per hour (Ritter, 1966, p. 28). This corresponds to alternative sources according to which goods transport was possible at a speed of about

---

[13] The potential distortions are quite small for cities close together, but increase with the distance between the cities. Hence, if not projected to an equidistant format, the distortions would increase with the distance to the harbor and thus introduce systematic and potentially substantial measurement error that might lead to misleading results.

Figure 2.4: Travel Distances from Entry Ports



Notes: Map of roads (brown) and waterways (blue) used to compute travel distances from entry ports (red triangles). Cities are depicted as black dots. Red line represents German border as of 1900.

30 kilometers per day (in flat areas up to 40 kilometers), which corresponds to about six to eight hours at a speed of five kilometers per hour (Bruns and Weczerka, 1962, 1967). Similarly, historical accounts of mail deliveries over long distances managed travel speeds of approximately 5.5 to 6.5 kilometers per hour (Hitzer, 1971). Since for horse coaches it was virtually impossible to travel on very steep roads, the travel time decreases with the slope and roads with a slope of more than 45^o constituted a natural barrier. Hence, following this literature, we assume specific travel speeds by surface type and slope of line segment.[14]

---

[14] See Table A.2 in the Appendix for details. For slopes steeper than 45^o, the transport was mostly done by physical man labor for purposes other than travel. Even today the transport of food and other necessary equipment to remote cottages in the hills is done by carrying. Line segments with a slope larger than 45^o are assigned a speed of zero and are thus assumed to be bypassed on other roads. Obviously, the measured time depends on the assumed travel speed. The precise assumptions about the travel speed itself are irrelevant for the empirical analysis (and only affect the size of the coefficient). The important feature is the relative decline in the travel speed for the different slope brackets. Since assigning the travel speed contains an arbitrary element, this constitutes the most serious threat to validity. The main problem is that there are not many sources that provide reliable travel speeds at the medieval times, other than that traveling was exhausting and took a long time. In order to check for robustness, the regression is performed with alternative speed schedules, with similar results as shown below.

The travel time is consequently defined as the minimum time necessary to travel the distance of the line segment given the speed restriction of the slope. The travel times to entry ports are then calculated in two steps. First the time to cover the particular line segment is assigned to the individual line segment given surface type and slope as described above. In the second step the path with the shortest sum of travel times is selected among all paths, and the total travel time from each entry port to each city is computed using the Dijkstra-algorithm (Dijkstra, 1959). The resulting variable *Travel Time* represents the travel time in hours from the closest port to the respective city. This variable serves as proxy for the relative risk of being exposed to outbreaks of the plague, which are expected to have occurred more often the closer the nearest entry port. The use of the travel times, rather than the simple distance, is essential to the analysis, since the spread of the plague requires human contact to infected hosts and vectors. The simple horizontal distance is therefore an inadequate proxy for the relative risk of being exposed to plague epidemics, since remote places were less likely to be affected by an outbreak. As additional control, the analysis also makes use of the variable *Number of Ports*, which measures the number of ports that can be reached from the respective city within 100 hours.

Other Variables. To account for relevant heterogeneity across cities and regions, we use additional information from various sources. The analysis controls for access to the trade network of the Hanseatic League, as well as distance to trade ports that became important after the discovery of the Americas and to the main trade ports of the 19th century. City-level controls for religion, the associated cultural differences, as well as for specific institutions, are taken from data constructed by Cantoni (2012). This data set includes 259 cities in Germany and Austria, with information about population at various points in time and other background information. In particular, the data include binary indicators that denote whether a city was considered protestant after the 15th and 16th century, respectively, whether a city belonged to the Hanseatic League, whether a city was considered a free imperial city, whether a city had a printing press by the year 1517 or whether a city had a university or was located on a navigable river.[15]

---

[15] Additional variables indicate the number of monasteries within a 10 km radius of the respective city for all monasteries and monasteries of the Order of Saint Augustine.

To account for agricultural potential, we use information about the soil suitability for agriculture (in terms of caloric yield of the most important crop) based on data constructed by Galor and Özak (2016).[16] Together with the measure for ruggedness, these variables provide valuable insight in the agricultural potential of a region. Additional indicator variables include information whether a city was affected by the 30-year war 1618-1648 or the 7-year war 1756-1763, in terms of plundering or other warfare events.[17]

2.3.2 Descriptive Statistics

Table 2.1 provides descriptive statistics for the core variables of the analysis, the distance, in terms of travel time in hours, to the closest entry port for new plague outbreaks, the number of entry ports within a 100-hour radius, population density in 1890, the (log) population in 1500, and population growth from 1300 to 1500.

Table 2.1: Descriptive Statistics

	Mean	SD	Min	Max
Onset Dem. Tr. (Year)	1,912.4	7.5	1,889	1,931
Number of Outbreaks (0-1900)	2.2	5.1	0	30
Number of Outbreaks (0-1555)	1.1	3.1	0	23
Number of Outbreaks (0-1618)	1.7	4.2	0	28
Number of Outbreaks (1360-1618)	1.5	3.9	0	26
Travel Time	48.3	19.5	.19	86
Travel Time (Roman Roads)	6.6	15.4	0	56
Travel Time (non-Roman Roads)	41.7	18.3	.19	81
Number of Plague Ports (100h)	3.0	0.9	2	6
Population Density 1900 (log)	4.8	0.7	3.7	10
Population in 1400(log)	0.5	0.9	0	3.7
Population Growth 1400-1600(log)	0.5	0.9	-2.2	3
Protestant	0.8	0.4	0	1
Monasteries (p.c.)	1.3	1.8	0	15
Augustian Monasteries (p.c.)	0.1	0.3	0	1
University	0.1	0.2	0	1
Hanseatic City	0.1	0.3	0	1
Reichsstadt	0.2	0.4	0	1
Printing Press	0.1	0.3	0	1
River	0.4	0.5	0	1
Caloric Yield	9,103.2	454.6	7,614	10,109
30y War	0.5	0.5	0	1
7y War	0.2	0.4	0	1
Latitude	50.9	1.6	48	54
Longitude	10.3	2.7	6.1	18

The statistics refer to 237 cities in Germany.

---

[16] This variable measures the average potential crop yield in terms of calories (millions of kilo calories per hectare and year) for the most productive crop available for cultivation before 1500CE. In robustness tests, we also consider an index of land suitability for agriculture designed by Ramankutty et al. (2002) that uses the daily sum of temperature over a base temperature of 5 degree Celsius, the pH-level of the soil, the soil carbon density and a moisture index, calculated by the actual evapotranspiration over the potential evapotranspiration, in order to calculate a single number that indicate the suitability for agriculture.

[17] The information for these variables is taken from records of city archives (Keyser, 1974).

2.3.3 Empirical Strategy

The empirical analysis tests the hypothesis that cities with greater exposure to plague epidemics experienced an earlier fertility transition during the 19th Century. The analysis is based on a simple linear regression model

$$Transition\ Year_i = \beta_0 + \beta_1 Plague\ Exposure_i + \gamma X_i + \varepsilon_i \tag{2.1}$$

where i indicates city, $Transition_i$ is the year of the onset of the demographic transition, which is measured in terms of the onset of the fertility decline, and $Plague\ Exposure_i$ is the exposure of city i to the plague. X is a vector of control variables, which include other relevant determinants of the timing of the fertility transition. The empirical analysis accounts for cities located within the same administrative region by clustering the standard errors correspondingly.[18]

The identification of the coefficient of interest, β_1, requires a reliable measure of plague exposure that is exogenous, conditional on variation captured by the control variables included in the vector X_i. The focus on cities in Germany (and below also France) has the advantage of comparing variation across environments that are otherwise rather comparable, other than when comparing across countries or even world regions like Europe and Asia.[19]

The main problem in this context is that existing measures of plague exposure, such as counts of outbreaks or plague-related casualties, are fraught with measurement error. In addition, the hypothesis to be tested is that the timing of the fertility transition, which took place in the late 19th and early 20th century, was related to the long-run exposure to plague epidemics centuries earlier through potentially various, mutually non-exclusive channels whose consequences unfolded over time.

To address these issues, the empirical strategy is based on the use of proxy measures for the exposure to repeated plague outbreaks in history. In particular, to account for the fact that the number of outbreaks affecting cities during different historical phases is a coarse measure that is likely to be fraught by measurement error, we apply geographic

---

[18] The data by Knodel (1974) is based on 56 regions.

[19] The obvious limitation of this approach is that the analysis does not provide insights as to why the demographic transition happened earlier in Europe than in other parts of the world.

proxies of the exposure to plague outbreaks. The use of geographic proxies, either in a reduced form approach or in the context of an instrumental variables approach, enables a better identification of the effect of plague exposure on the timing of the fertility transition than plain OLS. In particular, we use variables that are based on the exposure in terms of the travel distance to the ports where the new plague waves originated. The main measure accounts for the distance to the nearest entry port. Additional analyses also make use of a measure of the number of entry ports within a perimeter of 100 hours travel time.

According to the empirical hypothesis, β_1 is expected to be negative, in the sense that greater exposure to the plague led to an earlier fertility transition. The identification of the effect rests on the assumption that exposure to repeated outbreaks of the plague (in terms of location relative to entry ports) is conditionally exogenous to the timing of the fertility transition of a city. The key issue for identification is therefore to account for confounding factors, such as access to trade in medieval times and, especially, during the 19th century, or other historical or geographical features that might be picked up by the measure of exposure to repeated outbreaks of the plague. We thus apply specifications with various sets of controls, including geographic controls such as a measure whether a city was affected by the very first outbreak of the Black Death in 1347-1352, population controls, religion controls, institutional controls, controls for agricultural yields, and exposure to wars.

While these extensive controls help isolating the role of plague exposure, it is hard if not impossible to disentangle the role of different mechanisms through which plague exposure influenced the timing of the fertility transition as consequence of the singular nature of the fertility transition and the resulting restriction to the availability of cross-sectional variation in the timing of the fertility transition. For instance, an important determinant of plague exposure is related to closer access to the main trade network of medieval Europe, since plague contagion is related to human interaction. While it should be clear that the empirical analysis in this paper is confined to a reduced form approach, it is nevertheless possible to rule out contemporaneous trade access by disentangling the variation in the importance of trade ports over time and thereby isolating long-run effects of plague exposure from trade effects related to trade in the 19th century. Below, we present results from an extensive number of robustness checks.

2.4 Results

2.4.1 Plague Outbreaks and the Timing of the Demographic Transition

As a first step, we regress the timing of the demographic transition in Germany, measured as the year in which a city experienced the fertility decline in terms of a marital fertility below 0.5 as dependent variable, on exposure to plague shocks as measured by the total recorded number of plague outbreaks before 1900 in a city. The results, which are presented in Table 2.2 document a consistently negative effect of the number of plague outbreaks on the year of the fertility transition. This is an indication that cities that experienced more frequent plagues also experienced an earlier fertility transition. The prevalence of a plague outbreak during the first wave of the Black Death in 1347-1352, instead, does not seem to be related to the timing of the fertility transition. However, the discussion above suggests that the outbreak of the Black Death during the first wave might itself be related to access to trade at the time. In order to account for systematic heterogeneity that might affect this finding, we replicate the analysis by including various sets of control variables. In particular, we add demographic controls (for population density in 1400, as well as for population growth between 1400 and 1600), religion controls (whether a city had adopted Protestantism by 1600, the number of monasteries per capita, and the number of Augustinian monasteries), institution controls (the existence of a university, membership in the Hanseatic league, the status of a free imperial city, or the presence of a printing press by the time of the protestant reformation), controls for geography (location on a navigable river, maritime port, latitude and longitude), suitability for agriculture (in terms of caloric yield of the most important crop), and exposure of the city to wars (30-year war and 7-year war). Regardless of the specification, the coefficient estimates for plague outbreaks are significantly negative, indicating an earlier transition in line with the hypothesis. The similarity of the coefficients of interest across the different specifications suggests that the omission of relevant variables or problems due to the inclusion of endogenous (“bad”) controls are unlikely to drive the result.

The coefficient estimates for these control variables also reveal a coherent pattern.[20] Consistent with historical accounts that the demographic transition occurred first in France and North-West Europe, but also with the hypothesis that greater exposure to plague outbreaks implied an earlier onset of the fertility transition, we find evidence for an earlier onset being associated with greater latitude and longitude. Moreover, greater population density during the 19th century is associated with an earlier onset of the fertility transition, consistent with the conjecture maintained in unified growth theories. The results for the religion controls confirm the intuition of an earlier onset of the fertility transition in cities that adopted Protestantism. Adding controls for institutions reveals that the existence of a university or a printing press implied an earlier fertility transition, although the coefficient estimates are not significant. Greater agricultural potential, as proxied by caloric yield of the most important crop, is also associated with a significantly earlier fertility transition, supporting arguments that are based on the interplay between environmental and cultural factors (see, e.g., Galor and Özak, 2016). Finally, in line with previous arguments on the role of wars, we find that a greater exposure to the 30-year war was associated with an earlier onset of the demographic transition. Together, these findings are consistent with the joint role of population shocks, access to trade, and war for the demographic development as suggested by Voigtländer and Voth (2013a). Importantly, however, accounting for these control variables leaves the main results regarding the role of the exposure to the plague for the timing of the fertility transition essentially unaffected. As suggested by the relatively low variance inflation factors, the estimation results also seem not to be affected by multicollinearity.

This finding provides a first piece of evidence that population shocks, proxied by the exposure to plague outbreaks, indeed had an effect on the timing of the demographic transition. However, while the stability of the coefficient estimates with respect to the addition of different sets of control variables indicates that plague outbreaks exert a largely independent effect that is unlikely driven by third factors, the use of historical data on plague outbreaks might be problematic as these data are based on various sources of dif-

---

[20] See Table A.3 in the Appendix for the respective results.

Table 2.2: Plague Outbreaks and the Timing of the Demographic Transition

Dependent Variable	Onset of the Demographic Transition (Year)						
Number of Outbreaks (0-1900)	-0.411*** (0.153)	-0.391*** (0.118)	-0.375*** (0.108)	-0.344*** (0.100)	-0.327*** (0.101)	-0.311*** (0.101)	-0.343*** (0.102)
Controls							
Geography		✓	✓	✓	✓	✓	✓
Population			✓	✓	✓	✓	✓
Religion				✓	✓	✓	✓
Institutions					✓	✓	✓
Agriculture						✓	✓
Wars							✓
Observations	237	237	237	237	237	237	237
R^2	0.043	0.329	0.410	0.439	0.447	0.480	0.491
Adjusted R^2	0.035	0.312	0.387	0.409	0.407	0.439	0.446
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.61	1.66	2.42	2.43	2.69	2.71	2.73

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

ferent quality and reliability. In particular, the data on outbreaks exhibit little variation and are measured very coarsely. Recent papers have emphasized several shortcomings of historical plague data, including the lack of heterogeneity and reliability (see, e.g., Alfani, 2013), or comparability as consequence of different data sources and coverage (see, e.g., Roosen and Curtis, 2018).[21] The results of a significant and robust relation between plague outbreaks and the timing of the fertility transition should therefore be seen as preliminary evidence in support of the hypothesis of the influence of plague exposure. The size of the estimates is not informative as result of measurement error.

2.4.2 Plague Exposure and the Timing of the Demographic Transition

Reduced Form Estimates: Plague Exposure and the Timing of the Demographic Transition. In order to explore the measurement issue and the robustness of the results, and to obtain more reliable estimates, we next replicate the analysis using information from a geography-based measure of plague exposure in a reduced form exercise. In particular, we use the distance to the closest entry port for plague outbreaks in terms of travel time, instead of the measured number of plague outbreaks, as proxies for

---

[21] Even greater concerns apply to data of plague casualties before the outbreak of the 30-year war, e.g., by Biraben (1975, 1976), or Büntgen et al. (2012), or mortality data (in terms of the percentage of the population killed by the Black Death after 1348) that has been constructed for selected cities by Olea and Christakos (2005), which is why we refrain from considering these data.

plague exposure. Otherwise, we apply the same specifications of the empirical model in terms of controls as before.

The results are shown in Table 2.3. The results in Panel A document that greater exposure to plague outbreaks, proxied by greater proximity to the nearest entry port in terms of travel time is associated with a significantly earlier onset of the fertility transition in German regions. This finding is robust to the inclusion of an indicator of outbreaks during the first wave of the Black Death, geographic controls such as (in the order of columns) latitude, longitude, or access to riverine or maritime trade routes; controls for population density and dynamics; controls for religious factors like protestantism or the number of monasteries; controls for institutions like free imperial city, university, printing press, or membership to the Hanseatic league; agricultural suitability; and the exposure to wars.[22] Taken together, the findings indicate that the fertility transition occurred earlier in more densely populated (and presumably richer since more urbanized) areas. These findings are robust across different specifications that become increasingly more comprehensive. They are consistent with the main mechanism underlying the onset of the demographic transition in the canonical unified growth model, which relates to greater population density and greater demand for human capital as the main factors behind the onset. However, the results suggest that the exposure to population shocks as reflected by the exposure to plague outbreaks potentially was a key factor for the shifts in the Malthusian equilibrium that eventually gave way to the demographic transition.

This finding is unaffected when measuring travel time distance along all roads or when distinguishing between Roman and non-Roman roads, respectively. In particular, Panel B shows the respective results when accounting separately for distance on Roman roads versus non-Roman roads to account for the persistent role of Roman institutions and the Roman road network for long-run development (see, e.g., Wahl, 2017).[23] Overall, the results are qualitatively similar and quantitatively even slightly larger when considering Roman roads, but the coefficients are not significantly different from each other and from those in Panel A. The plague exposure proxy alone explains around 25 percent of

---

[22] The respective estimation results are reported in Table A.4 in the Appendix.

[23] Roman roads in this context are defined as roads within the borders of the Roman Empire at maximum extent, Non-Roman roads are defined as roads in areas that were never under the control of the Roman empire. The respective estimation results for the control variables are reported in Table A.5 in the Appendix.

the variation in the timing of the fertility transition, whereas adding the extensive set of additional control variables does not deliver a drastic increase in explanatory power of the empirical model. As with the OLS results, the estimation results seem not to be affected greatly by multicollinearity. Quantitatively, the coefficient estimates individually imply that a reduction in the travel distance to the nearest plague port by 100 hours is equivalent to an onset of the fertility transition that occurs a quarter of a century earlier.

Table 2.3: Exposure to Plague Outbreaks and the Timing of the Demographic Transition

Dependent Variable	Onset of the Demographic Transition (Year)						
	Panel A: Baseline Specification						
Travel Time	0.206***	0.213***	0.243***	0.234***	0.246***	0.255***	0.253***
	(0.044)	(0.073)	(0.065)	(0.067)	(0.068)	(0.062)	(0.062)
Observations	237	237	237	237	237	237	237
R^2	0.249	0.357	0.471	0.495	0.510	0.550	0.557
Adjusted R^2	0.243	0.340	0.450	0.468	0.474	0.515	0.518
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.02	4.32	4.41	4.42	4.90	4.91	5.10
	Panel B: Accounting for Roman Roads						
Travel Time (Roman Roads)	0.260***	0.430***	0.377***	0.354***	0.360***	0.338***	0.338***
	(0.054)	(0.102)	(0.089)	(0.090)	(0.091)	(0.082)	(0.082)
Travel Time (non-Roman Roads)	0.171***	0.264***	0.271***	0.262***	0.271***	0.273***	0.272***
	(0.047)	(0.069)	(0.063)	(0.065)	(0.066)	(0.061)	(0.061)
Observations	237	237	237	237	237	237	237
R^2	0.273	0.411	0.490	0.509	0.523	0.557	0.564
Adjusted R^2	0.263	0.393	0.468	0.480	0.486	0.521	0.524
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.20	6.50	6.61	6.72	7.02	7.11	7.23
joint F	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Controls (both Panels)						
Geography		✓	✓	✓	✓	✓	✓
Population			✓	✓	✓	✓	✓
Religion				✓	✓	✓	✓
Institutions					✓	✓	✓
Agriculture						✓	✓
Wars							✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2SLS Results: Plague Exposure, Plague Outbreaks, and the Timing of the Demographic Transition. To shed light on the quantitative implications of these results and, indirectly, whether and how the previous regression results are affected by measurement error, we report the results from the application of an instrumental variables approach. Since travel distance to the entry ports represents a proxy for plague exposure that exhibits sufficient (continuous) variation, we use this variable as an instrument for the number of plague outbreaks. In addition, we consider the most extensive specification of control variables, including the prevalence of a plague outbreak during the first wave of the Black Death in 1347-1352. Notice that the validity of an instrumental variables approach in this context requires the instrument to be correlated with the instrumented variable (relevance) but uncorrelated with the measurement error (validity). The validity assumption appears plausible in the present context since the geographic distance from entry ports is unlikely to be relevant for the reliability of the count of plague outbreaks that is based on archival information. Moreover, the extensive specification controls for correlations between the outcome variable, the timing of the fertility transition, and the geographic features contained in the instrument through the presence of proxies (in particular the prevalence of a plague outbreak during the first wave of the Black Death).

Table 2.4 presents the corresponding estimation results. Panel A contains the results for travel distance to plague ports on any road, while Panel B contains results when distinguishing between Roman and non-Roman roads. The first column in both panels replicates the OLS results of Column (7) of Table 2.2 for all plague outbreaks before 1900. The coefficient estimate for the number of plague outbreaks is negative and significant, indicating an earlier onset of the fertility transition. The remaining columns of Table 2.4 report the 2SLS results for different specifications of the variable of plague outbreaks. Throughout all specifications, the first stage results suggest that the instrument is relevant. In particular, the estimates document that the proxies of plague exposure are indeed correlated (positively) with the frequency of plague outbreaks in different epochs.[24]

Column (2) contains the results when all outbreaks before 1900 are instrumented using the travel distance to the nearest entry port of the plague. The second stage results reveal a significant negative IV-estimate for the number of outbreaks, which suggests an earlier onset of the fertility transition in cities that experienced more plague shocks. The coefficient estimate is more than ten times larger than the OLS estimate, which indicates substantial attenuation of the OLS results due to measurement error. The estimates are even larger when restricting attention to plague outbreaks before the peace of Augsburg 1555, or before the onset of the 30-year war 1618, as indicated by the results in Columns (3) and (4). Column (5) presents results for the number of outbreaks between 1360 and

---

[24] Table A.6 in the Appendix reports the respective coefficient estimates of the first stage regressions.

1618, i.e., when excluding the first wave of the Black Death that began in 1347.[25] These results are robust to the distinction of travel times on Roman and non-Roman roads, as indicated by the very similar results in Panel B.[26]

Taken together these estimates suggest that an additional plague outbreak during the middle ages implied that the onset of the fertility transition occurred around four to six years earlier, holding everything else constant.

Table 2.4: Plague Exposure and the Timing of the Demographic Transition: IV Results

Dependent Variable	Onset of the Demographic Transition (Year)				
Panel A: Baseline Specification					
	OLS	IV			
Number of Outbreaks (0-1900)	-0.343***	-4.869***			
	(0.102)	(1.846)			
Number of Outbreaks (0-1555)			-7.981***		
			(2.963)		
Number of Outbreaks (0-1618)				-6.785**	
				(2.644)	
Number of Outbreaks (1360-1618)					-7.036**
					(2.788)
First Stage					
Travel Time		-0.052***	-0.032***	-0.037**	-0.036**
		(0.019)	(0.011)	(0.014)	(0.014)
Observations	237	237	237	237	237
F-Stat in FS		7.57	8.91	6.68	6.29
Kleinbergen-Paap rk LM (p-value)		0.01	0.01	0.02	0.02
Panel B: Accounting for Roman Roads					
	OLS	IV			
Number of Outbreaks (0-1900)	-0.343***	-4.926***			
	(0.102)	(1.838)			
Number of Outbreaks (0-1555)			-8.113***		
			(2.924)		
Number of Outbreaks (0-1618)				-6.893***	
				(2.486)	
Number of Outbreaks (1360-1618)					-7.118***
					(2.587)
First Stage					
Travel Time (Roman Roads)		-0.055*	-0.035**	-0.046**	-0.046**
		(0.030)	(0.016)	(0.023)	(0.022)
Travel Time (non-Roman Roads)		-0.053***	-0.032***	-0.039***	-0.038***
		(0.019)	(0.010)	(0.014)	(0.014)
Observations	237	237	237	237	237
F-Stat in FS		3.93	4.87	3.84	3.68
Kleinbergen-Paap rk LM (p-value)		0.04	0.02	0.04	0.04
Hansen J (p-value)		0.57	0.60	0.87	0.91
Full Set of Controls (both Panels)	✓	✓	✓	✓	✓

Standard errors, clustered by administrative region, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

---

[25] The corresponding coefficient estimates for all variables are contained in Table A.7 in the Appendix.

[26] The coefficient estimates for the other variables can be found in Tables A.8 and A.9 in the Appendix respectively.

2.4.3 Robustness and Additional Results

To investigate the robustness of these results, we conducted different robustness checks. Instead of exploring the role of the exposure to repeated population shocks as consequence of plague outbreaks using city-level data, one might alternatively analyze the data on the level of regions. Given that the main information source on the timing of the fertility transition is on the regional level (Knodel, 1974), this could be viewed as a more natural level of the analysis. On the other hand, however, this means using variation in the data at a higher level of aggregation. Checking the sensitivity of the empirical results with respect to the level of aggregation also provides a sensible robustness check in general. The results confirm the findings on the city level, namely that regions with more entry ports in a reasonably close distance are associated with a significantly earlier fertility transition. Likewise, regions that are less exposed to plague outbreaks as measured by a greater distance in terms of travel time to the nearest plague entry port experience a significantly later onset of the fertility transition.[27] Interestingly, the coefficient estimates are quantitatively very comparable to those obtained for data on the city level. At the same time, the findings regarding an earlier transition for more densely populated regions, for regions that are predominantly of Protestant denomination, and for regions that have better access (in terms of lower distance) to major trade routes are confirmed using regional data.

A second set of robustness refers to the measurement of the timing of the fertility transition. To this end, we use an alternative measure based on a threshold of marital fertility of 0.6 instead of 0.5 relative to maximum (Hutterite) fertility to indicate the onset of the fertility transition, using the same data source (Knodel, 1974). The results obtained for the two alternative measures of the timing of the fertility transition are qualitatively very similar to the baseline results.[28] As alternative measure, we construct the timing of the fertility transition from vital rates provided by Galloway (2007). The advantage of the Galloway data is that they allow for a robustness check with data from a second source; the disadvantage is that they available for Prussia only and thus only contain information for a small subset of the cities in the baseline data set. Nevertheless,

---

[27] Table A.10 in the Appendix presents the respective results. The travel times are computed as average of the cities located in the region.

[28] See Table A.11 in the Appendix for the respective results.

the results are qualitatively similar.[29] The results of unreported estimates also reveal similar results when weighting the distance to the nearest port by the number of plague outbreaks as reported in Figure 2.1, or when distinguishing between Roman and non-Roman roads.

A third set of robustness checks concerns the relevance of the assumptions about travel speeds and road structures. In general, historical sources on travel speeds both over land and on waterways are both rather scarce and vague. There are several ways of addressing this issue. When performing robustness checks based on a different travel time schedule or when calibrating the Dijkstra-algorithm in order to minimize the travel time avoiding roads whenever possible, and restricting to only roads, the results are qualitatively similar to the baseline results, which suggests that these results are not due to assumptions about travel speeds or transportation mode.[30]

A fourth set of robustness exercises addresses the possible confound that instead of distance to entry ports from which the plague spread repeatedly during the middle ages, travel time to the entry ports is merely a proxy for access to (maritime) trade. In order to account for this possibility and to rule out potentially spurious results, the baseline results are obtained with an extensive specification of control variables. As an additional robustness check to address this issue, we estimate extended empirical specifications that the number of plague entry ports within a travel distance of 100 hours. This variable can be viewed as alternative proxy for plague exposure (akin to an extensive margin), whose inclusion is justified by the moderate correlation and the fact that the use of more than one suitable proxy is strictly preferable. Alternatively, however, this proxy can pick up access to medieval trade routes related to proximity to entry ports. The reduced form results for this extended specification indicate that the inclusion of the this measure of exposure leaves the results for the travel distance unchanged and instead also delivers a significant and negative coefficient indicating that an additional plague port anticipates the fertility transition by more than two years.[31] Aggregating the effects following the methodology of Lubotsky and Wittenberg (2006) delivers a total estimate of a reduction

---

[29] See Table A.12 in the Appendix.

[30] Completely deleting roads would reduce the number of observations dramatically as many cities cannot be reached solely by waterways due to their location away from rivers or within river deltas. See Table A.13 in the Appendix for the respective results of the reduced form and 2SLS analysis.

[31] See Table A.14 for the corresponding results.

in the travel distance to the nearest plague port by 100 hours of about 35 years, which can be seen as an upper bound of the effect which likely comprises plague and trade exposure.[32] We also replicated the instrumental variables approach while including the number of plague ports within a 100-hour perimeter as additional control. Together with the prevalence of a plague outbreak during the first wave of the Black Death in 1347-1352, this control implies that the identifying variation of the travel distance now comes from the variation above and beyond the variation accounted for by the controls, which proxy for access to trade and exposure to the singular epidemic of the Black Death. The results again deliver a very similar picture and leave the main results unaffected qualitatively and quantitatively.[33]

2.4.4 External Validity: The Demographic Transition in France

The hypothesis that greater exposure to population shocks such as repeated plague outbreaks ultimately contributes to an earlier fertility transition is generic and not restricted to the context of Germany. In an attempt to investigate the external validity of the empirical results, we replicate the same empirical approach for France. The case of France is particularly interesting for several reasons. France was the first country to experience the demographic transition. In addition, it has been argued that the fertility transition in Europe was influenced by social and behavioral changes that originated in France (Spolaore and Wacziarg, 2014). Moreover, outbreaks of the plague to Europe occurred first in France, and much research on the Black Death has focused on France as consequence of an arguably higher data quality for plague outbreaks in France than in other parts of Europe.[34]

---

[32] Following Lubotsky and Wittenberg (2006, p. 534), and noting a covariance of the onset of the fertility transition with the number of plague ports within 100 hours circumference of -0.0256 and with the distance to the nearest plague port of 0.4911, the respective effect in terms of distance is given by, e.g., $0.238 + (-0.0256/0.4911) \cdot (-2.253) = 0.355$ for the estimates the first column of Table A.14 Panel A, and by $0.187 + (-0.0256/0.4911) \cdot (-3.172) = 0.352$ for the estimates in the last column of Table A.14 Panel A.

[33] See Table A.15 in the Appendix for details. We refrain from including both travel distance to the nearest plague port and the number of plague ports in a 100-hour perimeter as instrumental variables, because the null of both being relevant instruments for the number of plague outbreaks is rejected by conventional Hansen tests of overidentification. Details are available upon request.

[34] For instance, the coverage of the data by Biraben (1975, 1976) is comparably high for France, while even here full availability and comparability of sources is not ensured, see, e.g., Roosen and Curtis (2018).

The replication of the main analysis for France requires the use of different data and data sources, and thus puts limits on the comparability with the earlier estimation results for Germany, particularly concerning the control variables. At the same time, this is a useful complement to the analysis for data from Germany as it provides insights into the external validity and greater statistical power. The timing of the fertility transition is constructed based on data from the Princeton European Fertility Project (Coale and Coats-Watkins, 1986) using the same definition as for Germany.[35] Other variables are constructed from different sources. The onset of the fertility transition in France, although occurring earlier than in Germany, also exhibits considerably variation (see Figure A.3 in the Appendix).

In terms of the specification, the analysis of France requires several modifications. First, whereas Germany was largely located beyond the Roman Limes, which implies that most streets were not of Roman origin, France had entirely belonged to the Roman empire.This makes the distinction between roads of Roman and non-Roman origin even more relevant when extending the analysis to include France. In light of arguments that social and behavioral changes that affected the timing of the fertility transition spread concentrically from Paris (Spolaore and Wacziarg, 2014), the empirical specification includes a measure of the travel distance to Paris.

Repeating the OLS regressions of the timing of the fertility transition on the number of plague outbreaks before 1900 at the city level delivers mixed results for France, whereas for the pooled sample the estimates appear indicative of an earlier fertility transition in cities with a greater number of plague-related population shocks, although coefficient estimates are insignificant.[36]

Table 2.5 presents the reduced form results for the proxy measures of plague exposure for France (Panel A) and when pooling cities in Germany and France (Panel B) while accounting separately for travel distances along Roman and non-Roman roads. The estimates confirm the earlier results for Germany that a greater plague exposure, as proxied by proximity to the entry ports, is associated with an earlier onset of the fertility transition. Coefficients for distances on Roman roads are significant but similar in size to

---

[35] As baseline, we code the first year in which marital fertility reached a threshold of 0.5 as the onset, for robustness we also present results for an alternative threshold of 0.6 with similar results.

[36] See Table A.16 in the Appendix for the respective results.

the insignificant coefficients for distances on non-Roman roads. The size of the coefficient estimates as well as the findings for the other regressors are comparable when not distinguishing between Roman and non-Roman roads.[37]

Table 2.5: Plague Exposure and Timing of the Demographic Transition: Germany and France

Dependent Variable	Onset of the Demographic Transition (Year)							
Panel A: France								
Travel Time (Roman Roads)	0.085	0.655***	0.678***	0.699***	0.699***	0.708***	0.718***	0.193
	(0.188)	(0.216)	(0.215)	(0.211)	(0.211)	(0.213)	(0.224)	(0.398)
Travel Time (non-Roman Roads)	-0.002	0.537	0.560	0.572	0.572	0.558	0.559	-0.309
	(0.295)	(0.355)	(0.358)	(0.345)	(0.345)	(0.343)	(0.344)	(0.532)
Observations	281	281	281	281	281	281	281	281
R^2	0.007	0.113	0.115	0.133	0.133	0.141	0.141	0.190
Adjusted R^2	-0.003	0.097	0.093	0.104	0.104	0.106	0.102	0.148
Number of Cluster	80	80	80	80	80	80	80	80
Highest VIF	1.01	2.80	3.09	3.10	3.10	3.14	3.38	17.74
joint F	0.90	0.01	0.01	0.01	0.01	0.01	0.01	0.13
Panel B: Germany and France								
Travel Time (Roman Roads)	0.114	0.356***	0.352***	0.352***	0.348***	0.353***	0.356***	0.303**
	(0.152)	(0.128)	(0.126)	(0.126)	(0.129)	(0.130)	(0.128)	(0.118)
Travel Time (non-Roman Roads)	0.043	0.305	0.311	0.311*	0.307	0.303	0.314*	0.263
	(0.176)	(0.188)	(0.188)	(0.187)	(0.188)	(0.186)	(0.188)	(0.165)
Observations	518	518	518	518	518	518	518	518
R^2	0.623	0.654	0.655	0.656	0.657	0.659	0.660	0.672
Adjusted R^2	0.620	0.650	0.649	0.650	0.649	0.650	0.650	0.662
Number of Cluster	136	136	136	136	136	136	136	136
Highest VIF	2.20	2.98	3.17	3.22	4.93	4.94	4.97	9.78
joint F	0.75	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Controls (both Panels								
Distance to Paris		✓	✓	✓	✓	✓	✓	✓
Geography			✓	✓	✓	✓	✓	✓
Population				✓	✓	✓	✓	✓
Religion					✓	✓	✓	✓
Institutions						✓	✓	✓
Calories							✓	✓
Coordinates								✓
France Dummy (Panel B)	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors, clustered by administrative region, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Finally, we replicate the IV approach for city samples for Germany and France. Table 2.6 reports the results for the baseline specification in Panel A, and when accounting for travel time along Roman and non-Roman roads in Panel B. In addition, the analysis accounts for plague outbreaks during different phases. The results for Germany are replicated for completeness and comparability with the results for France, since some of the controls in the baseline specification are not available for the sample of cities in France.[38] Overall, the results confirm the earlier findings for Germany and document

---

[37] See Table A.17 in the Appendix. and Tables A.18 and A.19 in the Appendix contain detailed results for all covariates.

[38] The corresponding coefficient estimates for the first stages are reported in Tables A.20 and A.22, and for the second stages in Tables A.21 and A.23.

that a greater exposure to plague-related population shocks is associated with an earlier fertility transition in both countries. The effect of one additional outbreak varies across samples but amounts to roughly one decade, regardless of whether all plague outbreaks are considered or whether one restricts attention to plague outbreaks before the peace of Augsburg 1555, before the outbreak of the 30-year war 1618, or when restricting to plague outbreaks after the first wave of the Black Death. Similar results are obtained for more extensive specifications regarding geographic controls.[39]

2.4.5 Disentangling Plague Exposure and 19th Century Trade

While the results so far are indicative of an effect of the proxy of plague exposure in terms of travel distance to the closest plague entry port above and beyond a rich set of control variables, the observation that new waves of the plague repeatedly spread across Europe, initiating from ports and spreading through overland trade routes and waterways, raises the concern that the timing of the fertility transition might have been determined entirely by trade. When considering the role of trade for the timing of the fertility transition, it is important to recognize that the plague outbreaks mainly occurred during the (late) middle ages while the fertility transition happened during the late 19th Century. The final step of the analysis therefore disentangles the role of trade and plague exposure that is related to medieval trade by accounting for the differences in trade access during the middle ages and the 19th century. In light of this, the analysis makes use of the fact that not all maritime harbors were recognized as entry points of new epidemic outbreaks, but all were access hubs to trade. In addition, trade networks during the 19th century had changed in comparison to the time of the plague outbreaks. This allows us to disentangle the role of the exposure to plague-related population shocks (which spread along trade routes, but much earlier in time) from access to trade during the 19th Century as a direct driver of the timing of the fertility transition.

In order to explore the relevance whether a greater proximity to a port or generally a good connection to trade networks are a driver for the fertility transition, we perform several analyses. The first uses information about ports that had no relevance during medieval times but during the 19th century. In particular, we explore the robustness of

---

[39] See Table A.24 in the Appendix.

Table 2.6: Plague Exposure and the Timing of the Demographic Transition: IV Results for Germany and France

Dependent Variable	Onset of the Demographic Transition (Year)											
	Panel A: Baseline Specification											
	Germany				France				Germany and France			
Number of Outbreaks (0-1900)	-5.954** (2.736)				-24.617 (16.166)				-10.012* (5.929)			
Number of Outbreaks (0-1555)		-8.406*** (3.224)				-18.106** (7.857)				-9.640* (5.013)		
Number of Outbreaks (0-1618)			-7.461** (3.281)				-19.059** (9.624)				-9.472* (5.195)	
Number of Outbreaks (1360-1618)				-7.502** (3.251)				-19.059** (9.624)				-9.499* (5.208)
First Stage												
Travel Time	-0.027** (0.013)	-0.019*** (0.007)	-0.022** (0.010)	-0.022** (0.010)	-0.026* (0.015)	-0.035*** (0.009)	-0.033*** (0.012)	-0.033*** (0.012)	-0.027*** (0.010)	-0.028*** (0.006)	-0.028*** (0.008)	-0.028*** (0.008)
Observations	237	237	237	237	281	281	281	281	518	518	518	518
Number of Cluster	56	56	56	56	80	80	80	80	136	136	136	136
F-Stat in FS	4.38	7.55	4.73	4.81	3.03	14.65	7.32	7.32	7.58	18.69	11.68	11.66
Kleinbergen-Paap rk LM (p-value)	0.04	0.01	0.03	0.03	0.06	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	Panel B: Accounting for Roman Roads											
	Germany				France				Germany and France			
Number of Outbreaks (0-1900)	-4.684* (2.402)				-21.368* (12.640)				-12.336** (5.876)			
Number of Outbreaks (0-1555)		-6.748** (3.025)				-16.608** (6.911)				-11.591*** (4.496)		
Number of Outbreaks (0-1618)			-6.138* (3.200)				-16.759** (8.307)				-11.428** (4.872)	
Number of Outbreaks (1360-1618)				-6.051* (3.151)				-16.759** (8.307)				-11.429** (4.853)
First Stage												
Travel Time (Roman Roads)	-0.020 (0.024)	-0.010 (0.013)	-0.018 (0.019)	-0.020 (0.019)	-0.033* (0.018)	-0.043*** (0.011)	-0.039*** (0.014)	-0.039*** (0.014)	-0.029*** (0.011)	-0.031*** (0.007)	-0.030*** (0.009)	-0.031*** (0.009)
Travel Time (non-Roman Roads)	-0.028*	-0.019**	-0.020*	-0.020*	-0.027	-0.033***	-0.037**	-0.037**	-0.026**	-0.026***	-0.029**	-0.028**
Observations	237	237	237	237	281	281	281	281	518	518	518	518
F-Stat in FS	1.80	3.13	1.69	1.68	2.01	8.53	4.71	4.71	4.20	11.60	7.10	7.18
Kleinbergen-Paap rk LM (p-value)	0.17	0.04	0.19	0.20	0.12	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Hansen J (p-value)	0.71	0.86	0.59	0.49	0.94	0.98	0.75	0.75	0.98	0.95	0.90	0.94
Full Set of Controls (both Panels)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors, clustered by administrative region, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

the results with respect to accounting for the proximity to ports that were only founded (or gained importance) after the middle ages and that were important trade hubs in the 19th century (such as Rotterdam). The second analysis controls for access to the Hanseatic trade network, accounting for the shortest way along which goods could be shipped or transported over land. For both explorations, we estimate more extensive specifications by adding controls for the travel distance to the closest trade port in the 19th Century, or for the distance to the closest Hanseatic city, or both, and alternatively for the average distance to the 19th century trade ports. Notice that these estimations correspond to a falsification test in the sense that if access to trade was the main trigger for the fertility transition, it should be the distance to the 19th Century trade ports that affects the timing of the transition, and not the distance to medieval entry ports, which already had lost importance. The results leave the main findings unaffected.[40] Additional unreported falsification tests based on variables for access to placebo ports including or excluding Hamburg using similar variables (regarding the number of maritime ports in a perimeter of 100 hours travel time and the distance to the closest maritime port for maritime ports that were not entry ports for the plague) confirm the main results and document that the findings are not merely driven the distance to maritime harbors. In particular, while the main results for plague exposure are unchanged, these estimates deliver no evidence for an influence of the placebo ports on the timing of the fertility transition.

In a final step, we additionally exploit variation in distance to 19th century trade ports and to the closest hanseatic city or maritime port in the pooled data for Germany and France. In particular, conducting similar robustness and placebo checks for access to trade as before does not affect the reduced form results.[41] Moreover, also 2SLS estimates with additional controls for trade access and accounting for different waves of plague outbreaks analogous to the analysis in Table 2.6 confirm the main findings.[42] In particular, the results are qualitatively and quantitatively similar regardless of considering all plague outbreaks in history, or when considering only plague outbreaks before 1555 (the peace

---

[40] See Tables A.25 and A.26 in the Appendix for the estimation results for the reduced form and IV specifications, respectively, for Germany.

[41] See Tables A.27 and A.28 in the Appendix.

[42] See Table A.29 in the Appendix.

of Augsburg) or excluding outbreaks related to the Black Death of 1347 or the 30-year war and focusing on outbreaks during the period 1360-1618. Interestingly, when restricting attention to outbreaks during the 30-year war, the instrumentation becomes weak and the second stage delivers positive instead of negative coefficient estimates. This is reassuring and constitutes a falsification test of the empirical approach, since during the war, outbreaks did not spread through the usual routes but were governed by war-related movements of troops and population. Additional unreported robustness checks that account for institutional differences during the 19th century by controlling for membership to centralized states such as Prussia or France also confirm the main results.

Taken together, the robustness of the result to the inclusion of controls for trade, particularly during the 19th century, suggests that trade per se is unlikely to be the sole determinant of the timing of the fertility transition. Instead, plague outbreaks in the centuries before appear to be systematically related to the onset of the fertility transition.

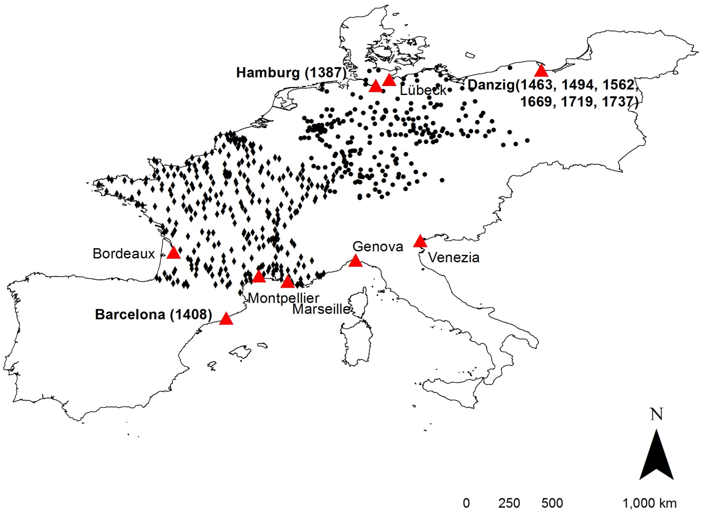
2.5 Conclusion

This paper presented an empirical investigation of the hypothesis that cities or regions that that were more (and more often) exposed to major population shocks related to the medieval plague experienced an earlier fertility transition. This hypothesis follows from recent work on the long-run implications of plague outbreaks and complements existing evidence that has not considered the timing of the fertility transition. The findings provide novel evidence in line with the implications of earlier contributions predicting that the population shock associated with the plague led to shifts in the Malthusian equilibrium and ultimately accelerated the mechanisms behind the demographic transition as predicted by the canonical unified growth framework.

Given the importance of the demographic transition for long-run development, the evidence shown here provides new insights into the reasons for regional development differences that might be related to historical coincidences and points to various directions for future research regarding the underlying mechanisms. The literature has described several candidate mechanisms working through fertility which are related to age of first marriage or knowledge and attitudes regarding birth control. However, direct evidence on these mechanisms is scarce and empirical findings indicate no clear correlation between age of first marriage and total fertility. Others have pointed to changes in the population composition as result of plague shocks, which are related to gender ratio, age composition, and household size. Finally, repeated plague outbreaks might have led to the adoption of institutions, e.g., regarding inheritance rules, that might have ultimately led to a reduced demand for children and an earlier demographic transition. More evidence is needed to shed light on the empirical relevance and relative importance of these mechanisms.

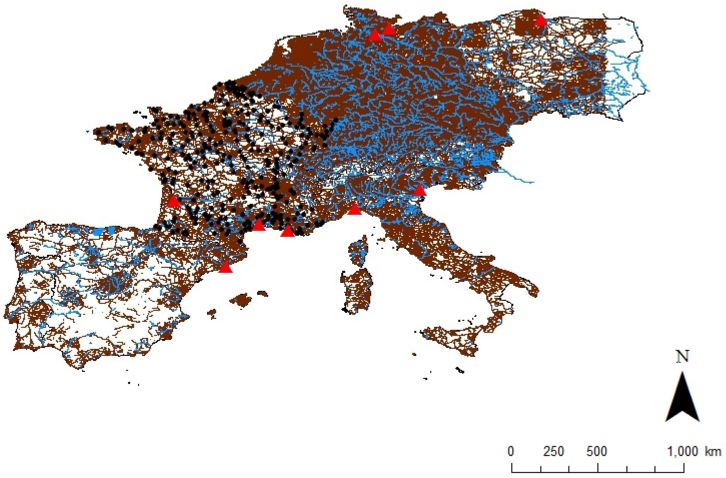
Appendix A

Figure A.1: Plague Reintroductions in Europe



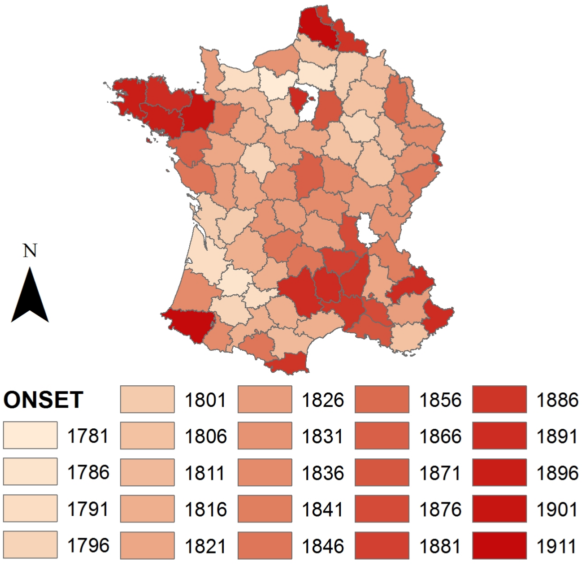
Notes: Red triangles denote plague entry ports in terms of maritime harbors exhibiting plague outbreaks that are not related to nearby land-based or maritime outbreaks, bold face names denote entry ports for plague reintroductions, reproduced from Figure 1 in Schmid et al. (2015). The years next to the cities indicate plague outbreaks that have not been preceded by a plague outbreak on land within a 500 km radius and on harbors within a 1000 km radius for two years prior to the outbreak. Black dots indicate cities contained in the data set for Germany. Black diamonds indicate cities contained in the data set for France.

Figure A.2: Travel Distances from Entry Ports: France



Notes: Map of roads (brown) and waterways (blue) used to compute travel distances from entry ports (red triangles). Cities are depicted as black dots, Red line represents French border.

Figure A.3: The Timing of the Fertility Transition in France



Notes: Departements colored by the year of the fertility transition (threshold 0.5) according to Coale and Coats-Watkins (1986).

Table A.1: Hutterite Fertility: Number of births per married woman conditional on age

Age group (i)	Number of Births (F_i)
20-14	0.55
25-29	0.502
30-34	0.447
35-39	0.406
40-44	0.222
45-49	0.061

Notes:Standard schedule according to Henry (1961). The numbers are a benchmark for the natural fertility without active birth control.

Table A.2: Assumptions about Travel Speed

Type of line segment	Slope	Speed normal	Speed slow
River		15 km/h	10 km/h
Road	0	7 km/h	5 km/h
Road	(0;15]	5 km/h	3 km/h
Road	(15;30]	3 km/h	2 km/h
Road	(30;45]	1 km/h	1 km/h
Road	>45	0 km/h	0 km/h

Notes: Assumed travel speeds per hour by type (river, road) and slope of the line segment (in degrees). The main analysis uses assumptions about normal speed.

Table A.3: Plague Outbreaks and The Timing of the Demographic Transition

	None	Geographic	Population	Religion	Insitutions	Calories	Wars
Number of Outbreaks (0-1900)	-0.411***	-0.391***	-0.375***	-0.344***	-0.327***	-0.311***	-0.343***
	(0.153)	(0.118)	(0.108)	(0.100)	(0.101)	(0.101)	(0.102)
Outbreak following 1348	4.520	4.779**	3.244	1.736	1.965	2.133	1.982
	(2.920)	(2.221)	(2.095)	(1.868)	(2.025)	(1.937)	(1.882)
Latitude		-1.845***	-1.772***	-1.531***	-1.592***	-1.725***	-1.880***
		(0.576)	(0.542)	(0.539)	(0.567)	(0.535)	(0.542)
Longitude		-0.873**	-1.089***	-1.024**	-1.013**	-0.867**	-0.826**
		(0.370)	(0.381)	(0.397)	(0.415)	(0.402)	(0.400)
Navigable River		1.058	0.850	0.747	0.942	1.692	1.724
		(1.241)	(1.192)	(1.122)	(1.145)	(1.153)	(1.134)
City with Maritime Port		-1.045	-0.952	-0.514	-0.678	-0.559	-0.015
		(3.050)	(2.957)	(2.777)	(2.797)	(2.655)	(2.368)
Population Density (log)			-3.223***	-2.989***	-3.028***	-3.550***	-3.641***
			(0.848)	(0.844)	(0.866)	(0.834)	(0.843)
Population in 1400(log)			0.798*	0.705	0.824	1.084*	1.158**
			(0.451)	(0.474)	(0.568)	(0.549)	(0.568)
Population Growth 1400-1600(log)			-0.028	-0.030	-0.018	0.120	0.266
			(0.698)	(0.685)	(0.683)	(0.664)	(0.677)
Protestant				-3.757**	-4.070**	-3.583**	-4.060**
				(1.581)	(1.576)	(1.527)	(1.596)
Monasteries (p.c.)				-0.410	-0.467	-0.390	-0.289
				(0.290)	(0.302)	(0.299)	(0.301)
Augustian Monasteries (p.c.)				0.440	0.538	1.208	1.210
				(1.365)	(1.416)	(1.483)	(1.495)
University					-2.254	-2.518	-2.257
					(1.906)	(1.836)	(1.823)
Hanseatic City					0.508	-0.447	-0.257
					(1.677)	(1.590)	(1.473)
Reichsstadt					0.042	-0.454	-0.050
					(1.046)	(1.070)	(1.047)
Printing Press					-1.237	-0.677	-0.883
					(1.884)	(1.906)	(1.854)
Caleoric Yield						-0.004**	-0.003**
						(0.001)	(0.001)
30y War							-1.887**
							(0.910)
7y War							0.610
							(1.091)
Constant	1912.779***	2015.566***	2029.328***	2018.920***	2022.424***	2061.367***	2069.161***
	(1.082)	(27.976)	(25.266)	(25.415)	(26.833)	(30.241)	(29.999)
Observations	237	237	237	237	237	237	237
R^2	0.043	0.329	0.410	0.439	0.447	0.480	0.491
Adjusted R^2	0.035	0.312	0.387	0.409	0.407	0.439	0.446
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.61	1.66	2.42	2.43	2.69	2.71	2.73

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.4: Exposure to Plague Outbreaks and the Timing of the Demographic Transition

	None	Geographic	Population	Religion	Insitutions	Calories	Wars
Travel Time	0.206***	0.213***	0.243***	0.234***	0.246***	0.255***	0.253***
	(0.044)	(0.073)	(0.065)	(0.067)	(0.068)	(0.062)	(0.062)
Outbreak following 1348	2.179	2.611	2.313	1.233	1.442	1.766	1.503
	(1.683)	(1.819)	(2.043)	(1.739)	(1.904)	(1.800)	(1.739)
Latitude		0.382	0.689	0.775	0.891	0.838	0.697
		(1.053)	(0.905)	(0.947)	(0.934)	(0.828)	(0.833)
Longitude		-0.943***	-1.199***	-1.182***	-1.151***	-0.995***	-0.962***
		(0.344)	(0.319)	(0.324)	(0.333)	(0.308)	(0.307)
Navigable River		0.398	0.131	0.186	0.418	1.231	1.258
		(1.169)	(1.104)	(1.016)	(1.042)	(1.009)	(1.004)
City with Maritime Port		-1.657	-0.436	-0.185	-0.337	-0.186	0.239
		(2.916)	(2.648)	(2.527)	(2.605)	(2.505)	(2.335)
Population Density (log)			-3.816***	-3.574***	-3.560***	-4.142***	-4.225***
			(0.790)	(0.765)	(0.752)	(0.765)	(0.782)
Population in 1400(log)			-0.137	-0.224	-0.188	0.136	0.133
			(0.462)	(0.467)	(0.532)	(0.513)	(0.512)
Population Growth 1400-1600(log)			-0.307	-0.347	-0.354	-0.182	-0.098
			(0.727)	(0.704)	(0.689)	(0.650)	(0.667)
Protestant				-3.062*	-3.606**	-3.027**	-3.421**
				(1.624)	(1.547)	(1.502)	(1.571)
Monasteries (p.c.)				-0.496*	-0.558**	-0.473*	-0.396
				(0.251)	(0.268)	(0.269)	(0.273)
Augustian Monasteries (p.c.)				-0.169	-0.125	0.581	0.595
				(1.267)	(1.328)	(1.336)	(1.352)
University					-3.477*	-3.783**	-3.603**
					(1.789)	(1.738)	(1.735)
Hanseatic City					0.771	-0.231	-0.134
					(1.380)	(1.305)	(1.268)
Reichsstadt					0.922	0.398	0.711
					(1.150)	(1.126)	(1.120)
Printing Press					-0.944	-0.290	-0.470
					(1.594)	(1.539)	(1.485)
Caleoric Yield						-0.004***	-0.004***
						(0.001)	(0.001)
30y War							-1.466*
							(0.803)
7y War							0.506
							(1.026)
Constant	1902.589***	1892.510***	1896.639***	1894.621***	1888.193***	1926.201***	1933.486***
	(2.406)	(55.310)	(47.742)	(50.353)	(49.676)	(46.389)	(46.526)
Observations	237	237	237	237	237	237	237
R^2	0.249	0.357	0.471	0.495	0.510	0.550	0.557
Adjusted R^2	0.243	0.340	0.450	0.468	0.474	0.515	0.518
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.02	4.32	4.41	4.42	4.90	4.91	5.10

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.5: Exposure to Plague Outbreaks and the Timing of the Demographic Transition: Accounting for Roman Roads

	None	Geographic	Population	Religion	Insitutions	Calories	wars
Travel Time (Roman Roads)	0.260***	0.430***	0.377***	0.354***	0.360***	0.338***	0.338***
	(0.054)	(0.102)	(0.089)	(0.090)	(0.091)	(0.082)	(0.082)
Travel Time (non-Roman Roads)	0.171***	0.264***	0.271***	0.262***	0.271***	0.273***	0.272***
	(0.047)	(0.069)	(0.063)	(0.065)	(0.066)	(0.061)	(0.061)
Outbreak following 1348	1.470	2.233	2.137	1.257	1.327	1.660	1.369
	(1.430)	(1.538)	(1.819)	(1.605)	(1.730)	(1.665)	(1.599)
Latitude		2.062*	1.711*	1.662*	1.698*	1.436*	1.298
		(1.053)	(0.937)	(0.942)	(0.948)	(0.838)	(0.857)
Longitude		-1.061***	-1.240***	-1.228***	-1.208***	-1.047***	-1.016***
		(0.333)	(0.311)	(0.313)	(0.325)	(0.300)	(0.299)
Navigable River		0.204	0.044	0.094	0.311	1.099	1.109
		(1.113)	(1.074)	(1.016)	(1.044)	(0.995)	(0.993)
City with Maritime Port		-3.198	-1.548	-1.205	-1.201	-0.832	-0.366
		(2.771)	(2.644)	(2.557)	(2.567)	(2.495)	(2.355)
Population Density (log)			-3.329***	-3.179***	-3.210***	-3.846***	-3.921***
			(0.739)	(0.703)	(0.697)	(0.694)	(0.705)
Population in 1400(log)			-0.142	-0.225	-0.148	0.144	0.142
			(0.425)	(0.433)	(0.530)	(0.507)	(0.505)
Population Growth 1400-1600(log)			-0.275	-0.322	-0.314	-0.164	-0.085
			(0.666)	(0.654)	(0.641)	(0.617)	(0.636)
Protestant				-2.590	-3.104**	-2.695*	-3.095**
				(1.572)	(1.492)	(1.449)	(1.526)
Monasteries (p.c.)				-0.421	-0.489*	-0.428	-0.348
				(0.254)	(0.268)	(0.276)	(0.279)
Augustian Monasteries (p.c.)				-0.733	-0.653	0.145	0.126
				(1.436)	(1.503)	(1.455)	(1.459)
University					-3.691**	-3.921**	-3.746**
					(1.763)	(1.733)	(1.745)
Hanseatic City					0.815	-0.132	-0.051
					(1.313)	(1.233)	(1.204)
Reichsstadt					0.499	0.122	0.436
					(1.188)	(1.156)	(1.148)
Printing Press					-0.622	-0.096	-0.274
					(1.611)	(1.572)	(1.531)
Caleoric Yield						-0.004***	-0.004***
						(0.001)	(0.001)
30y War							-1.495*
							(0.798)
7y War							0.671
							(1.005)
Constant	1903.753***	1804.867***	1840.732***	1845.734***	1843.908***	1891.046***	1897.951***
	(2.401)	(55.261)	(49.033)	(49.499)	(49.728)	(45.436)	(46.288)
Observations	237	237	237	237	237	237	237
R^2	0.273	0.411	0.490	0.509	0.523	0.557	0.564
Adjusted R^2	0.263	0.393	0.468	0.480	0.486	0.521	0.524
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.20	6.50	6.61	6.72	7.02	7.11	7.23
joint F	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.6: Plague Exposure and the Timing of the Demographic Transition: First Stage Results

	0-1900	0-1555	0-1618	1360-1618
Travel Time	-0.052***	-0.032***	-0.037**	-0.036**
	(0.019)	(0.011)	(0.014)	(0.014)
Outbreak following 1348	5.025***	3.221***	4.432***	3.332**
	(1.787)	(0.961)	(1.431)	(1.387)
Latitude	-0.507**	-0.232**	-0.332**	-0.318**
	(0.215)	(0.115)	(0.163)	(0.159)
Longitude	0.035	0.026	0.034	0.030
	(0.070)	(0.037)	(0.055)	(0.055)
Navigable River	0.126	0.012	0.077	0.034
	(0.456)	(0.245)	(0.352)	(0.346)
City with Maritime Port	0.097	0.687	0.127	0.233
	(2.876)	(1.758)	(2.306)	(2.263)
Population Density (log)	0.619*	0.466*	0.533*	0.525*
	(0.369)	(0.259)	(0.317)	(0.308)
Population in 1400(log)	2.509***	1.313***	1.991***	1.947***
	(0.479)	(0.250)	(0.383)	(0.378)
Population Growth 1400-1600(log)	1.172***	0.521***	0.833***	0.813***
	(0.289)	(0.142)	(0.222)	(0.215)
Protestant	0.321	0.015	0.280	0.345
	(0.572)	(0.299)	(0.434)	(0.432)
Monasteries (p.c.)	0.165	0.072	0.103	0.104
	(0.120)	(0.063)	(0.087)	(0.087)
Augustian Monasteries (p.c.)	-0.188	-0.164	-0.134	-0.176
	(0.578)	(0.292)	(0.432)	(0.445)
University	1.433	0.661	0.933	1.032
	(1.647)	(0.891)	(1.191)	(1.159)
Hanseatic City	1.719	1.022	1.523	1.461
	(1.860)	(1.081)	(1.523)	(1.469)
Reichsstadt	-0.152	0.373	0.030	-0.073
	(0.609)	(0.375)	(0.499)	(0.476)
Printing Press	0.435	-0.190	0.151	0.045
	(1.746)	(0.938)	(1.346)	(1.280)
Caleoric Yield	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
30y War	-0.866*	-0.493*	-0.610	-0.598
	(0.482)	(0.266)	(0.374)	(0.370)
7y War	-0.507	-0.392	-0.403	-0.361
	(0.544)	(0.302)	(0.447)	(0.442)
Constant	21.453*	8.580	13.529	12.901
	(12.275)	(6.602)	(9.511)	(9.259)
Observations	237	237	237	237

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.7: Plague Exposure and the Timing of the Demographic Transition: IV Results

	OLS	0-1900	0-1555	0-1618	1360-1618
Number of Outbreaks (0-1900)	-0.343***	-4.869***			
	(0.102)	(1.846)			
Number of Outbreaks (0-1555)			-7.981***		
			(2.963)		
Number of Outbreaks (0-1618)				-6.785**	
				(2.644)	
Number of Outbreaks (1360-1618)					-7.036**
					(2.788)
Outbreak following 1348	1.982	25.970**	27.210**	31.572**	24.943*
	(1.882)	(12.654)	(12.067)	(14.966)	(12.933)
Latitude	-1.880***	-1.772***	-1.157*	-1.553**	-1.543**
	(0.542)	(0.670)	(0.679)	(0.686)	(0.697)
Longitude	-0.826**	-0.791*	-0.751*	-0.728	-0.748
	(0.400)	(0.438)	(0.418)	(0.456)	(0.458)
Navigable River	1.724	1.870	1.354	1.778	1.499
	(1.134)	(2.149)	(1.912)	(2.287)	(2.281)
City with Maritime Port	-0.015	0.711	5.724	1.100	1.875
	(2.368)	(13.258)	(13.233)	(14.728)	(15.010)
Population Density (log)	-3.641***	-1.209	-0.508	-0.607	-0.529
	(0.843)	(1.810)	(2.079)	(2.134)	(2.166)
Population in 1400(log)	1.158**	12.349**	10.612***	13.641**	13.829**
	(0.568)	(4.842)	(4.033)	(5.467)	(5.693)
Population Growth 1400-1600(log)	0.266	5.607***	4.064***	5.556***	5.624**
	(0.677)	(2.046)	(1.437)	(2.121)	(2.211)
Protestant	-4.060**	-1.859	-3.302	-1.521	-0.995
	(1.596)	(2.898)	(2.493)	(3.095)	(3.226)
Monasteries (p.c.)	-0.289	0.405	0.178	0.300	0.337
	(0.301)	(0.661)	(0.540)	(0.620)	(0.634)
Augustian Monasteries (p.c.)	1.210	-0.319	-0.711	-0.316	-0.643
	(1.495)	(2.700)	(2.341)	(2.777)	(2.975)
University	-2.257	3.373	1.670	2.731	3.655
	(1.823)	(8.287)	(7.472)	(8.344)	(8.510)
Hanseatic City	-0.257	8.233	8.022	10.199	10.145
	(1.473)	(9.290)	(9.029)	(10.803)	(10.805)
Reichsstadt	-0.050	-0.029	3.687	0.915	0.201
	(1.047)	(2.756)	(3.138)	(3.093)	(3.024)
Printing Press	-0.883	1.647	-1.987	0.553	-0.156
	(1.854)	(8.160)	(7.226)	(8.675)	(8.520)
Caleoric Yield	-0.003**	-0.002	-0.002	-0.003	-0.003
	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
30y War	-1.887**	-5.681*	-5.403**	-5.607*	-5.675*
	(0.910)	(2.935)	(2.642)	(3.114)	(3.237)
7y War	0.610	-1.963	-2.623	-2.226	-2.035
	(1.091)	(2.443)	(2.558)	(2.847)	(2.850)
Constant	2069.161***	2037.936***	2001.964***	2025.287***	2024.250***
	(29.999)	(38.609)	(41.369)	(41.625)	(42.025)
Observations	237	237	237	237	237
R^2	0.491	-2.739	-2.170	-3.387	-3.557
Adjusted R^2	0.446	-3.066	-2.447	-3.771	-3.956
Number of Cluster	56	56	56	56	56
F-Stat in FS		7.57	8.91	6.68	6.29
Kleinbergen-Paap rk LM (p-value)		0.01	0.01	0.02	0.02

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.8: Plague Exposure and the Timing of the Demographic Transition: First Stage Results

	0-1900	0-1555	0-1618	1360-1618
Travel Time (Roman Roads)	-0.055*	-0.035**	-0.046**	-0.046**
	(0.030)	(0.016)	(0.023)	(0.022)
Travel Time (non-Roman Roads)	-0.053***	-0.032***	-0.039***	-0.038***
	(0.019)	(0.010)	(0.014)	(0.014)
Outbreak following 1348	5.030***	3.226***	4.446***	3.347**
	(1.796)	(0.965)	(1.438)	(1.392)
Latitude	-0.528**	-0.253*	-0.396**	-0.388**
	(0.262)	(0.141)	(0.200)	(0.195)
Longitude	0.037	0.028	0.040	0.037
	(0.074)	(0.039)	(0.058)	(0.058)
Navigable River	0.131	0.017	0.093	0.052
	(0.466)	(0.249)	(0.356)	(0.348)
City with Maritime Port	0.118	0.708	0.192	0.303
	(2.889)	(1.763)	(2.316)	(2.276)
Population Density (log)	0.609	0.455*	0.501	0.490
	(0.382)	(0.271)	(0.322)	(0.311)
Population in 1400(log)	2.509***	1.313***	1.990***	1.946***
	(0.481)	(0.251)	(0.385)	(0.380)
Population Growth 1400-1600(log)	1.171***	0.521***	0.832***	0.812***
	(0.290)	(0.142)	(0.221)	(0.214)
Protestant	0.309	0.004	0.245	0.307
	(0.579)	(0.301)	(0.431)	(0.431)
Monasteries (p.c.)	0.163	0.070	0.097	0.099
	(0.121)	(0.064)	(0.087)	(0.087)
Augustian Monasteries (p.c.)	-0.171	-0.147	-0.084	-0.121
	(0.606)	(0.307)	(0.461)	(0.469)
University	1.438	0.666	0.949	1.048
	(1.659)	(0.898)	(1.211)	(1.178)
Hanseatic City	1.716	1.019	1.514	1.451
	(1.865)	(1.083)	(1.526)	(1.473)
Reichsstadt	-0.142	0.382	0.060	-0.040
	(0.630)	(0.387)	(0.516)	(0.489)
Printing Press	0.428	-0.197	0.130	0.022
	(1.769)	(0.951)	(1.372)	(1.304)
Caleoric Yield	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
30y War	-0.865*	-0.492*	-0.607	-0.595
	(0.485)	(0.267)	(0.376)	(0.372)
7y War	-0.513	-0.398	-0.420	-0.380
	(0.546)	(0.305)	(0.445)	(0.440)
Constant	22.705	9.809	17.338	17.041
	(16.095)	(8.890)	(12.622)	(12.252)
Observations	237	237	237	237

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.9: Plague Exposure and the Timing of the Demographic Transition: IV Results

	OLS	0-1900	0-1555	0-1618	1360-1618
Number of Outbreaks (0-1900)	-0.343***	-4.926***			
	(0.102)	(1.838)			
Number of Outbreaks (0-1555)			-8.113***		
			(2.924)		
Number of Outbreaks (0-1618)				-6.893***	
				(2.486)	
Number of Outbreaks (1360-1618)					-7.118***
					(2.587)
Outbreak following 1348	1.982	26.276**	27.658**	32.071**	25.233**
	(1.882)	(12.594)	(11.915)	(14.081)	(12.146)
Latitude	-1.880***	-1.771***	-1.145*	-1.548**	-1.539**
	(0.542)	(0.674)	(0.682)	(0.693)	(0.702)
Longitude	-0.826**	-0.791*	-0.750*	-0.726	-0.747
	(0.400)	(0.440)	(0.420)	(0.456)	(0.459)
Navigable River	1.724	1.872	1.348	1.779	1.497
	(1.134)	(2.171)	(1.941)	(2.318)	(2.311)
City with Maritime Port	-0.015	0.720	5.820	1.119	1.898
	(2.368)	(13.424)	(13.479)	(14.983)	(15.207)
Population Density (log)	-3.641***	-1.178	-0.453	-0.556	-0.491
	(0.843)	(1.814)	(2.088)	(2.109)	(2.125)
Population in 1400(log)	1.158**	12.492***	10.783***	13.852***	13.987***
	(0.568)	(4.848)	(4.018)	(5.264)	(5.411)
Population Growth 1400-1600(log)	0.266	5.675***	4.134***	5.646***	5.692***
	(0.677)	(2.064)	(1.457)	(2.096)	(2.156)
Protestant	-4.060**	-1.831	-3.287	-1.478	-0.957
	(1.596)	(2.931)	(2.529)	(3.152)	(3.272)
Monasteries (p.c.)	-0.289	0.414	0.187	0.310	0.345
	(0.301)	(0.667)	(0.547)	(0.629)	(0.641)
Augustian Monasteries (p.c.)	1.210	-0.339	-0.745	-0.342	-0.666
	(1.495)	(2.729)	(2.369)	(2.830)	(3.016)
University	-2.257	3.445	1.742	2.817	3.729
	(1.823)	(8.367)	(7.571)	(8.378)	(8.495)
Hanseatic City	-0.257	8.341	8.170	10.375	10.274
	(1.473)	(9.386)	(9.139)	(10.858)	(10.814)
Reichsstadt	-0.050	-0.029	3.749	0.931	0.204
	(1.047)	(2.787)	(3.156)	(3.131)	(3.058)
Printing Press	-0.883	1.679	-2.002	0.579	-0.146
	(1.854)	(8.276)	(7.334)	(8.863)	(8.648)
Caleoric Yield	-0.003**	-0.002	-0.002	-0.003	-0.003
	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)
30y War	-1.887**	-5.730*	-5.466**	-5.671*	-5.723*
	(0.910)	(2.949)	(2.650)	(3.066)	(3.161)
7y War	0.610	-1.996	-2.680	-2.274	-2.068
	(1.091)	(2.474)	(2.591)	(2.898)	(2.892)
Constant	2069.161***	2037.538***	2000.810***	2024.553***	2023.698***
	(29.999)	(38.897)	(41.552)	(42.194)	(42.516)
Observations	237	237	237	237	237
R^2	0.491	-2.822	-2.266	-3.521	-3.659
Adjusted R^2	0.446	-3.156	-2.552	-3.916	-4.067
Number of Cluster	56	56	56	56	56
F-Stat in FS		3.93	4.87	3.84	3.68
Kleinbergen-Paap rk LM (p-value)		0.04	0.02	0.04	0.04
Hansen J (p-value)		0.57	0.60	0.87	0.91

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.10: Exposure to Plague Outbreaks and the Timing of the Demographic Transition - Region Level (based on Knodel, 1974)

Dependent Variable	Onset of the Demographic Transition (Year)						
	Panel A: OLS Results						
Number of Outbreaks (0-1900)	-0.609***	-0.538***	-0.341*	-0.204	-0.207	-0.232	-0.363
	(0.158)	(0.143)	(0.192)	(0.186)	(0.224)	(0.226)	(0.246)
Observations	56	56	56	56	56	56	56
R^2	0.149	0.323	0.466	0.532	0.594	0.642	0.674
Adjusted R^2	0.117	0.255	0.375	0.415	0.442	0.496	0.515
Highest VIF	1.31	1.37	3.63	3.75	4.82	5.00	5.23
	Panel B: Reduced Form						
Travel Time	0.223***	0.315***	0.307***	0.296***	0.355***	0.344***	0.338***
	(0.051)	(0.099)	(0.100)	(0.097)	(0.104)	(0.089)	(0.089)
Observations	56	56	56	56	56	56	56
R^2	0.285	0.315	0.531	0.604	0.680	0.721	0.739
Adjusted R^2	0.258	0.246	0.451	0.505	0.560	0.606	0.612
Highest VIF	1.08	6.34	6.41	6.66	9.07	9.09	9.52
	Controls (Panel A & B)						
Geography		✓	✓	✓	✓	✓	✓
Population			✓	✓	✓	✓	✓
Religion				✓	✓	✓	✓
Institutions					✓	✓	✓
Agriculture						✓	✓
Wars							✓
	Panel C: IV Results (Full Set of Controls)						
Number of Outbreaks (0-1900)	-2.309**						
	(1.093)						
Number of Outbreaks (0-1555)		-3.840**					
		(1.580)					
Number of Outbreaks (0-1618)			-2.950**				
			(1.373)				
Number of Outbreaks (1360-1618)				-3.163**			
				(1.554)			
First Stage							
Travel Time	-0.146**	-0.088**	-0.114**	-0.107*			
	(0.071)	(0.036)	(0.055)	(0.055)			
Observations	56	56	56	56			
F-Stat in FS	4.23	6.06	4.41	3.78			
Kleinbergen-Paap rk LM (p-value)	0.03	0.01	0.02	0.03			

Robust standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.11: Plague Exposure and Timing of the Demographic Transition: Robustness Coding of Onset at Alternative Threshold 0.6

Dependent Variable	Onset of the Demographic Transition (Year), Alternative Threshold						
	Panel A: OLS Results						
Number of Outbreaks (0-1900)	-0.572**	-0.523**	-0.667***	-0.626***	-0.621***	-0.600**	-0.636***
	(0.257)	(0.209)	(0.237)	(0.220)	(0.229)	(0.228)	(0.232)
Observations	237	237	237	237	237	237	237
R^2	0.042	0.339	0.349	0.372	0.377	0.405	0.408
Adjusted R^2	0.033	0.322	0.323	0.338	0.332	0.359	0.357
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.61	1.66	2.42	2.43	2.69	2.71	2.73
	Panel B: Reduced Form						
Travel Time	0.332***	0.337***	0.352***	0.343***	0.364***	0.377***	0.378***
	(0.079)	(0.115)	(0.112)	(0.111)	(0.113)	(0.109)	(0.112)
Observations	237	237	237	237	237	237	237
R^2	0.292	0.381	0.394	0.414	0.427	0.463	0.464
Adjusted R^2	0.286	0.365	0.370	0.383	0.386	0.421	0.417
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.02	4.32	4.41	4.42	4.90	4.91	5.10
	Controls (Panel A & B)						
Geography		✓	✓	✓	✓	✓	✓
Population			✓	✓	✓	✓	✓
Religion				✓	✓	✓	✓
Institutions					✓	✓	✓
Agriculture						✓	✓
Wars							✓
	Panel C: IV Results (Full Set of Controls)						
Number of Outbreaks (0-1900)	-4.869***						
	(1.846)						
Number of Outbreaks (0-1555)		-7.981***					
		(2.963)					
Number of Outbreaks (0-1618)			-6.785**				
			(2.644)				
Number of Outbreaks (1360-1618)				-7.036**			
				(2.788)			
First Stage							
Travel Time	-0.052***	-0.032***	-0.037**	-0.036**			
	(0.019)	(0.011)	(0.014)	(0.014)			
Observations	237	237	237	237			
Number of Cluster	56	56	56	56			
F-Stat in FS	7.57	8.91	6.68	6.29			
Kleinbergen-Paap rk LM (p-value)	0.01	0.01	0.02	0.02			

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.12: Plague Exposure and Timing of the Demographic Transition: Robustness
Onset following Galloway (1994)

Dependent Variable	Onset of the Demographic Transition (Year)						
	Panel A: Baseline Specification						
Travel Time	0.161***	0.198	0.117	0.157	0.155	0.149	0.140
	(0.053)	(0.121)	(0.105)	(0.111)	(0.113)	(0.117)	(0.122)
Observations	131	131	131	131	131	131	131
R^2	0.107	0.124	0.250	0.287	0.305	0.308	0.309
Adjusted R^2	0.093	0.082	0.194	0.215	0.207	0.203	0.191
Number of Cluster	27	27	27	27	27	27	27
Highest VIF	1.01	3.80	3.86	4.21	4.28	4.57	4.83
	Panel B: Accounting for Roman Roads						
Travel Time (Roman Roads)	-2.229***	-2.133***	-2.385***	-2.325**	-2.370**	-2.464**	-2.399**
	(0.304)	(0.728)	(0.695)	(1.037)	(1.030)	(0.966)	(1.137)
Travel Time (non-Roman Roads)	0.163***	0.210	0.130	0.164	0.163	0.156	0.150
	(0.054)	(0.130)	(0.108)	(0.115)	(0.117)	(0.120)	(0.127)
Observations	131	131	131	131	131	131	131
R^2	0.119	0.135	0.262	0.299	0.317	0.320	0.321
Adjusted R^2	0.098	0.086	0.200	0.221	0.214	0.211	0.197
Number of Cluster	27	27	27	27	27	27	27
Highest VIF	1.01	3.86	3.91	4.27	4.33	4.61	4.90
	Controls (both Panels)						
Geography		✓	✓	✓	✓	✓	✓
Population			✓	✓	✓	✓	✓
Religion				✓	✓	✓	✓
Institutions					✓	✓	✓
Agriculture						✓	✓
Wars							✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.13: Plague Exposure and Timing of the Demographic Transition: Robustness to Assumed Travel Speeds and Modes

Dependent Variable	Onset of the Demographic Transition (Year)							
	Baseline		Slow Travel Speed		Avoiding Roads		Roads Only	
	Panel A: Reduced Form							
Travel Time	0.206***	0.253***						
	(0.044)	(0.062)						
Travel Time (slow)			0.140***	0.175***				
			(0.031)	(0.044)				
Travel Time (avoiding roads)					0.162***	0.141***		
					(0.035)	(0.043)		
Travel Time (roads only)							0.149***	0.186***
							(0.043)	(0.065)
Full Set of Controls		✓		✓		✓		✓
Observations	237	237	237	237	237	237	227	227
R^2	0.249	0.557	0.236	0.551	0.252	0.527	0.160	0.521
Adjusted R^2	0.243	0.518	0.229	0.512	0.246	0.486	0.152	0.477
Number of Cluster	56	56	56	56	56	56	56	56
Highest VIF	1.02	5.10	1.02	5.35	1.02	4.09	1.03	6.73
	Panel B: IV Results							
Number of Outbreaks (0-1900)	-4.869***		-4.913**		-6.925		-3.457**	
	(1.846)		(1.952)		(4.423)		(1.591)	
Number of Outbreaks (0-1555)		-7.981***		-8.099**		-9.234**		-5.784**
		(2.963)		(3.167)		(4.570)		(2.752)
First Stage								
Travel Time	-0.052***	-0.032***						
	(0.019)	(0.011)						
Travel Time (slow)			-0.036**	-0.022***				
			(0.014)	(0.008)				
Travel Time (avoiding roads)					-0.020	-0.015**		
					(0.014)	(0.007)		
Travel Time (roads only)							-0.054**	-0.032**
							(0.023)	(0.014)
Full Set of Controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	237	237	237	237	237	237	227	227
Number of Cluster	56	56	56	56	56	56	56	56
F-Stat in FS	7.57	8.91	6.54	7.44	2.13	4.36	5.68	5.21
Kleinbergen-Paap rk LM (p-value)	0.01	0.01	0.02	0.01	0.14	0.04	0.02	0.02

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.14: Exposure to Plague Outbreaks and the Timing of the Demographic Transition: Extended Specifications

Dependent Variable	Onset of the Demographic Transition (Year)						
	Panel A: Baseline Specification						
Travel Time	0.238***	0.164**	0.183***	0.167**	0.178***	0.187***	0.187***
	(0.040)	(0.073)	(0.060)	(0.064)	(0.064)	(0.059)	(0.060)
Number of Plague Ports (100h)	-2.253**	-1.655	-2.770**	-3.313***	-3.215***	-3.194***	-3.172***
	(1.004)	(1.186)	(1.094)	(1.097)	(1.077)	(1.049)	(1.034)
Observations	237	237	237	237	237	237	237
R^2	0.292	0.360	0.499	0.540	0.551	0.590	0.597
Adjusted R^2	0.285	0.343	0.479	0.515	0.518	0.558	0.561
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.16	7.00	7.08	7.28	7.77	7.78	7.89
joint F	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	Panel B: Accounting for Roman Roads						
Travel Time (Roman Roads)	0.413***	0.417***	0.361***	0.328***	0.331***	0.312***	0.312***
	(0.059)	(0.104)	(0.089)	(0.090)	(0.091)	(0.083)	(0.082)
Travel Time (non-Roman Roads)	0.188***	0.207***	0.212***	0.196***	0.205***	0.208***	0.208***
	(0.039)	(0.065)	(0.057)	(0.060)	(0.062)	(0.058)	(0.058)
Number of Plague Ports (100h)	-4.322***	-2.852**	-3.476***	-3.850***	-3.716***	-3.607***	-3.580***
	(1.052)	(1.101)	(1.090)	(1.101)	(1.083)	(1.038)	(1.026)
Observations	237	237	237	237	237	237	237
R^2	0.403	0.439	0.537	0.568	0.576	0.606	0.613
Adjusted R^2	0.396	0.422	0.516	0.543	0.543	0.574	0.578
Number of Cluster	56	56	56	56	56	56	56
Highest VIF	1.82	8.14	8.36	8.69	9.08	9.14	9.22
joint F	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Controls (both Panels)						
Geography		✓	✓	✓	✓	✓	✓
Population			✓	✓	✓	✓	✓
Religion				✓	✓	✓	✓
Institutions					✓	✓	✓
Agriculture						✓	✓
Wars							✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.15: Plague Exposure and the Timing of the Demographic Transition: IV Results – Extended Specifications

Dependent Variable	Onset of the Demographic Transition (Year)				
Panel A: Baseline Specification					
	OLS	IV			
Number of Outbreaks (0-1900)	-0.290^{***}	-3.918^{**}			
	(0.101)	(1.576)			
Number of Outbreaks (0-1555)			-6.621^{**}		
			(2.691)		
Number of Outbreaks (0-1618)				-5.855^{**}	
				(2.570)	
Number of Outbreaks (1360-1618)					-6.034^{**}
					(2.665)
First Stage					
Travel Time		-0.049^{**}	-0.029^{***}	-0.033^{**}	-0.032^{**}
		(0.019)	(0.010)	(0.015)	(0.015)
F-Stat in FS		6.45	7.96	4.90	4.64
Kleinbergen-Paap rk LM (p-value)		0.02	0.01	0.03	0.04
Panel B: Accounting for Roman Roads					
	OLS	IV			
Number of Outbreaks (0-1900)	-0.290^{***}	-4.113^{**}			
	(0.101)	(1.598)			
Number of Outbreaks (0-1555)			-7.080^{***}		
			(2.698)		
Number of Outbreaks (0-1618)				-6.338^{***}	
				(2.452)	
Number of Outbreaks (1360-1618)					-6.507^{***}
					(2.513)
First Stage					
Travel Time (Roman Roads)		-0.054^{*}	-0.034^{**}	-0.045^{*}	-0.044^{**}
		(0.029)	(0.015)	(0.023)	(0.022)
Travel Time (non-Roman Roads)		-0.050^{***}	-0.030^{***}	-0.035^{**}	-0.034^{**}
		(0.019)	(0.010)	(0.014)	(0.014)
F-Stat in FS		3.39	4.39	3.00	2.89
Kleinbergen-Paap rk LM (p-value)		0.05	0.03	0.07	0.07
Hansen J (p-value)		0.31	0.36	0.68	0.70
Full Set of Controls (both Panels)	✓	✓	✓	✓	✓

Standard errors, clustered by administrative region, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.16: Plague Outbreaks and The Timing of the Demographic Transition: Germany and France

Dependent Variable	Onset of the Demographic Transition (Year)							
	Panel A: France							
Number of Outbreaks (0-1900)	-0.038	0.056	0.080	-0.395	-0.395	-0.267	-0.242	0.013
	(0.505)	(0.495)	(0.511)	(0.612)	(0.612)	(0.618)	(0.600)	(0.541)
Observations	281	281	281	281	281	281	281	281
R^2	0.004	0.023	0.030	0.046	0.046	0.054	0.054	0.161
Adjusted R^2	-0.003	0.013	0.012	0.022	0.022	0.022	0.019	0.124
Number of Cluster	80	80	80	80	80	80	80	80
Highest VIF	1.61	1.64	1.92	2.54	2.54	2.67	2.70	6.20
	Panel B: Germany and France							
Number of Outbreaks (0-1900)	-0.162	-0.094	-0.121	-0.449	-0.424	-0.382	-0.376	-0.298
	(0.357)	(0.354)	(0.359)	(0.441)	(0.441)	(0.436)	(0.435)	(0.420)
Observations	523	518	518	518	518	518	518	518
R^2	0.623	0.634	0.635	0.639	0.639	0.641	0.641	0.660
Adjusted R^2	0.621	0.630	0.630	0.632	0.632	0.632	0.632	0.650
Number of Cluster	136	136	136	136	136	136	136	136
Highest VIF	1.65	1.96	2.21	2.42	4.16	4.20	4.24	9.32
	Controls (both Panels							
Distance to Paris		✓	✓	✓	✓	✓	✓	✓
Geography			✓	✓	✓	✓	✓	✓
Population				✓	✓	✓	✓	✓
Religion					✓	✓	✓	✓
Institutions						✓	✓	✓
Calories							✓	✓
Coordinates								✓
France Dummy (Panel B)	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors, clustered by administrative region, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.17: Exposure to Plague Outbreaks and the Timing of the Demographic Transition: France and Germany

Dependent Variable	Onset of the Demographic Transition (Year)							
	Panel A: France							
Travel Time	0.053	0.607***	0.627***	0.640***	0.640***	0.634***	0.633***	0.183
	(0.169)	(0.222)	(0.228)	(0.224)	(0.224)	(0.225)	(0.228)	(0.365)
Observations	281	281	281	281	281	281	281	281
R^2	0.006	0.111	0.113	0.131	0.131	0.137	0.137	0.164
Adjusted R^2	-0.001	0.101	0.097	0.108	0.108	0.109	0.105	0.126
Number of Cluster	80	80	80	80	80	80	80	80
Highest VIF	1.00	3.30	3.71	3.72	3.72	3.75	4.22	14.27
	Panel B: Germany and France							
Travel Time	0.084	0.246*	0.242*	0.244*	0.240*	0.244*	0.266*	0.277**
	(0.133)	(0.140)	(0.139)	(0.138)	(0.138)	(0.137)	(0.136)	(0.122)
Observations	518	518	518	518	518	518	518	518
R^2	0.623	0.633	0.634	0.636	0.640	0.643	0.646	0.648
Adjusted R^2	0.621	0.630	0.629	0.630	0.633	0.635	0.638	0.638
Number of Cluster	136	136	136	136	136	136	136	136
Highest VIF	1.05	2.74	2.80	2.81	4.01	4.02	4.08	8.64
	Controls (both Panels							
Distance to Paris		✓	✓	✓	✓	✓	✓	✓
Geography			✓	✓	✓	✓	✓	✓
Population				✓	✓	✓	✓	✓
Religion					✓	✓	✓	✓
Institutions						✓	✓	✓
Calories							✓	✓
Coordinates								✓
France Dummy (Panel B)	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors, clustered by administrative region, in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.18: Exposure to Plague Outbreaks and the Timing of the Demographic Transition: France

	None	Paris	Geographic	Population	Religion	Insitutions	Calories	Coordinates
Travel Time	0.053	0.607***	0.627***	0.640***	0.640***	0.634***	0.633***	0.183
	(0.169)	(0.222)	(0.228)	(0.224)	(0.224)	(0.225)	(0.228)	(0.365)
Outbreak following 1348	-6.267	-8.436	-10.007*	-14.370**	-14.370**	-12.200*	-12.154*	-11.013
	(5.993)	(5.819)	(5.828)	(6.806)	(6.806)	(6.869)	(7.140)	(6.724)
PARIS_T_med		0.630***	0.653***	0.669***	0.669***	0.655***	0.651**	0.834**
		(0.228)	(0.235)	(0.236)	(0.236)	(0.234)	(0.250)	(0.342)
Navigable River			8.014	0.022	0.022	2.153	2.112	2.556
			(8.779)	(9.284)	(9.284)	(9.007)	(9.342)	(9.588)
City with Maritime Port			0.998	0.892	0.892	0.323	0.140	-0.573
			(9.236)	(10.070)	(10.070)	(9.993)	(9.572)	(8.990)
Population in 1400(log)				6.646**	6.646**	6.590*	6.577*	5.089
				(3.180)	(3.180)	(3.606)	(3.619)	(3.347)
Population Growth 1400-1600(log)				-0.055	-0.055	-0.256	-0.284	-0.408
				(3.130)	(3.130)	(3.329)	(3.426)	(3.283)
University						7.901	7.883	9.018
						(9.791)	(9.726)	(10.403)
Printing Press						-10.919	-10.917	-9.425
						(6.594)	(6.604)	(6.979)
Caleoric Yield							-0.000	-0.000
							(0.006)	(0.008)
Latitude								9.278
								(6.948)
Longitude								0.526
								(2.240)
Constant	1839.384***	1768.175***	1765.167***	1762.553***	1762.553***	1763.995***	1766.774***	1347.544***
	(10.471)	(25.334)	(26.631)	(26.697)	(26.697)	(26.712)	(64.131)	(346.379)
Observations	281	281	281	281	281	281	281	281
R^2	0.006	0.111	0.113	0.131	0.131	0.137	0.137	0.164
Adjusted R^2	-0.001	0.101	0.097	0.108	0.108	0.109	0.105	0.126
Number of Cluster	80	80	80	80	80	80	80	80
Highest VIF	1.00	3.30	3.71	3.72	3.72	3.75	4.22	14.27
joint F	0.75	0.01	0.01	0.01	0.01	0.01	0.01	0.62

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.19: Exposure to Plague Outbreaks and the Timing of the Demographic Transition: Germany and France

	None	Paris	Geographic	Population	Religion	Insitutions	Calories	Coordinates
Travel Time	0.084	0.246*	0.242*	0.244*	0.240*	0.244*	0.266*	0.277**
	(0.133)	(0.140)	(0.139)	(0.138)	(0.138)	(0.137)	(0.136)	(0.122)
Outbreak following 1348	-3.217	-3.532	-4.152	-6.162	-7.994*	-5.513	-4.925	-4.986
	(3.765)	(3.729)	(3.753)	(4.655)	(4.695)	(4.879)	(5.051)	(5.048)
France	-71.732***	-65.347***	-65.640***	-65.262***	-73.764***	-73.606***	-75.025***	-78.265***
	(5.121)	(6.585)	(6.381)	(6.444)	(5.706)	(5.751)	(5.383)	(10.504)
PARIS_T_med		0.200*	0.195*	0.201*	0.219**	0.217**	0.207**	0.284*
		(0.104)	(0.102)	(0.103)	(0.105)	(0.104)	(0.096)	(0.166)
Navigable River			0.054	-0.604	-1.289	-0.751	0.297	-0.398
			(2.461)	(2.406)	(2.384)	(2.317)	(2.289)	(2.536)
City with Maritime Port			4.557	4.087	4.942	3.743	0.787	-0.475
			(7.251)	(7.404)	(7.530)	(7.385)	(6.916)	(7.121)
Population in 1400(log)				2.397	2.633	3.092	2.977	3.072
				(1.752)	(1.742)	(1.923)	(1.905)	(1.927)
Population Growth 1400-1600(log)				-0.350	-0.044	0.032	-0.199	-0.258
				(1.721)	(1.722)	(1.749)	(1.710)	(1.685)
Protestant					-11.441***	-11.263***	-10.008**	-10.150**
					(3.952)	(3.968)	(3.867)	(4.221)
University						5.972	5.395	5.762
						(6.405)	(6.023)	(6.032)
Printing Press						-9.479**	-8.861*	-8.378*
						(4.647)	(4.604)	(4.433)
Caleoric Yield							-0.005	-0.002
							(0.004)	(0.005)
Latitude								0.439
								(1.619)
Longitude								-1.117
								(1.719)
Constant	1908.837***	1880.656***	1881.174***	1880.076***	1887.753***	1887.556***	1929.554***	1888.751***
	(6.362)	(14.707)	(14.448)	(14.625)	(14.221)	(14.133)	(36.746)	(97.049)
Observations	518	518	518	518	518	518	518	518
R^2	0.623	0.633	0.634	0.636	0.640	0.643	0.646	0.648
Adjusted R^2	0.621	0.630	0.629	0.630	0.633	0.635	0.638	0.638
Number of Cluster	136	136	136	136	136	136	136	136
Highest VIF	1.05	2.74	2.80	2.81	4.01	4.02	4.08	8.64
joint F	0.53	0.08	0.08	0.08	0.08	0.08	0.05	0.02

Standard errors, clustered by administrative regions, in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.20: Germany and France: First Stage Results

	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618
Travel Time	-0.027**	-0.019***	-0.022**	-0.022**	-0.026*	-0.035***	-0.033***	-0.033***	-0.027***	-0.028***	-0.028***	-0.028***
	(0.013)	(0.007)	(0.010)	(0.010)	(0.015)	(0.009)	(0.012)	(0.012)	(0.010)	(0.006)	(0.008)	(0.008)
Outbreak following 1348	5.459***	3.432***	4.785***	3.673**	7.410***	5.331***	6.477***	5.477***	6.742***	4.654***	5.865***	4.829***
	(1.818)	(0.969)	(1.450)	(1.418)	(1.345)	(1.004)	(1.260)	(1.260)	(1.096)	(0.768)	(0.988)	(0.986)
France	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.933***	2.082***	3.090***	3.174***
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(0.676)	(0.440)	(0.578)	(0.581)
PARIS_T_med	-0.011	-0.007*	-0.008	-0.008	-0.017	-0.024**	-0.024*	-0.024*	-0.022***	-0.018***	-0.022***	-0.022***
	(0.007)	(0.004)	(0.005)	(0.005)	(0.016)	(0.011)	(0.014)	(0.014)	(0.007)	(0.005)	(0.006)	(0.006)
Navigable River	0.034	-0.059	0.005	-0.022	3.254*	2.663**	3.281**	3.281**	0.736	0.568	0.719	0.710
	(0.445)	(0.236)	(0.334)	(0.327)	(1.916)	(1.247)	(1.609)	(1.609)	(0.563)	(0.371)	(0.472)	(0.472)
City with Maritime Port	0.964	1.339	0.980	1.034	1.152	0.266	0.706	0.706	0.845	0.214	0.409	0.411
	(2.491)	(1.598)	(1.966)	(1.944)	(0.999)	(0.669)	(0.820)	(0.820)	(1.034)	(0.671)	(0.847)	(0.843)
Population in 1400(log)	2.701***	1.520***	2.195***	2.126***	3.047***	1.388***	2.337***	2.337***	2.966***	1.561***	2.387***	2.351***
	(0.462)	(0.256)	(0.368)	(0.353)	(0.591)	(0.394)	(0.524)	(0.524)	(0.383)	(0.249)	(0.337)	(0.336)
Population Growth 1400-1600(log)	1.108***	0.517***	0.809***	0.784***	1.681***	0.621	1.124**	1.124**	1.433***	0.584***	1.006***	0.993***
	(0.266)	(0.138)	(0.210)	(0.203)	(0.536)	(0.419)	(0.500)	(0.500)	(0.300)	(0.217)	(0.266)	(0.265)
Protestant	0.607	0.288	0.556	0.603	0.000	0.000	0.000	0.000	1.440**	0.957***	1.345***	1.422***
	(0.548)	(0.259)	(0.398)	(0.396)	(.)	(.)	(.)	(.)	(0.585)	(0.347)	(0.477)	(0.478)
University	1.146	0.368	0.703	0.838	0.436	0.438	0.606	0.606	1.099	0.625	0.949	1.028
	(1.795)	(1.009)	(1.311)	(1.281)	(1.245)	(0.864)	(1.078)	(1.078)	(1.076)	(0.715)	(0.904)	(0.905)
Printing Press	0.393	-0.169	0.092	-0.027	3.530**	1.680	2.844**	2.844**	2.218**	0.954	1.746*	1.687*
	(1.786)	(0.963)	(1.380)	(1.327)	(1.417)	(1.143)	(1.367)	(1.367)	(1.102)	(0.825)	(1.004)	(1.000)
Caleoric Yield	0.000	0.000	-0.000	-0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.757	0.886	1.356	1.332	-1.723	1.761	-0.557	-0.557	-1.481	0.243	-1.104	-1.101
	(3.136)	(1.570)	(2.354)	(2.300)	(4.606)	(3.445)	(4.340)	(4.340)	(3.001)	(2.194)	(2.722)	(2.723)
Observations	237	237	237	237	281	281	281	281	518	518	518	518

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.21: Germany and France: IV Results Germany and France

	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618
Number of Outbreaks (0-1900)	-5.954**				-24.617				-10.012*			
	(2.736)				(16.166)				(5.929)			
Number of Outbreaks (0-1555)		-8.406***				-18.106**				-9.640*		
		(3.224)				(7.857)				(5.013)		
Number of Outbreaks (0-1618)			-7.461**				-19.059**				-9.472*	
			(3.281)				(9.624)				(5.195)	
Number of Outbreaks (1360-1618)				-7.502**				-19.059**				-9.499*
				(3.251)				(9.624)				(5.208)
Outbreak following 1348	34.427*	30.774**	37.626**	29.476*	170.270	84.372**	111.296*	92.236*	62.572	39.943	50.625	40.944
	(18.280)	(13.337)	(18.655)	(15.156)	(119.070)	(42.981)	(63.202)	(54.480)	(42.223)	(25.367)	(32.711)	(27.686)
France	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-35.648	-54.955***	-45.758**	-44.872**
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(25.269)	(12.521)	(17.995)	(18.471)
PARIS_T_med	-0.116***	-0.110***	-0.112***	-0.110***	0.242	0.222	0.199	0.199	-0.012	0.035	0.001	-0.000
	(0.041)	(0.034)	(0.037)	(0.037)	(0.318)	(0.226)	(0.258)	(0.258)	(0.144)	(0.117)	(0.134)	(0.135)
Navigable River	1.402	0.698	1.238	1.032	82.227	50.334	64.651	64.651	7.666	5.775	7.103	7.038
	(2.718)	(2.095)	(2.558)	(2.486)	(73.818)	(32.070)	(45.468)	(45.468)	(7.356)	(4.726)	(6.006)	(5.977)
City with Maritime Port	5.428	10.941	6.997	7.442	28.503	4.961	13.606	13.606	9.248	2.853	4.664	4.694
	(14.066)	(12.787)	(13.863)	(13.852)	(24.799)	(16.070)	(18.859)	(18.859)	(12.886)	(10.220)	(11.335)	(11.315)
Population in 1400(log)	15.811**	12.506***	16.102**	15.675**	81.583	31.702**	51.121**	51.121**	32.675*	18.029**	25.584**	25.307**
	(7.234)	(4.847)	(7.061)	(6.867)	(53.605)	(13.851)	(25.554)	(25.554)	(18.313)	(8.400)	(13.010)	(12.877)
Population Growth 1400-1600(log)	6.419**	4.162**	5.855**	5.703**	41.091	10.961	21.141	21.141	14.142	5.428	9.332	9.234
	(3.095)	(1.842)	(2.770)	(2.661)	(31.502)	(9.336)	(15.021)	(15.021)	(9.130)	(3.689)	(5.887)	(5.845)
Protestant	-0.324	-1.520	0.215	0.585	0.000	0.000	0.000	0.000	4.409	-0.785	2.729	3.503
	(3.915)	(2.636)	(3.796)	(3.880)	(.)	(.)	(.)	(.)	(12.265)	(7.976)	(10.394)	(10.777)
University	4.013	0.282	2.432	3.474	18.609	15.820	19.426	19.426	16.396	11.416	14.379	15.164
	(11.181)	(8.424)	(9.881)	(9.751)	(33.954)	(20.030)	(25.574)	(25.574)	(14.283)	(9.761)	(12.019)	(12.255)
Printing Press	2.105	-1.656	0.454	-0.433	75.978	19.494	43.285	43.285	13.348	0.337	7.673	7.161
	(10.252)	(7.958)	(9.934)	(9.606)	(59.483)	(22.679)	(34.225)	(34.225)	(16.072)	(8.855)	(12.468)	(12.267)
Caleoric Yield	-0.003	-0.003	-0.003	-0.003	0.016	0.005	0.010	0.010	-0.002	-0.003	-0.002	-0.002
	(0.003)	(0.002)	(0.003)	(0.003)	(0.017)	(0.009)	(0.012)	(0.012)	(0.005)	(0.005)	(0.005)	(0.005)
Constant	1945.872***	1948.812***	1951.477***	1951.358***	1724.368***	1798.653***	1756.163***	1756.163***	1914.729***	1931.894***	1919.095***	1919.092***
	(24.659)	(19.685)	(23.344)	(23.167)	(141.748)	(84.607)	(107.486)	(107.486)	(47.274)	(41.094)	(44.260)	(44.334)
Observations	237	237	237	237	281	281	281	281	518	518	518	518
R^2	-4.775	-2.720	-4.533	-4.410	-8.363	-2.235	-3.997	-3.997	-0.109	0.334	0.136	0.134
Adjusted R^2	-5.057	-2.902	-4.803	-4.674	-8.710	-2.355	-4.182	-4.182	-0.136	0.319	0.116	0.113
Number of Cluster	56	56	56	56	80	80	80	80	136	136	136	136
F-Stat in FS	4.38	7.55	4.73	4.81	3.03	14.65	7.32	7.32	7.58	18.69	11.68	11.66
Kleinbergen-Paap rk LM (p-value)	0.04	0.01	0.03	0.03	0.06	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Hansen J (p-value)	.	.	.	.	.	.	.	.	.	.	.	.

Standard errors, clustered by administrative regions, in parentheses.
multicolumn13l* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.22: Germany and France: First Stage Results Accounting for Roman Roads

	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618
Travel Time (Roman Roads)	-0.020	-0.010	-0.018	-0.020	-0.033*	-0.043***	-0.039***	-0.039***	-0.029***	-0.031***	-0.030***	-0.031***
	(0.024)	(0.013)	(0.019)	(0.019)	(0.018)	(0.011)	(0.014)	(0.014)	(0.011)	(0.007)	(0.009)	(0.009)
Travel Time (non-Roman Roads)	-0.028*	-0.019**	-0.020*	-0.020*	-0.027	-0.033***	-0.037**	-0.037**	-0.026**	-0.026***	-0.029**	-0.028**
	(0.015)	(0.008)	(0.011)	(0.011)	(0.018)	(0.011)	(0.016)	(0.016)	(0.013)	(0.008)	(0.011)	(0.011)
Outbreak following 1348	5.469***	3.447***	4.814***	3.705***	7.449***	5.357***	6.525***	5.525***	6.749***	4.666***	5.874***	4.839***
	(1.827)	(0.979)	(1.461)	(1.425)	(1.342)	(0.998)	(1.259)	(1.259)	(1.101)	(0.768)	(0.991)	(0.989)
France	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.015***	2.211***	3.132***	3.238***
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(0.831)	(0.540)	(0.722)	(0.723)
Paris (TT, Roman Roads)	-0.026	-0.026	-0.022	-0.018	-0.014	-0.022**	-0.021	-0.021	-0.025**	-0.022***	-0.026**	-0.027**
	(0.034)	(0.018)	(0.027)	(0.027)	(0.016)	(0.011)	(0.014)	(0.014)	(0.012)	(0.008)	(0.011)	(0.011)
Paris (TT, non-Roman Roads)	-0.011	-0.007*	-0.008	-0.007	-0.073	-0.073**	-0.085**	-0.085**	-0.020***	-0.014***	-0.018***	-0.018***
	(0.007)	(0.004)	(0.006)	(0.006)	(0.045)	(0.031)	(0.039)	(0.039)	(0.007)	(0.005)	(0.006)	(0.006)
Navigable River	0.054	-0.035	0.016	-0.019	3.249*	2.644**	3.287**	3.287**	0.718	0.537	0.690	0.678
	(0.461)	(0.242)	(0.349)	(0.343)	(1.916)	(1.232)	(1.618)	(1.618)	(0.555)	(0.364)	(0.465)	(0.465)
City with Maritime Port	0.960	1.335	0.994	1.054	1.206	0.333	0.748	0.748	0.848	0.217	0.385	0.391
	(2.504)	(1.601)	(1.977)	(1.957)	(0.988)	(0.653)	(0.795)	(0.795)	(1.023)	(0.667)	(0.840)	(0.837)
Population in 1400(log)	2.706***	1.527***	2.202***	2.133***	3.005***	1.350***	2.294***	2.294***	2.969***	1.565***	2.391***	2.355***
	(0.467)	(0.259)	(0.372)	(0.358)	(0.590)	(0.395)	(0.527)	(0.527)	(0.383)	(0.249)	(0.337)	(0.336)
Population Growth 1400-1600(log)	1.102***	0.508***	0.803***	0.779***	1.629***	0.580	1.065**	1.065**	1.430***	0.579***	0.999***	0.986***
	(0.271)	(0.141)	(0.213)	(0.204)	(0.543)	(0.423)	(0.505)	(0.505)	(0.304)	(0.220)	(0.271)	(0.270)
Protestant	0.616	0.296	0.535	0.570	0.000	0.000	0.000	0.000	1.346**	0.797**	1.180***	1.248***
	(0.576)	(0.267)	(0.409)	(0.409)	(.)	(.)	(.)	(.)	(0.582)	(0.318)	(0.453)	(0.454)
University	1.097	0.307	0.653	0.798	0.376	0.378	0.549	0.549	1.097	0.623	0.957	1.035
	(1.796)	(1.009)	(1.324)	(1.300)	(1.263)	(0.874)	(1.088)	(1.088)	(1.085)	(0.722)	(0.910)	(0.911)
Printing Press	0.396	-0.164	0.101	-0.017	3.657**	1.811	2.964**	2.964**	2.217**	0.950	1.726*	1.670*
	(1.795)	(0.968)	(1.392)	(1.341)	(1.447)	(1.169)	(1.393)	(1.393)	(1.102)	(0.823)	(1.000)	(0.996)
Caleoric Yield	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	1.914	2.328	2.441	2.160	0.308	3.781	1.424	1.424	-1.086	0.916	-0.391	-0.352
	(4.045)	(2.155)	(3.291)	(3.270)	(4.951)	(3.727)	(4.664)	(4.664)	(3.511)	(2.584)	(3.230)	(3.231)
Observations	237	237	237	237	281	281	281	281	518	518	518	518

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.23: Germany and France: IV Results Germany and France Accounting for Roman Roads

	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618	0-1900	0-1555	0-1618	1360-1618
Number of Outbreaks (0-1900)	-4.684*				-21.368*				-12.336**			
	(2.402)				(12.640)				(5.876)			
Number of Outbreaks (0-1555)		-6.748**				-16.608**				-11.591***		
		(3.025)				(6.911)				(4.496)		
Number of Outbreaks (0-1618)			-6.138*				-16.759**				-11.428**	
			(3.200)				(8.307)				(4.872)	
Number of Outbreaks (1360-1618)				-6.051*				-16.759**				-11.429**
				(3.151)				(8.307)				(4.853)
Outbreak following 1348	26.889*	24.529*	30.793*	23.622*	147.035	76.888**	97.167*	80.408*	77.925*	48.733**	61.820**	49.988*
	(16.168)	(12.656)	(18.087)	(14.234)	(93.455)	(38.592)	(54.583)	(47.103)	(42.552)	(23.576)	(31.453)	(26.764)
France	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-26.640	-51.033***	-39.826**	-38.857**
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(25.682)	(11.725)	(17.617)	(17.926)
Paris (TT, Roman Roads)	0.106	0.090	0.070	0.070	0.354	0.287	0.306	0.306	0.124	0.166	0.124	0.120
	(0.123)	(0.116)	(0.134)	(0.130)	(0.335)	(0.244)	(0.270)	(0.270)	(0.229)	(0.198)	(0.218)	(0.218)
Paris (TT, non-Roman Roads)	-0.115***	-0.110***	-0.111***	-0.109***	-0.737	-0.341	-0.689	-0.689	-0.221**	-0.142**	-0.180**	-0.179**
	(0.035)	(0.030)	(0.033)	(0.033)	(1.062)	(0.786)	(0.848)	(0.848)	(0.108)	(0.062)	(0.081)	(0.080)
Navigable River	1.289	0.730	1.172	0.996	71.904	46.421	57.331	57.331	10.464	7.845	9.471	9.353
	(2.222)	(1.754)	(2.174)	(2.065)	(61.136)	(28.901)	(39.633)	(39.633)	(8.163)	(4.834)	(6.277)	(6.238)
City with Maritime Port	3.888	8.419	5.433	5.611	25.267	4.908	12.446	12.446	12.605	4.529	6.691	6.693
	(10.895)	(10.178)	(11.305)	(11.100)	(21.842)	(14.948)	(16.860)	(16.860)	(14.274)	(10.936)	(12.354)	(12.312)
Population in 1400(log)	12.221*	9.844**	13.068*	12.470*	70.974*	29.215**	45.099**	45.099**	39.404**	20.927***	30.107**	29.699**
	(6.431)	(4.620)	(6.999)	(6.772)	(41.538)	(12.382)	(22.201)	(22.201)	(18.164)	(7.630)	(12.281)	(12.085)
Population Growth 1400-1600(log)	5.114**	3.398**	4.869*	4.646*	34.615	9.453	17.630	17.630	17.799*	6.862*	11.588**	11.433**
	(2.550)	(1.538)	(2.529)	(2.429)	(25.407)	(8.872)	(13.408)	(13.408)	(9.286)	(3.722)	(5.866)	(5.797)
Protestant	-0.432	-1.408	0.015	0.208	0.000	0.000	0.000	0.000	14.159	6.799	11.013	11.808
	(3.261)	(2.366)	(3.354)	(3.404)	(.)	(.)	(.)	(.)	(12.161)	(6.463)	(9.169)	(9.457)
University	3.368	0.405	2.167	2.925	16.300	14.642	17.217	17.217	18.460	12.192	15.803	16.724
	(8.604)	(6.699)	(8.031)	(7.798)	(29.972)	(18.819)	(22.966)	(22.966)	(16.116)	(10.677)	(13.198)	(13.368)
Printing Press	1.401	-1.557	0.165	-0.549	66.408	18.057	38.475	38.475	19.493	3.083	11.959	11.274
	(7.746)	(6.371)	(7.980)	(7.617)	(47.258)	(20.130)	(29.489)	(29.489)	(17.460)	(9.781)	(13.341)	(13.157)
Caleoric Yield	-0.002	-0.002	-0.003	-0.003	0.011	0.003	0.007	0.007	0.000	-0.002	-0.000	-0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.014)	(0.009)	(0.011)	(0.011)	(0.006)	(0.005)	(0.006)	(0.006)
Constant	1927.658***	1931.795***	1935.571***	1935.481***	1761.068***	1814.480***	1785.838***	1785.838***	1883.189***	1907.340***	1892.100***	1892.541***
	(23.581)	(20.021)	(25.139)	(24.703)	(125.420)	(82.363)	(99.905)	(99.905)	(59.884)	(49.714)	(55.165)	(55.154)
Observations	237	237	237	237	281	281	281	281	518	518	518	518
R^2	-2.642	-1.490	-2.800	-2.583	-6.251	-1.860	-3.056	-3.056	-0.501	0.199	-0.093	-0.093
Adjusted R^2	-2.837	-1.623	-3.003	-2.775	-6.548	-1.977	-3.222	-3.222	-0.539	0.179	-0.121	-0.121
Number of Cluster	56	56	56	56	80	80	80	80	136	136	136	136
F-Stat in FS	1.80	3.13	1.69	1.68	2.01	8.53	4.71	4.71	4.20	11.60	7.10	7.18
Kleinbergen-Paap rk LM (p-value)	0.17	0.04	0.19	0.20	0.12	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Hansen J (p-value)	0.71	0.86	0.59	0.49	0.94	0.98	0.75	0.75	0.98	0.95	0.90	0.94

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.24: Germany and France: IV Results – Alternative Specifications

Dependent Variable	Onset of the Demographic Transition (Year)											
Panel A: Including Latitude and Longitude												
	Germany				France				Germany and France			
Number of Outbreaks (0-1900)	-4.653**				-8.417				-10.382*			
	(1.842)				(18.620)				(5.567)			
Number of Outbreaks (0-1555)		-7.037***				-4.875				-9.950**		
		(2.519)				(9.823)				(4.526)		
Number of Outbreaks (0-1618)			-6.242***				-5.881				-9.841**	
			(2.420)				(12.320)				(4.765)	
Number of Outbreaks (1360-1618)				-6.564**				-5.881				-9.831**
				(2.632)				(12.320)				(4.751)
First Stage												
Travel Time	-0.048**	-0.032***	-0.036**	-0.034**	-0.022	-0.038**	-0.031	-0.031	-0.027***	-0.028***	-0.028***	-0.028***
	(0.019)	(0.010)	(0.014)	(0.014)	(0.023)	(0.016)	(0.021)	(0.021)	(0.010)	(0.006)	(0.008)	(0.008)
Observations	237	237	237	237	281	281	281	281	518	518	518	518
F-Stat in FS	6.62	9.87	6.62	6.06	0.88	5.30	2.27	2.27	7.51	19.92	12.25	12.34
Kleinbergen-Paap rk LM (p-value)	0.02	0.00	0.02	0.02	0.35	0.03	0.15	0.15	0.00	0.00	0.00	0.00
Panel B: Including Latitude and Longitude (Accounting for Roman Roads)												
	Germany				France				Germany and France			
Number of Outbreaks (0-1900)	-4.351***				-13.259				-10.722**			
	(1.586)				(15.018)				(5.295)			
Number of Outbreaks (0-1555)		-6.921***				-8.163				-10.224**		
		(2.534)				(7.864)				(4.238)		
Number of Outbreaks (0-1618)			-5.664***				-7.950				-10.119**	
			(2.012)				(9.606)				(4.531)	
Number of Outbreaks (1360-1618)				-5.674***				-7.950				-10.118**
				(2.013)				(9.606)				(4.511)
First Stage												
Travel Time (Roman Roads)	-0.066*	-0.033	-0.053*	-0.055*	-0.031	-0.045**	-0.041*	-0.041*	-0.028**	-0.030***	-0.029***	-0.029***
	(0.040)	(0.022)	(0.030)	(0.030)	(0.025)	(0.018)	(0.022)	(0.022)	(0.011)	(0.007)	(0.009)	(0.009)
Travel Time (non-Roman Roads)	-0.052***	-0.032***	-0.039***	-0.038***	-0.016	-0.030	-0.031	-0.031	-0.026*	-0.026***	-0.028**	-0.027**
	(0.019)	(0.011)	(0.014)	(0.014)	(0.030)	(0.022)	(0.027)	(0.027)	(0.013)	(0.009)	(0.012)	(0.012)
Observations	237	237	237	237	281	281	281	281	518	518	518	518
F-Stat in FS	3.61	4.97	3.80	3.71	0.82	3.39	1.75	1.75	3.81	10.56	6.33	6.41
Kleinbergen-Paap rk LM (p-value)	0.06	0.02	0.04	0.05	0.46	0.06	0.21	0.21	0.01	0.00	0.00	0.00
Hansen J (p-value)	0.62	0.91	0.54	0.46	0.32	0.18	0.16	0.16	0.93	0.99	0.86	0.90

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.25: Exposure to Plague Outbreaks and the Timing of the Demographic Transition: Extended Specifications – Placebo for Trade

Outcome Variable	Year of the Demographic Transition					
Panel A: Controlling for Access to Trade						
Travel Time	0.253^{***}	0.224^{***}	0.256^{***}	0.247^{***}	0.237^{***}	0.278^{***}
	(0.062)	(0.074)	(0.064)	(0.061)	(0.085)	(0.067)
Observations	237	237	237	237	237	237
R^2	0.557	0.560	0.557	0.561	0.562	0.573
Adjusted R^2	0.518	0.520	0.516	0.521	0.519	0.531
Number of Cluster	56	56	56	56	56	56
Highest VIF	5.10	7.59	11.33	9.81	14.66	33.13
Panel B: Controlling for Access to Trade (Accounting for Roman Roads)						
Travel Time (Roman Roads)	0.338^{***}	0.339^{***}	0.387^{***}	0.335^{***}	0.341^{***}	0.386^{***}
	(0.082)	(0.121)	(0.096)	(0.090)	(0.122)	(0.096)
Travel Time (non-Roman Roads)	0.272^{***}	0.266^{***}	0.295^{***}	0.251^{***}	0.260^{***}	0.296^{***}
	(0.061)	(0.081)	(0.071)	(0.054)	(0.090)	(0.067)
Observations	237	237	237	237	237	237
R^2	0.564	0.574	0.568	0.568	0.576	0.580
Adjusted R^2	0.524	0.530	0.523	0.524	0.528	0.533
Number of Cluster	56	56	56	56	56	56
Highest VIF	7.23	12.51	17.86	10.11	16.80	32.90
Controls (both Panels						
Full Set of Controls	✓	✓	✓	✓	✓	✓
Closest 19th Century Port		✓			✓	
Average 19th Century Port			✓			✓
Closest Hanse				✓	✓	✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.26: Plague Exposure and the Timing of the Demographic Transition: IV Results – Placebo for Trade

Dependent Variable	Onset of the Demographic Transition (Year)			
Panel A: Controlling for Trade				
Number of Outbreaks (0-1900)	-4.869***	-5.131**	-4.657***	-6.216**
	(1.846)	(2.120)	(1.795)	(2.576)
First Stage				
Travel Time	-0.052***	-0.050**	-0.053***	-0.045**
	(0.019)	(0.021)	(0.020)	(0.019)
Observations	237	237	237	237
F-Stat in FS	7.57	5.87	7.07	5.37
Kleinbergen-Paap rk LM (p-value)	0.01	0.02	0.01	0.03
Panel B: Controlling for Trade (Accounting for Roman Roads)				
Number of Outbreaks (0-1900)	-4.926***	-7.101*	-3.536***	-5.520**
	(1.838)	(3.676)	(1.232)	(2.436)
First Stage				
Travel Time (Roman Roads)	-0.055*	-0.047	-0.055	-0.041
	(0.030)	(0.037)	(0.034)	(0.034)
Travel Time (non-Roman Roads)	-0.053***	-0.041*	-0.063***	-0.048**
	(0.019)	(0.023)	(0.022)	(0.024)
Observations	237	237	237	237
F-Stat in FS	3.93	1.66	4.08	2.06
Kleinbergen-Paap rk LM (p-value)	0.04	0.21	0.04	0.15
Hansen J (p-value)	0.57	0.73	0.11	0.21
Full Set of Controls (both Panels)	✓	✓	✓	✓
Average 19th Century Port		✓		✓
Closest Hanseatic City			✓	✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.27: France: Reduced Form Accounting for Trade Access

Outcome Variable	Year of the Demographic Transition					
Panel A: Controlling for Access to Trade						
Travel Time	0.633***	0.416	0.440*	0.633***	0.451*	0.460*
	(0.228)	(0.260)	(0.260)	(0.220)	(0.257)	(0.256)
Observations	281	281	281	281	281	281
R^2	0.137	0.160	0.159	0.159	0.175	0.176
Adjusted R^2	0.105	0.126	0.124	0.125	0.138	0.139
Number of Cluster	80	80	80	80	80	80
Highest VIF	4.22	7.98	6.62	4.26	8.32	6.71
Panel B: Controlling for Access to Trade (Accounting for Roman Roads)						
Travel Time (Roman Roads)	0.718***	0.461	0.525*	0.743***	0.490*	0.552**
	(0.224)	(0.280)	(0.274)	(0.226)	(0.285)	(0.271)
Travel Time (non-Roman Roads)	0.559	-0.249	-0.121	0.476	-0.296	-0.195
	(0.344)	(0.396)	(0.410)	(0.377)	(0.412)	(0.417)
Observations	281	281	281	281	281	281
R^2	0.141	0.203	0.195	0.168	0.223	0.222
Adjusted R^2	0.102	0.161	0.156	0.124	0.176	0.178
Number of Cluster	80	80	80	80	80	80
Highest VIF	3.38	10.92	11.06	3.45	11.18	11.07
Controls (both Panels						
Full Set of Controls	✓	✓	✓	✓	✓	✓
Closest 19th Century Port		✓			✓	
Average 19th Century Port			✓			✓
Closest Port				✓	✓	✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.28: Germany and France: Reduced Form Accounting for Trade Access

Outcome Variable	Year of the Demographic Transition					
Panel A: Controlling for Access to Trade						
Travel Time	0.266*	0.253**	0.245**	0.318**	0.317**	0.284**
	(0.136)	(0.121)	(0.123)	(0.153)	(0.139)	(0.142)
Observations	518	518	518	518	518	518
R^2	0.646	0.648	0.653	0.652	0.652	0.655
Adjusted R^2	0.638	0.639	0.644	0.643	0.642	0.646
Number of Cluster	136	136	136	136	136	136
Highest VIF	4.08	6.08	8.41	4.15	6.31	8.87
Panel B: Controlling for Access to Trade (Accounting for Roman Roads)						
Travel Time (Roman Roads)	0.356***	0.358**	0.414**	0.485***	0.398**	0.422**
	(0.128)	(0.146)	(0.204)	(0.169)	(0.167)	(0.203)
Travel Time (non-Roman Roads)	0.314*	0.221	0.220	0.345	0.185	0.142
	(0.188)	(0.149)	(0.217)	(0.230)	(0.171)	(0.216)
Observations	518	518	518	518	518	518
R^2	0.660	0.678	0.680	0.675	0.687	0.689
Adjusted R^2	0.650	0.667	0.669	0.664	0.675	0.678
Number of Cluster	136	136	136	136	136	136
Highest VIF	4.97	13.28	25.23	6.28	13.81	25.88
Controls (both Panels						
Full Set of Controls	✓	✓	✓	✓	✓	✓
Closest 19th Century Port		✓			✓	
Average 19th Century Port			✓			✓
Closest Hanse (DE) / Closest Port (FR)				✓	✓	✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.29: Germany and France: IV Results Accounting for Trade Access and Different Phases of Plague Outbreaks

Dependent Variable	Onset of the Demographic Transition (Year)			
Panel A: Outbreaks 0 - 1900				
Number of Outbreaks (0-1900)	-10.382*	-14.427**	-11.616**	-14.034**
	(5.567)	(6.553)	(5.541)	(5.956)
First Stage				
Travel Time	-0.027***	-0.028***	-0.032***	-0.032***
	(0.010)	(0.011)	(0.012)	(0.012)
F-Stat in FS	7.51	7.08	7.56	7.19
Kleinbergen-Paap rk LM (p-value)	0.00	0.01	0.01	0.01
Panel B: Outbreaks 0 - 1555				
Number of Outbreaks (0-1555)	-9.950**	-13.243***	-11.920**	-13.879***
	(4.526)	(4.868)	(4.850)	(4.838)
First Stage				
Travel Time	-0.028***	-0.031***	-0.031***	-0.033***
	(0.006)	(0.007)	(0.008)	(0.008)
F-Stat in FS	19.92	20.25	16.96	17.45
Kleinbergen-Paap rk LM (p-value)	0.00	0.00	0.00	0.00
Panel C: Outbreaks 1360 - 1618				
Number of Outbreaks (1360-1618)	-9.831**	-12.948**	-11.518**	-13.360***
	(4.751)	(5.149)	(5.063)	(5.107)
First Stage				
Travel Time	-0.028***	-0.031***	-0.032***	-0.034***
	(0.008)	(0.009)	(0.010)	(0.010)
F-Stat in FS	12.34	12.48	10.80	11.15
Kleinbergen-Paap rk LM (p-value)	0.00	0.00	0.00	0.00
Panel D: Outbreaks 1618 - 1648				
Number of Outbreaks (1618-1648)	49.012	63.541*	94.626	98.673
	(30.727)	(36.226)	(73.120)	(68.097)
First Stage				
Travel Time	0.006**	0.006**	0.004	0.005*
	(0.003)	(0.003)	(0.003)	(0.003)
F-Stat in FS	4.45	5.29	2.19	2.90
Kleinbergen-Paap rk LM (p-value)	0.05	0.03	0.14	0.09
All Panels (A-D)				
Observations	518	518	518	518
Number of Cluster	136	136	136	136
Full Set of Controls	✓	✓	✓	✓
Average 19th Century Port		✓		✓
Closest Hanseatic City / Port			✓	✓

Standard errors, clustered by administrative regions, in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Chapter 3

Childlessness and Inter-Temporal Fertility Choice in Germany

3.1 Introduction

From the second half of the 20th century until today, sustained below-replacement fertility has become a common phenomenon in many developed countries. Germany, the world's fifth largest economy, is a particular case in point: Until the late 1960s, Germany's total fertility rate was still well above replacement level, but then declined sharply in the decade that followed. From the early-1980s until the mid-2010s, the fertility rate has been below 1.5, at times as low as 1.3, which is far below the 2.1 children per women necessary to maintain a stable population size.

What is behind this decrease in the total fertility rate is not so much a change along the intensive margin of fertility as it is a change along its extensive margin. For example, among women born between 1945 and 1965, the average number of children per mother decreased moderately from roughly 1.8 to 1.6, whereas the rate of childlessness almost doubled from about 12% to more than 20%. This demographic development, and the rise of childlessness in particular, is highly relevant for economic and social outcomes. At the macro level, rising childlessness is one important factor that increases the ratio of older to working-age adults, implying that the latter need to contribute a larger share of their income to support social security and health care for the elderly. At the micro level, parenthood entails substantial social and psychological benefits, and so childlessness—especially if involuntary—may lower people's well-being. Despite the importance of the issue, there is still a lack of theoretically founded research that looks into the mechanisms and parameters governing childlessness and fertility in the population at large. In particular, the interplay between economic conditions that lead to women postponing children and childlessness that results from naturally declining fecundity by age has not been thoroughly assessed.

In this paper, I develop and estimate a dynamic structural model of childlessness and fertility with endogenous marriage formation. The model's key innovation is that it endogenizes the timing of fertility in the context of childlessness. This allows me to address long-standing questions related to the relationship between fertility postponement and childlessness. In particular, the magnitude of this postponement effect has not yet been assessed. My model fills this gap by linking the timing of fertility to its intensive and extensive margin. Moreover, by implementing the model in the context of Germany, and by focusing on cohorts of East and West German women and men socialized in different political regimes (the FRG versus the GDR), I provide a new perspective on how institutions shape childlessness and fertility.

The economy features men and women who, in the beginning of the first period, are matched with a potential partner of the opposite sex and decide whether to enter marriage or not.[43] In the first two periods of the model, couples and singles[44] make decisions about consumption and fertility. A key feature of the model is that individuals are faced with a natural decline of fecundity over time: in the first period, individuals are "young" and have a relatively high natural fecundity. In the second period, they are "old" and their ability to conceive is lower. In the third and final period of the model, women and men are no longer able to reproduce; Individuals who decide to distribute the birth of their children over both fertile periods will experience lower wages as a result of long lasting absence from the job market due to child-rearing.[45]

In every period, individuals face a trade-off between child-rearing and income-earning. The timing of fertility, however, involves an inter-temporal trade-off: working less to have children early has a negative impact on earnings potential later in life, due to negative experience effects on wages. At the same time, however, the decision against children, to accumulate work experience, carries the risk of not being able to conceive later in life. Marriage alleviates these trade-offs as it allows partners to share the time cost of raising children and other household chores. In addition, it generates economies of scale from sharing household public goods. Finally, marriage is assumed to be the only path to fatherhood for men.

I use the model to characterize various fertility regimes that emerge from optimal behavior. In terms of the intensive margin of fertility, I decompose the fertility of mothers into "early" and "late" fertility. In terms of the extensive margin of fertility, I differentiate between voluntary and involuntary childlessness. Voluntary childlessness can be in form of social sterility[46] or opportunity cost. Involuntary childlessness is driven by

---

[43] Marriage formation is assumed friction-less.

[44] For a clearer distinction and to avoid confusion I refer to "never married" as "single".

[45] These lower wages can be a result of discrimination or human capital effects beyond the effect of part time work for a short period of time.

[46] Social sterility refers to a too low level of consumption if having children.

biological sterility and postponement of childbirth in combination with decreases in biological fecundity. The distinction of those channels allows for a better understanding of the drivers of childlessness and the economic origins of low fertility rates.

I estimate the model using simulated methods of moments, and exploit four distinct demographic facts in Germany—some well-known and others less so—to identify the model parameters: (i) fertility until age 30 is decreasing for married and single women in mother's education, (ii) fertility after age 30 is increasing for married and single women in mother's education, (iii) childlessness is increasing in women's education, (iv) marriage rates are decreasing in education for women and increasing in education for men. Identification is achieved through differences in initial wages, returns to experience by education, and the resulting fertility consumption trade-offs.

The main findings are threefold. First, I estimate that the postponement effect accounts for 7.8% of total childlessness (or 33.3% of involuntary childlessness). Depending on women's education, the share increases from 4.4% (20.7%) for women with low levels of education to 15.6% (68.2%) for women with the highest level of education. For married women, childlessness is mostly a choice driven by high opportunity cost. When it comes to single childless women, the wish to have children is often restrained by economic conditions. For involuntary childlessness, the importance of biological sterility is decreasing in importance with growing levels of education. Postponement effects in combination with decreasing fecundity by age become more important with education. I quantify the individual's loss in utility for realization of involuntary childlessness. Involuntary childlessness has two counteracting effects on lifetime utility: disutility due to the lower number of children and a higher utility due to higher consumption as more labor income is available. I find that being unable to conceive already early in life results in a negative effect on lifetime utility (measured in equivalent net present value consumption) four times the size of the effect when realized only later in life. However, the labor income effect is larger for involuntary childlessness that occurs early in life, thus making involuntary childlessness more costly in relative terms.

Second, I compare former East and West German states. This comparison is interesting for two reasons: (i) Compared to West Germany, public provision of childcare was (and partly still is) fundamentally different (ii) non-employment and taking time off work was less acceptable for women (and even more so for men) in East Germany. I find lower time cost of having children and a larger negative wage effect of spacing children across time in East Germany. Unlike many reduced form empirical studies that look at immediate effects on "at-risk" sub-groups of the population, the results of this study apply to the general population. Furthermore, I find that social sterility and postponement of children explain a larger share of childlessness in West Germany.

Third, I perform counterfactual analyses of fertility and childlessness for increases in public provision of childcare and changes in labor market conditions. In particular, I simulate the effect of the full application of the East German public childcare system to West Germany and the application of the East German wage penalty for long term private child-rearing to West Germany. These counterfactuals indicate that reductions in the costs of children mainly affect the timing of childbirth rather than the final number of children. Childlessness can be reduced significantly by an expansion of available public childcare for both married and unmarried women. Furthermore, I show that an expansion of publicly available childcare that would contribute to the development of children's human capital can function as a counteracting measure to increases in wage penalties of extended child-rearing times.

This paper contributes to two distinct strands of literature: The literature on childlessness and the literature on optimal allocation of children across time. The first paper separating the extensive from the intensive margin of fertility is by Baudin et al. (2015), who investigate this issue in a static one period model using US data. Myong et al. (2018) build on this model to address the impact of social norms, such as Confucianism, on fertility along both dimensions for a large set of East Asian countries. In a follow-up paper, Baudin et al. (2020) investigate cross-country variation in fertility and childlessness. I build on the model of Baudin et al. (2015) and expand the model to a three period setting.

Earlier work on labor market participation and skill acquisition includes Rios-Rull (1993) who builds an overlapping generation model in which individuals choose between market and home production. In this way, the model endogenously creates heterogeneous agents through individual choices. Caucutt et al. (2002) find that when women face a high wage penalty for childbirth, they tend to postpone having children and build up human capital first. Greenwood et al. (2003) and Regalia et al. (2011) propose household models which include fertility and parental investment in a marriage market equilibrium framework. Adda et al. (2017) estimate the short and long-term career cost of children in a model of labor supply and fertility with occupational choice.

My paper combines the two strands of literature by adding fertility timing and the resulting wage dynamics to the model of Baudin et al. (2015). Compared to the baseline one period model, the dynamic setting allows me to investigate the interaction of econmic reasons that lead individuals to postpone children and and natural decreases in fecundity by age that jointly result in involuntary childlessness. The structural results on fertility postponement are furthermore in line with much of the reduced form literature on the relationship between fertility choices and labor market outcomes. See for example Bertrand et al. (2010), Wood et al. (1993), Budig and England (2001) or Lundborg et al. (2017) for labor market consequences of childbirth, or Miller (2011) and Herr (2016) for the effects of postponement of children on labor market outcomes.

The remainder of the paper is structured in the following way: Section 3.2 motivates the research by illustrating the importance of both margins of fertility and discussing some distinct empirical facts from the German Microcensus. Section 3.3 introduces the theoretical model. Section 3.4 describes the data, estimation strategy and results. Counterfactual policy simulations are provided in Section 3.5 and Section 3.6 concludes.

3.2 Motivation

3.2.1 Historic Development in Germany

Germany's remarkable demographic development during the last years results from significant changes in both the extensive (decision to become a mother) and the intensive (number of children conditional on being a mother) margin of fertility. This is illustrated in Figure 3.1, which plots the historic development of both margins of fertility by focusing on cohorts of German women born between 1933 and 1966.[47] Overall, Germany experi-

---

[47] Birth cohorts marked in red are used for model identification. Figure B.1 in the Appendix plots the extensive and intensive margin of fertility by birth cohort for different broad levels of education categories. The pattern observed in Figure 3.1 remains relatively unchanged when splitting up birth cohorts by educational background of the women.

enced an increase in the rate of childless women and a decrease in the average number of children per mother. This development can broadly be separated in two distinct phases.

In the early phase (birth cohorts from 1933 to 1945, regular dashed line), childlessness rates remained relatively constant while the average number of children per mother decreased from about 2.2 to 1.8. This phenomenon is in line with the theory of the demographic transition[48], which phased out at approximately that time in Germany.[49] In the second phase (birth cohorts after 1945, bold dashed line), I observe a much more moderate decrease in the average number of children per mother but a strong increase in the childlessness rate from about 12.4% to 20.3%.

While the first phase is in line with the literature on fertility decrease, increases in (female) education and economic growth, as suggested by standard fertility theories (see, e.g., Becker and Barro, 1988; Becker et al., 1990; Galor and Weil, 2000; Lee, 2003; Doepke, 2004), this is not the case for the rapid increase in childlessness during the second phase, which still remains a puzzle.

3.2.2 Cross-sectional Evidence for Germany

Figure 3.2 provides a cross-sectional analysis of birth cohorts in the 2008 and 2012 waves of the German Microcensus. The 2008 and 2012 waves of the German Microcensus are the only waves that include a question on completed fertility. I restrict the sample to individuals where I can infer the timing of childbirth. Years of education are assigned to secondary, tertiary and/or vocational qualification.[50] The birth cohorts (1960-1966) are marked red in Figure 3.1. Several stylized facts about fertility and marriage patterns in Germany emerge.

Empirical Fact 1 - Fertility until Age 30: Panel (I) of Figure 3.2 plots the number of children born to women until age 30 who have at least one child during their lifetime against years of education. This represents the intensive margin of fertility, namely the decision on the number of children conditional on having at least one child, for model

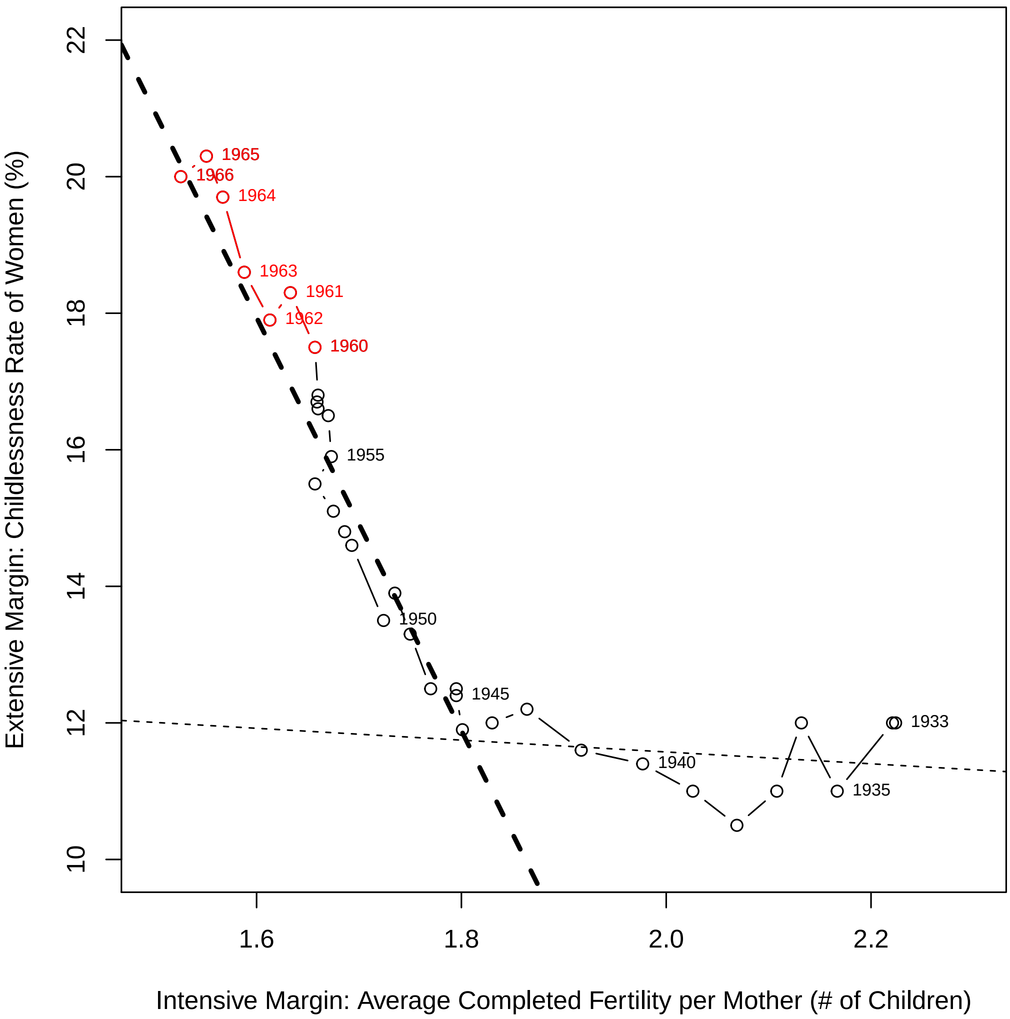
---

[48] The deliberate reduction in fertility and the increase in human capital investment into children (Galor and Weil, 2000; Galor, 2011)

[49] Knodel (1974) dates the onset of the demographic transition for various regions (and different definitions of the onset) in Germany from 1871 to 1939.

[50] For information regarding data and methods used, see chapter 3.4.1.

Figure 3.1: Fertility along the Intensive and Extensive Margin



Notes: Childlessness (y-axis) is defined as the share of the female population that remains without children by age 45. Average Completed Fertility (x-axis) is the total fertility of all women above age 45. Birth cohorts used for estimation in the empirical part of this paper are marked red. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

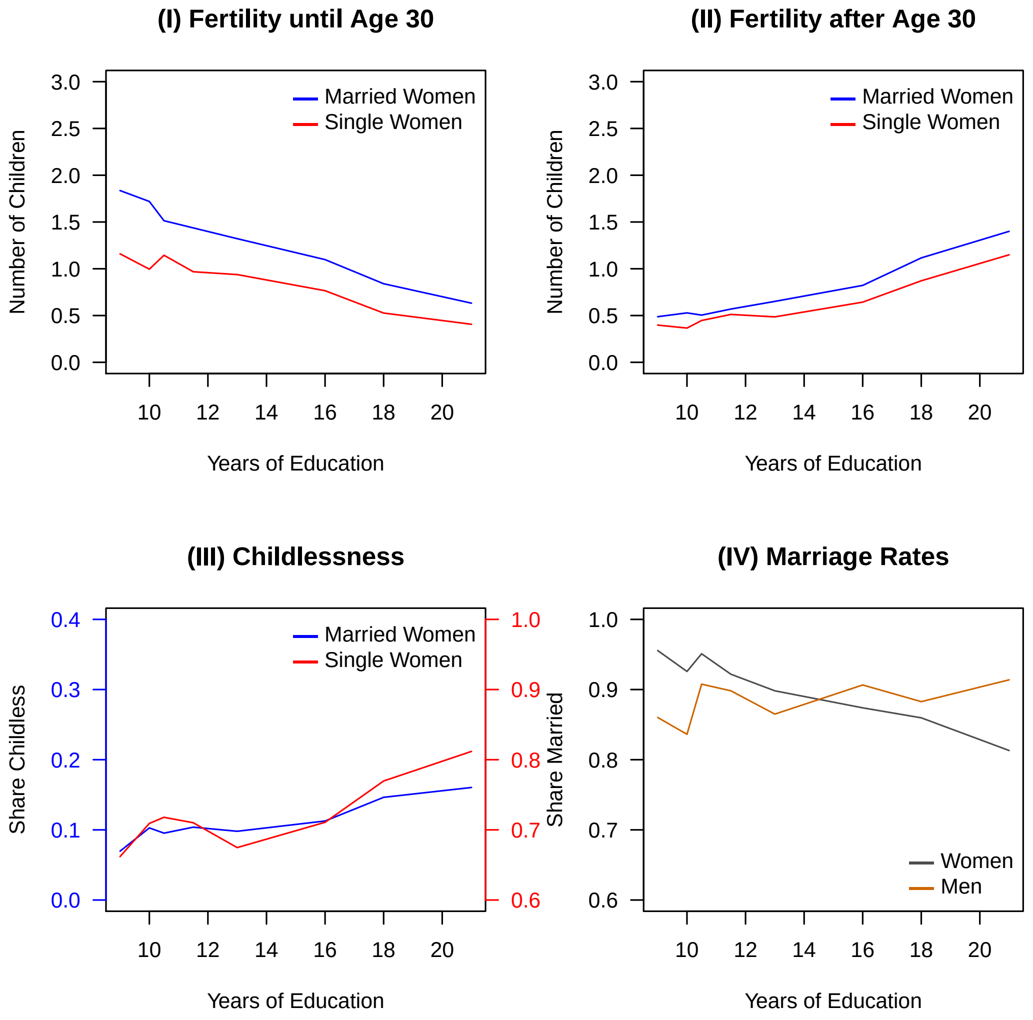


Figure 3.2: Facts from the 2008 & 2012 German Microcensus

Notes: (I) Fertility of mothers until age 30 for married (blue) and single (red) women for different education groups. (II) Fertility of mothers after age 30 for married (blue) and single (red) women for different education groups. (III) Childlessness rate for married (blue, black y-axis on the left) and single (red, red y-axis on the right) women for different education groups. (IV) Marriage rates for women (gray) and men (orange) for different education groups. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

period[51] 1. The relationship between education and the number of children born before age 30 is downward sloping for both married (blue) and single women (red). Across all education groups, married women have on average a higher number of children than unmarried women.

Empirical Fact 2 - Fertility after Age 30: Panel (II) of Figure 3.2 plots the number of children born to women after age 30 who have at least one child during their lifetime against years of education. This is the intensive margin of fertility for model period[52] 2. The relationship between education and the number of children born after age 30 is upward sloping for both married (blue) and single women (red). Similar to the intensive margin for model period 1, married women have on average a higher number of children than unmarried women for model period 2.

Empirical fact 1 and empirical fact 2 jointly indicate the postponement of having children for higher educated women. While women with a relatively low level of education have their children relatively early in life, highly educated women choose to have children later. This can be observed for both married and single women.

Empirical Fact 3 - Increasing Childlessness: Panel (III) plots the share of women who never become mothers by years of education. This represents the extensive margin of fertility, namely the decision to become a mother and have at least one child. The relationship between education and childlessness is upward sloping for both married (blue) and single (red) women. Between 67 and 80 % of single women remain childless. Childlessness rates of married women more than double from less than 8% for women with 9 years of education to almost 18% for women with a PhD.

Empirical Fact 4 - Marriage Patterns: Panel (IV) plots marriage rates for women (gray) and men (orange) by their respective education level. The relationship between education and marriage rates for women is downward sloping, indicating that women with a higher level of education are less likely to get married. The same relationship for

---

[51] Model period 1 refers to individuals until age 30.

[52] Model period 2 refers to individuals above age 30 and until age 45.

men is upward sloping, indicating that men with a higher education level are more likely to get married.

3.2.3 Fertility and Childlessness across Countries

Low fertility rates and high levels of childlessness are not confined to Germany. As a matter of fact, low fertility rates and high levels of childlessness have become a common phenomenon in many countries, both developed and developing. Table B.1 in the appendix provides an overview of total fertility rates and childlessness for a sample of OECD and developing countries.

Germany serves as an exceptionally good example for this phenomenon as it is among the countries with the lowest total fertility rate and highest childlessness rate. Moreover, Germany is composed of regions that belonged to different states until 1990, GDR (German Democratic Republic; East Germany) and FRG (Federal Republic of Germany; West Germany). Both countries had very different approaches to providing publicly available childcare and to encourage female labor force participation.

3.3 Model

In order to capture postponement and childlessness in a structural model, I expand the model by Baudin et al. (2015) to a three-period model.[53] Individuals face a trade-off between accumulating experience during period 1 and a lower likelihood of conception in period 2. Conception in period 1 is more likely, but also costlier in terms of foregone wage growth.[54] The model aims to capture the very basic idea that (female) fecundity decreases with age. In a three-period model, this is reflected by a higher rate of individuals who are unable to conceive for biological reasons. Lastly, the model captures negative wage

---

[53] Baudin et al. (2015) build a model explaining childlessness and fertility conditional on having children in a one-period setting. Childlessness can occur due to biological sterility and economic factors. By additionally adding the timing of children, I expand the model to also include strategic postponement of children for economic reasons. In combination with a naturally decreasing fecundity over time, postponement of children constitutes an additional channel for unintended childlessness.

[54] Similar to Baudin et al. (2015), the model abstracts from unwanted births. Studies on unwanted births place the magnitude in the order between 5% and 8.5% of all births in the US (Mosher et al. (2012) or Bumpass and Westoff (1970)). Since unwanted births are concerning mainly least educated women, I exclude all individuals without any educational background from the analysis. This also partly tackles the issue of reverse causality when women drop out of education because they become pregnant.

penalties after longer times of part-time employment or non-employment due to time taken off for childcare.[55]

Decreases in biological fecundity in the three-period model are captured by a decreasing likelihood to conceive over periods.[56] For the remainder of the paper, "sterility" refers to the inability to conceive children in any period, and "infertility" refers to the inability to conceive children from period 2 onward. In period 3, all women are beyond of their reproductive age. The model assumes that everyone who is willing to have children and is not biologically sterile or infertile can have them in period 1 and 2.[57]

The sequence of events of the model is illustrated in Figure 3.3: In period 1, before fecundity shocks in period 1 are realized, women and men are matched with a potential partner of the opposite gender and have to make their decision on marriage. During the matching process, the share $\omega \in [0, 1]$ of individuals will be matched randomly with a potential partner across all education groups. The remaining share $(1 - \omega)$ is matched with someone within the individuals' own education group. The information available to them is gender, the education level of both partners and the non-labor income of both partners. This allows them to calculate the expected wages and thus expected gains from marriage.

The decision to get married is a non-cooperative decision on whether an individual will enter marriage.[58] Once marriage is entered both spouses behave cooperatively within. Individuals make the decision on entering marriage by calculating their gains from collective cooperative behavior under marriage and comparing their obtained utility to the outside option of single-hood. The model assumes that married couples and single women can have children, whereas single men can not.[59] Individuals who choose to stay single

---

[55] By focusing on never married (single) and always married (married) individuals, the model abstracts from the risk of marriage failure. I am, however, currently working on an extension of this model that will incorporate divorce risk and endogenous divorce decisions.

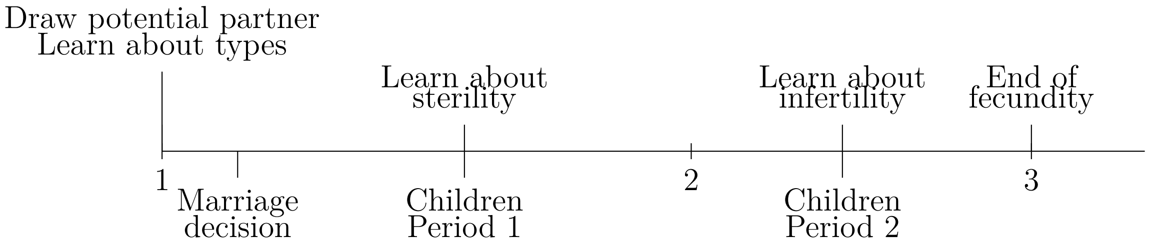
[56] Notes on terminology: The realized number of children is referred to as "fertility". "Fecundity" refers to the biological ability to have children. Some individuals are born sterile. Over time, the biological ability to produce children decreases and more individuals become sterile. For a clear distinction and to avoid confusion, I introduce the terms "sterility" and "infertility".

[57] Leridon (2004) shows that under normal conditions (e.g. without the additional use of assisted reproduction technologies) 75% of all women age 30 will conceive within 1 year and 91% within four years. Since the length of a period in the empirical part is 15 years, one can assume that conception can always be achieved when this is desired and biologically feasible.

[58] Alternatively, marriage could be described as "mutual coincidence of selfish wants".

[59] Women have both an earnings potential and reproductive capital (Low, 2017), whereas men are left with only their earnings potential.

Figure 3.3: Timeline of the Series of Events



Notes: Timeline of the series of events in the model. Numbers indicate the beginning of the respective period. Events depicted above the timeline are exogenous shocks or realizations of the agents. Events illustrated below the timeline are endogenous choices by the agents in the model. Sterility refers to the biological inability to conceive children in any period and is equally distributed between men and women. Infertility refers to the inability to conceive children from period 2 onward and only affects women. At the beginning of period 3 all individuals are no longer able to conceive.

in period 1 remain single in all subsequent periods. Lifetime utility from marriage and under single-hood is calculated by backward induction, given the available information on expected labor income and fecundity. After the decision on fertility is made, individuals (or couples) try to have children. If having children is desired and biologically feasible, the desired number of children is realized. If children are desired but not biologically feasible, individuals learn about their (or their partner's) biological sterility.

At the end of period 2, single women and married couples learn about their biological infertility by not being able to have children if biologically infertile.[60] In the last period, there is no additional decision on fertility, as all women are beyond of their reproductive phase. However, individuals, who had children in both previous periods experience lower wages in the last period.

3.3.1 Utility

The lifetime utility function of the individuals is independent of gender and marital status and defined by:

$$U^i = \sum_{t=1}^{t=3} \beta^{t-1}[\rho\, log(c_t^i) + (1-\rho) log(N_t + \nu)] \tag{3.1}$$

where i indicates individuals and t indicates periods. c_t^i is the consumption of individual i in period t . N_t is the number of children in the household in period t. This includes

---

[60] Biological infertility refers (slightly deviating from the medical usage of the term) to individuals who are unable to receive children during the later phase of what is usually considered the reproductive phase. The parameters for sterility and infertility are taken from the Hutterites and are assumed to be equally distributed across sex and education group. Values are taken from Tietze (1957).

children born in time t and born in all previous periods and can thus be interpreted as the stock of children living in the household at time t. ν is a preference parameter which ensures that utility is well defined even when the number of children is zero. This allows to disentangle childlessness and completed fertility conditional on having children. The model assumes the utility flows from children to be constant across the child's age.[61] The stock of children is considered a public good within the household, consumption is private. Marriage in itself does not provide utility directly, but rather through economies of scale and sharing of child-rearing time between spouses.

3.3.2 Budget Constraints

Having children and taking care of them requires time that would otherwise be available for labor market activity.[62] The time cost required to raise children is split up in a fixed and a variable term. The fixed cost ($\eta_t \in [0, 1]$) has to be paid each period in which a woman gives birth to at least one child. I allow the fixed cost for motherhood to vary across periods to capture changes that make the transition to motherhood less costly over time. This picks up the effect of changes in the children production function over time, as well changes in the costs of becoming a mother that depends on the mothers age at the time of birth of the child. The variable cost ($\phi \in [0, 1]$) has to be paid per child in the period the child is born. This implies that the time spent on child-rearing per child is constant across education groups and time.[63]

Similar to Baudin et al. (2015) and Echevarria and Merlo (1999), the husband contributes $(1 - \alpha)$ to the time spent on raising the children. The remaining share $\alpha \in [0, 1]$ is contributed by the wife. This allows married women to have more children than single

---

[61] During the early years of the child, the utility flow may come from watching the child play and learn. Later, the utility flow may very well come from the child's achievements or simply the fact that the child is able to fix the WiFi/printer/smartphone when visiting.

[62] The model abstracts from leisure. Furthermore, there is no saving or lending in the baseline model. In theory, couples with consumption above $\hat{c}$ but below what is necessary to have children could save in order to be able to be able to afford children later in life. Couples could also borrow money in order to have children early in life. Furthermore, savings that would be split up during a divorce could act as a marriage stabilizing device (similar to Lafortune and Low (2017)).

[63] Potentially, one can assume that more educated individuals spend less time with their children due to the larger opportunity costs. However, there are cases in which more educated individuals spend more time with their children in order to induce more human capital in them (Chiappori et al., 2017). Assuming ϕ to be constant across education groups constitutes a good combined effect and simplifies the model.

women and also makes married women less likely to remain childless. Furthermore, there is a public household good μ that has to be produced by the household, independent of household size. If married, this household good cost is produced jointly.[64]

Time available for work is reduced by the amount of time spent on children. For single women and men, the total time endowment is reduced by the amount $\delta^f \in [0,1]$ and $\delta^m \in [0,1]$, respectively. This cost of being single accounts for the time necessary for household chores that can not be shared with the spouse. δ^f is forced to be smaller than δ^m to account for the fact that women might receive help from others (e.g. their mothers or cohabiting partners) with raising the children, which is otherwise not captured in the model.[65]

There is a minimum consumption level ($\hat{c}$) required for women to be able to have children in a given period. The requirement of a minimum consumption level introduces a non-convexity in the budget constraint that is needed to generate the fertility-income relationship that discretely jumps from zero to one and then decreases in period 1 (as in, Baudin et al., 2015).

Individuals have two sources of income - labor (w) and non-labor (a) income.[66] Labor income partly depends on individual choices. In the model, wages depend on gender, education and previous labor market experience. Individuals observe the wage for their given education level and are fully aware of their return to experience. They are furthermore aware that long periods of part-time employment can impact their future wage substantially. With that in mind, individuals choose how many children to have and how to space them across time. Non-labor income does not depend on any choices or educational background and is drawn from a log-normal distribution with mean $\kappa = ln(\overline{m}_a \cdot \overline{w}) - \frac{1}{2}\sigma_a^2$ and variance σ_a^2. $\overline{w}$ is defined as the mean wage of all women. Thus, $\overline{m}_a$ can be interpreted as the average ratio of labor to non-labor income of women. The non-labor income can be

---

[64] Note that the public household good μ is produced using income rather than time. For married individuals, the public household good is produced before income is redistributed among spouses. See Section 3.3.4 for more details on the bargaining within marriage and resource allocation after bargaining.

[65] The penalty for single-hood also captures other benefits from marriages, such as joint taxation. A single-hood penalty that is smaller for women than for men would also capture relative advantages in home production that women may or may not have and taxation benefits that support single women/mothers.

[66] Non-labor income is necessary to generate the negative aggregate fertility-income behavior in the first period when using a log specification for utility (see, Jones et al., 2010; Baudin et al., 2015).

interpreted as the sum of unconditional transfers, gifts or bequests and is unconditional on education level or endogenous choices.

Formally, this translates into different per period budget constraints for single men (3.2), single women (3.3) and married couples (3.4), respectively.

$$b_t^{s,m}(c_t^m) = c_t^m - (1-\delta^m)w_t^m - a_t^m + \mu \leq 0 \tag{3.2}$$

$$b_t^{s,f}(c_t^f, n_t) = c_t^f + \eta_t w_t^f \mathbb{1}(n_t > 0) + n_t \phi w_t^f - (1-\delta^f)w_t^f - a_t^f + \mu \leq 0 \tag{3.3}$$

$$\begin{aligned} b_t^w(c_t^f, c_t^m, n_t) = c_t^f + c_t^m + \eta_t w_t^f \mathbb{1}(n_t > 0) + n_t \phi[\alpha w_t^m + (1-\alpha)w_t^f] \\ - w_t^f - w_t^m - a_t^f - a_t^m + \mu \leq 0 \end{aligned} \tag{3.4}$$

In addition to the budget constraint, women also face a pure time constraint in the production of children. Women who spend all their available time raising children in fertile periods are restricted in their per period fertility by the pure time constraint $\underline{n}_t^s = \dfrac{1-\delta^f-\eta_t}{\phi}$ for single women and $\underline{n}_t^w = \dfrac{1-\eta_t}{\alpha\phi}$ for married women. Married women can conceive a larger number of children as the husband helps raising the children and the cost of single-hood are absent.[67]

3.3.3 Wages and Labor Market Attachment

At the beginning of period 1, individuals learn about their expected wage for all periods conditional on their labor market participation. The realized wage is a function of their exogenous gender (gen) and education level (educ), as well as the endogenously determined previous labor market experience (exp):

$$w_t^i = f(gen, educ, exp) \tag{3.5}$$

If individuals choose to have children they lose labor market experience which negatively influences future wages. In addition to the loss of experience due to foregone labor market experience in every period, individuals also face a negative wage effect ($\epsilon \in [0,1]$)

---

[67] The resulting value is rounded (down) to the next integer as children are a discrete variable in the model. This makes the model both easier to compute as well as more realistic.

if they spend both fertile periods raising children. The negative wage effect can be a result of discrimination or human capital depreciation due to long absence from full time employment.[68] The negative wage effect is shared between spouses according to their relative share in child-rearing, α for married women and (1 - α) for married men.

3.3.4 Marriage and Bargaining

At the beginning of period 1, individuals draw from the pool of available singles. Each individual draws a peer of own educational background with probability (1 - ω) and randomly from the pool of all available singles with probability ω (drawn from uniform). This ensures some level (1 - ω) of assortatively matched couples by educational background. There is no altruism within marriage.[69] However, there can be transfers within a household as a result of the bargaining process over fertility and consumption choices. Spouses renegotiate their choice variables at the beginning of each period according the cooperative collective decision model:[70]:

$$u(c_t^f, c_t^m, N_t) = \theta_t(w_t^f, w_t^m)u(c_t^f, N_t) + (1 - \theta_t(w_t^f, w_t^m)u(c_t^m, N_t) \tag{3.6}$$

where $\theta \in [0, 1]$ is the wife's bargaining parameter, which itself is defined as:

$$\theta(w_t^f, w_t^m) = \frac{1}{2}\underline{\theta} + (1 - \underline{\theta})\frac{w_t^f}{w_t^f + w_t^m} \tag{3.7}$$

The first part of the bargaining parameter $\underline{\theta}$ is constant, whereas the second part $1 - \underline{\theta}$ varies with the relative income of the partner. This captures the fact that women, regardless of their relative income, always have some minimum level of bargaining power in the marriage.[71] If the parameter $\underline{\theta}$ takes the value of 1, then both spouses have the

---

[68] Long absence from full time employment can also increase the risk of unemployment, which may in addition affect the expected wage in the same way. However, the model does not distinguish those channels, but takes them as given and includes the effect on wages in individuals decision making.

[69] This assumption is in line with Chiappori (1988) and also made in Baudin et al. (2015).

[70] This follows Baudin et al. (2015). The alternative of Nash bargaining, where partners share the marriage surplus, requires some sort of shock to the quality of marriage in order to avoid marriage rates equal to 1. While something of that sort is possible in theory, this model assumes a cooperative collective decision model for simplicity.

[71] Alternative specifications could use relative labor income (as in, e.g., Iyigun and Walsh, 2007) or further include the non-labor income (as in, e.g., Pollak, 2005) instead of the relative wage of both spouses.

exact same bargaining power, irrespective of the relative wage they earn. When $\underline{\theta}$ takes the value 0, then only the relative wage they earn matters for the bargaining position within the marriage. For any given number of children, married individuals pool their financial resources and redistribute them according to the bargaining parameter θ.

When deciding about marriage formation both potential spouses evaluate the value functions for being single and being married and compare the expected obtained utilities. While both potential spouses do not know about their own and their partner's sterility, they take the potential sterility and expected wages for all periods into account. They calculate the expected value of marriage and being single.[72] Only if both agree that marriage is beneficial, they get married. If one of the partners decides not to marry, both remain single and behave optimally under single-hood. For tractability, individuals only have one single draw for a potential marriage partner. As a result, there is no option value of single-hood since there is no outside option of finding a potentially better partner in a subsequent period.

Marriage can be beneficial for several reasons: (i) it provides a higher time endowment as time costs for being single (δ^f and δ^m) are not endured; (ii) the cost for the public household good μ is shared;[73] (iii) women can reach a higher level of consumption for a given number of children as part of the husbands' income is transferred via the household bargaining; (iv) men can (in contrast to being single) enjoy their children and obtain utility from them; and (v) consequences of spacing children out over both periods are mitigated through transfers from the spouse and sharing of costs.

3.3.5 Value Functions and Marriage Decision

Before deciding on marriage formation, individuals calculate their expected utility of marriage and single-hood. In order to do this, individuals evaluate value functions for different potential states they could be in. These states depend on gender (women, men), marital status (married, single) and biological fecundity (sterile, infertile, fertile). The

---

[72] The expected values are calculated by weighting the optimization outcome under sterility (fertility) with the likelihood of being matched with someone who is biologically sterile (fertile), taking one's own potential sterility into account.

[73] A public good within the household is often used in the literature to create the incentive to form a couple.

Table 3.1: Value Functions

Value Functions for the Marriage Decision, t $\in \{1, 2, 3\}$	
$V^{s,m} \equiv \max U(\{c_t^m\}_{t=1}^{T=3}, 0, 0, 0)$ s.t. $\{b_t^m(c_t^m) \leq 0\}_{t=1}^{T=3}$	Single Men
$V^{s,f} \equiv \max U(\{c_t^f\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t^f(c_t^f, n_t) \leq 0\}_{t=1}^{T=3}$	Single Fertile Women
$\tilde{V}^{s,f} \equiv \max U(\{c_t^f\}_{t=1}^{T=3}, 0, 0, 0)$ s.t. $b_t^f(c_t^f) \leq 0\}_{t=1}^{T=3}$	Single Sterile Women
$\bar{V}^{s,f} \equiv \max U(\{c_t^f\}_{t=1}^{T=3}, N_1, N_1, N_1)$ s.t. $\{b_t^f(c_t^f, n_t) \leq 0\}_{t=1}^{T=3}$	Single Infertile Women
$V^{w,i} \equiv U(\{c_t^i\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$, where $\{c_t^f, c_t^m, n_t\}_{t=1}^{T=3} = \text{argmax } U(\{c_t^f\}_{t=1}^{T=3}, \{c_t^m\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t(c_t^f, c_t^m, n_t) \leq 0\}_{t=1}^{T=3}$	Married & Fertile
$\tilde{V}^{w,i} \equiv U(\{c_t^i\}_{t=1}^{T=3}, 0, 0, 0)$, where $\{c_t^f, c_t^m, 0, 0, 0\}_{t=1}^{T=3} = \text{argmax } U(\{c_t^f\}_{t=1}^{T=3}, \{c_t^m\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t(c_t^f, c_t^m, 0, 0, 0) \leq 0\}_{t=1}^{T=3}$	Married & Sterile
$\bar{V}^{w,i} \equiv U(\{c_t^i\}_{t=1}^{T=3}, N_1, N_1, N_1)$, where $\{c_t^f, c_t^m, n_1, 0, 0\}_{t=1}^{T=3} = \text{argmax } U(\{c_t^f\}_{t=1}^{T=3}, \{c_t^m\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t(c_t^f, c_t^m, n_1, 0, 0) \leq 0\}_{t=1}^{T=3}$	Married & Infertile

Notes: All relevant function values are being evaluated before the individuals make their choice on marriage. Women are only potentially fertile in period 1 and period 2.

different value functions for men and women are displayed in Table 3.1. Single men are not able to have children and do not care about sterility or infertility. All other combinations of marriage status and gender (single women, married women, married men) care about infertility and sterility and evaluate the corresponding value functions. Once these value functions are evaluated, the individual chooses the regime that provides most utility.

Marriage occurs if it is beneficial for both partners, which formally means that:

$$(\zeta_f+(1-\zeta_f)\zeta_m)\tilde{V}^{w,i}+(\xi_f(1-\xi_m-\zeta_m)+\xi_m(1-\zeta_f))\bar{V}^{w,i}+(1-\zeta_f-\xi_f)(1-\zeta_m-\xi_m)V^{w,i} \quad (3.8)$$

is larger than

$$\zeta_f\tilde{V}^{s,f} + \xi_f\bar{V}^{s,f} + (1 - \zeta_f - \xi_f)V^{s,f} \quad (3.9)$$

and

$$V^{s,m} \quad (3.10)$$

$\tilde{V}$, $\bar{V}$ and V denote the value of being sterile, infertile and fertile for status $\in (single, married)$ and gender $\in (women, men)$. ζ_i and ξ_i are parameters for sterility and infertility, respectively. Biological sterility and infertility are assumed to be equally distributed across education levels.

Women calculate the value of being married (Equation 3.8) and compare it to the value of single-hood (Equation 3.9). Men compare the value of being married (Equation 3.8) with the value of being single (Equation 3.10). Both individual decisions are independent and there are no general equilibrium effects as there is only a single draw for a potential marriage partner in the model.

3.4 Empirical Analysis

The estimation strategy fixes some parameters of the model and estimates the remaining parameters with a minimum distance estimation technique using Powell's UOBYQA algorithm. A detailed explanation of the identification of the remaining model parameter can be found in section B.9 in the Appendix.

The values for biological sterility and infertility are taken from the Hutterites[74], on whom a number of studies on fecundity exist. According to Tietze (1957), sterility is observed for 2.4% of couples. An additional 8.6% of couples are unable to bear any children after the age of 30. Following Baudin et al. (2015), sterility is split equally among men and women and set at 1.21%. The decrease in fecundity (8.6%, referred to as "infertility") is attributed exclusively to decreases in female fecundity. Both biological components of fecundity are assumed to be equally distributed across education groups and marital status.

Wages are estimated as described in section 3.4.2. I set the bargaining parameter $\underline{\theta}$ to 1. This reflects an equal bargaining weight between men and women that does not depend on the relative wage.[75] Following the specification of the utility function in Baudin et al. (2015), I set the preference parameter ρ to 0.5.

---

[74] Hutterites are a ethnoreligious group, similar to Amish or Monnonites. They are part of a christian movement that originated in the radical reformation in the 16th century. Today, most Hutterites live in North America.

[75] I thank David De La Croix for this helpful suggestion to reduce the estimated parameter space.

3.4.1 Empirical Moments

I obtain empirical moments from the pooled 2008 and 2012 waves of the German Microcensus. The German Microcensus is an annual survey that yields representative statistics on the German population and labor force. Data access is provided by the Research data center (FDZ) of the statistical offices of the German federal states. The Microcensus samples 1% of all persons legally residing in Germany. It is the largest household survey in Europe. Participation is mandatory[76] and only a subset of questions can be answered on a voluntary basis. Typically, one household member responds to the survey for all individuals living in the household, including the spouse and children. The survey program of the German Microcensus consists of a set of core questions that remains unchanged in each wave, covering general socio-demographic characteristics like marital status, education, employment status, individual and household income, and many other things. Unfortunately, only the 2008 and 2012 waves of the German Microcensus entail a question on the completed fertility of women, while all other waves only ask for the number of children (not distinguishing from own biological and other) at different age groups currently present in the household.

I exclude women under the age of 45 from the data to observe completed fertility. To further correctly identify women who gave birth before they were 30 years of age, I make two assumptions. The first one is that children live with their parents until age 18. This is supported by the fact that, from a legal perspective, children under the age of 18 are not allowed to sign legally binding contracts such as rental contracts for an apartment without parental consent. The second one is that in case of divorce and remarriage there is no systematic trend in the selection of a partner by education. This is necessary because remarried women are indistinguishable from only once married women in the data. On the basis of these two assumptions, the moments for identification per education group can be constructed. I subtract the children currently present in the household that were born after age 30 from the completed fertility. This separation gives me children born before and after age 30. Unfortunately, this reduces the sample further as now all mothers over the age of 48 (30 + 18) have to be excluded from the analysis.

---

[76] According to the German Microcensus law, non-response may be fined.

For the baseline results, both waves of the German Microcensus are used in order to maximize the number of observations per cell. Furthermore, I perform a sub-sample analysis for an East-West split and for both waves of the Microcensus separately. I construct the years of education by assigning years of education to individual degrees earned. Then I sum up those years of education across the individuals secondary and tertiary degree, if applicable. The year value assignment to secondary, tertiary and vocational degrees follows the standard of the German Socioeconomic Panel (GSOEP) and is displayed in Table B.2 in the Appendix. All statistics of the observed individuals are weighted by the official sample weights provided by the German Microcensus.

This results in a total of 64 (8 moment dimensions and 8 education groups per moment dimension) means and the corresponding standard deviations that are available as moments for model parameter identification. The moment dimensions are childlessness (for single and married women), children before age 30 (for single and married women), children after age 30 (for single and married women) and marriages rates (for women and men). Education groups (9, 10, 10.5, 11.5, 13, 16, 18 and 21) are constructed to always include a sufficiently high number of observations per cell as well as to reflect population groups with a roughly equivalent educational background.

3.4.2 Wages

In the model, education and gender are exogenous and known before any of the decisions of the individuals are made. Labor market participation is, in every period, a choice variable.[77] I estimate the return on education and experience using the 2015 wave of the German Socioeconomic Panel (GSOEP) and compute wages based on the results as model inputs. The GSOEP provides separate measures for labor market participation depending on full-time or part-time employment.[78] I add both those measures and weight the part time employment by the number of hours worked relative to full time employment. In addition, the GSOEP also provides detailed information on education (see Table B.2 for translation from educational degrees to years of education). The estimation includes an

---

[77] Technically speaking, individuals choose their time spent on reproductive activities and thereby determine their labor market activity. However, individuals are fully aware of the time cost of raising children and implicitly choose fertility and labor market activity simultaneously.

[78] I restrict the sample to individuals who were always employed, either part or full time.

intercept, a linear gender dummy (*gen*), education (*educ*) and labor market experience (*exp*). Education and experience are estimated using a third order polynomial to pick up non-linearities in the development of wages.[79] Table B.4 in the Appendix provides the results of the wage regression.

$$ln(wage) = \beta_0 + \beta_1 gen + \beta_2 educ + \beta_3 educ^2 + \beta_4 educ^3 + \beta_5 exp + \beta_6 exp^2 + \beta_7 exp^3 \quad (3.11)$$

3.4.3 Minimum Distance Estimation

The model is estimated by a minimum distance procedure of the following form:

$$f(p) = [d - s(p)][W][d - s(p)]', \quad (3.12)$$

where p is the vector of parameters, d is the vector of empirical moments and $s(p)$ is the vector of simulated moments, which depend on the model parameters. The weighting matrix W contains $1/var(d)$ on the main diagonal, thus putting a higher weight on more precise moments relative to less precise moments.

I set the parameters for wages (depending on education and experience) based on the estimation result of Section 3.4.2. The wage of individuals is normalized to the wage of a married male with a PhD who contributed all his time to work.[80] The mean (female) wage used for the estimation of non-labor income is taken from the same dataset. The bargaining weight $\underline{\theta}$ is set to 1 (reflecting equal bargaining power of both men and women), the elasticity of the utility function is set to 0.5 to comply with Baudin et al. (2015). Natural rates for sterility and infertility for men and women are taken from Tietze (1957). The remaining 14 parameters (see: Table 3.2) are estimated using the minimum distance procedure. Wages in period 1 are further scaled in order to account for the longer working period of lower educated in comparison to individuals who spend more time in education.

---

[79] I deflate net wage using the CPI with base year 2011. Reported net wages below EUR 1 are excluded as they are unrealistic.Descriptive statistics of the relevant variables are displayed in Table B.3 in the Appendix.

[80] This is simply to obtain relative wages. Married men, who contributed all their time to work have the highest labor income.

The objective function is minimized in three steps to reduce the time required for estimation. First, an initial grid of 500,000 random grid points is evaluated in order to obtain adequate starting values for the optimization routines. Then, a genetic algorithm is used to obtain a rough[81] vector of parameter values. Once the rough region of the global maximum is identified, I use Powell's UOBYQA algorithm to obtain the final results.

All optimization routine steps are performed under R version 3.5.1 with 10,000 observations (matched potential couples) per education group. A detailed description of the optimization routine of Powell can be found in Powell (2002). Standard errors are obtained in a bootstrapping style fashion. The optimization routine is performed for a smaller simulated sample size (10% sample) across various different (n = 500) random number seeds. Rather than drawing repeatedly from the same sample - as standard bootstrapping is performed - this approach samples from different populations to ensure that the parameter values are not a result of a specific drawn sample. The restrictions imposed by this approach are thus more restrictive compared to drawing sub-samples repeatedly from the same sample.

3.4.4 Estimation Results

3.4.4.1 Goodness of Fit

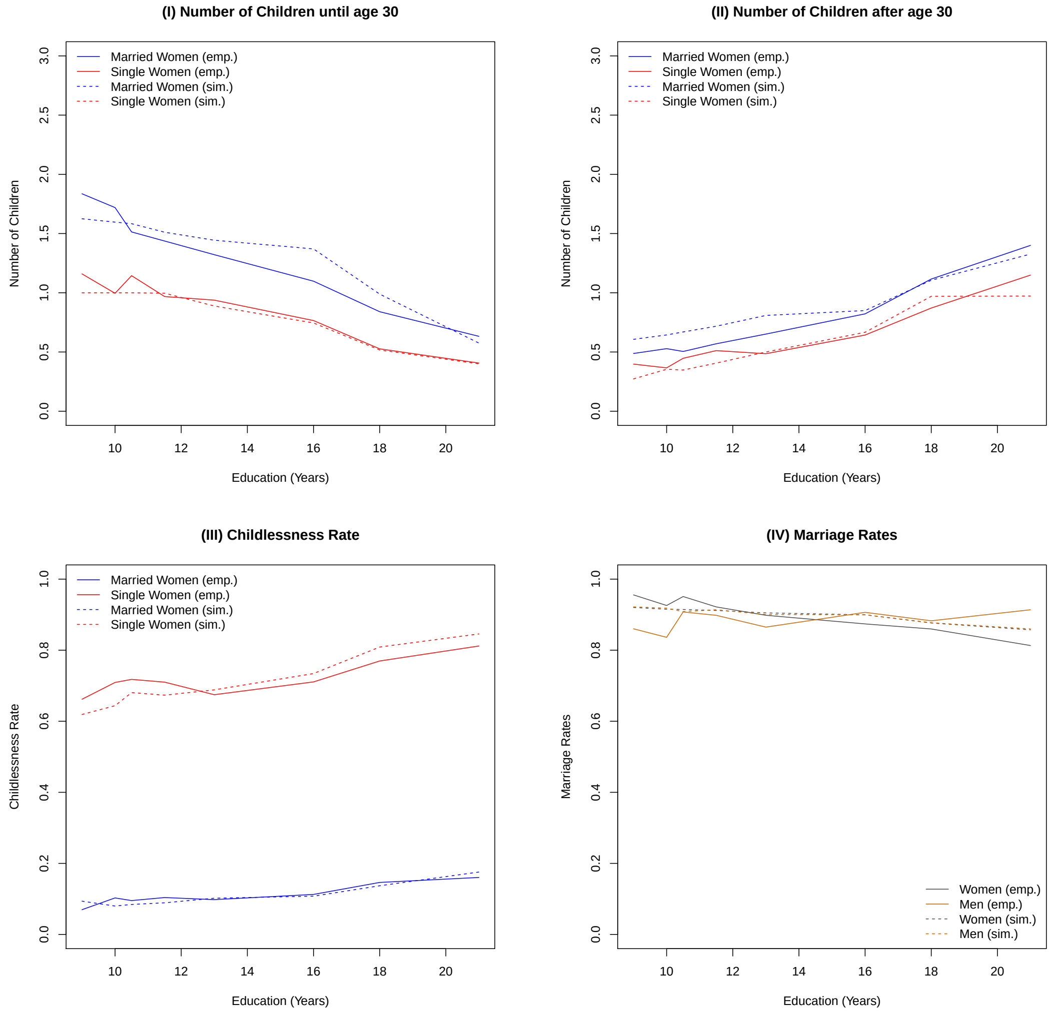
The model fit is illustrated in Figure 3.4. Empirical moments are depicted by solid lines. Simulated model moments are illustrated by dashed lines. The model performs reasonably well in terms of childlessness and fertility patterns for both married and single individuals. Section B.4 in the Appendix provides an overview over the normalized differences between the model and data moments along all model dimensions.

The fertility patterns (Sub-figures (I) and (II) of Figure 3.4) are captured very well for single women for both periods. For married women, the model predicts slightly higher fertility rates for medium educated women in the early life phase and women until 16 years of education after age 30. Sub-figure (III) of Figure 3.4 shows the childlessness rate

---

[81] The generic algorithm is a stochastic optimization method for finding global maxima. In order to save time, the optimization routine is performed until the optimization converges. Once the optimization converged, a more systematic local optimization routine is performed.

Figure 3.4: Model Fit



Notes: Internal fit of the simulated model. Lines are empirical moments, dashed lines are simulation results. (I) Completed Fertility for married (blue) and single (red) women for different educational groups. (II) Childlessness rate for married (blue) and single (red) women for different education groups. (III) Fertility of mothers until age 30 for married (blue) and single (red) women for different education groups. (IV) Fertility of mothers after age 30 for married (blue) and single (red) women for different education groups. (V) Marriage rates for women (gray) and men (orange) for different education groups. (VI) Divorce rates for women (gray) and men (orange) for different education groups. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

for married (blue) and single (red) women by education group, which are closely captured by the model.

The model does a fairly well job capturing the levels of marriages rates (Sub-figure (III) of Figure 3.4). In absence of many aspects that drive marriage formation are absent of the model[82], the model fails to capture the slope for marriage rates. However, normalized differences indicate a relatively good model fit, compared with the other model dimensions.

3.4.4.2 Parameter Values

The estimated structural parameters are reported in Table 3.2. I calculate the standard errors by estimating the model 500 times across different random number seeds for a 10% subset of simulated matched individuals. The discount factor β is estimated at 0.971, indicating very little discounting in the context of fertility planning. The estimated discount factor is roughly equivalent to a 0.2% annual discount rate.[83] The discount rate equivalent to an interest rate below the market rate on the capital market suggests that individuals are willing to save in period 1 in order to be able to afford children in period 2. The preference parameter (ν) is estimated to be 6.137.

On top of the cost of motherhood ($\eta_1 = 0.187$, $\eta_2 = 0.013$) women contribute the (slightly) larger share ($\alpha = 0.546$) of the variable time cost of children ($\phi = 0.620$). The estimated parameter α from Baudin et al. (2015) is very close to the α estimated here. However, in Baudin et al. (2015) the male partner also contributes to the fixed cost of becoming a parent, which results in a larger share of male participation. Comparing the total cost of children over the lifecycle indicates that both partners have a more equal share of the child-rearing for children born after the age of 30. This is due to the sharp decrease in the fixed costs of becoming a mother. In period 1, married women contribute 65.1% of the total child rearing time for the first child. This number decreases to 55.5% for married women in period 2. The negative wage effect of spacing children across both periods ϵ is estimated at 62%.

---

[82] Most prominently: Love

[83] Without savings/borrowing, the number of children is the only "asset" that can be inter-temporally allocated. The "consumption" of children throughout the lifecycle is thus driving this very low discount rate.

The time costs of single-hood δ^f and δ^m are estimated at 0.106 and 0.321, for women and men respectively. Thus, single women loose 10.6% of their available time per period (time is normalized to 1) for being single. In addition to the cost of single hood, single women also face the full cost of the public household good ($\mu = 0.677$), while married women share this cost with their spouse. The minimum consumption level ($\hat{c}$), after which individuals decide to have children, is estimated at 0.461. These numbers together indicate that married women can have two children per period, whereas single women can only have one child per period at most. While these numbers seem very low, it is important to keep in mind that public childcare during the times when those women became mothers was largely unavailable and even school for children ended around noon. This forced many women/couples to spent a considerable amount of time with their children rather than working.

The estimation results indicate that social benefits and other non-labor income ($\overline{m}_a$) roughly equals 1.3 times (standard deviation $\sigma_a = 0.513$) the average earnings of a female individual. While this seems to be rather high, Baudin et al. (2015) find their estimate to be around 1 in the context of the US, where social policies tend to be less generous than in Europe. A single woman of the lowest education level needs a non-labor income of 1.106 ($= \hat{c} + \mu - w(1 - \delta_f - \eta_1 - \phi)$, based on unrounded values) in period 1 not to be social sterile. In period 2, a single woman of the highest educational background needs a non-labor income of 0.947 ($= \hat{c} + \mu - w(1 - \delta_f - \eta_2 - \phi)$, based on unrounded values) not to end up childless.[84]

Germany has a relatively generous social system, supporting (single) mothers in financial distress. Nevertheless, the non-labor income is unreasonable large unless we include potential monetary flows from parents and biological fathers, who do not live with the single mother, to the interpretation. However, it is also important to keep in mind that this is an "optimal choice" model that abstracts from unwanted births. In reality, this may not always be given. When getting shocked with a "non-optimal" child[85], (single) women would probably end up consuming less than under optimality, investing less in

---

[84] The non-labor income is relative to the earnings of a married male with a PhD, since time is normalized to 1 for married and wages are normalized to the wage of a married male with a PhD. Furthermore, consumption above the minimum consumption level does not automatically result in children as those may not be optimal.

[85] Conditional on giving birth, as abortions are an option.

their child (e.g. through ϕ), save on the public household good μ or do a combination of those things.

The percentage of individuals marrying someone with the same educational background is almost 60%. While this may be surprising in the context of other countries, this is very much within expectations for Germany, given the education system that puts children into certain academic achievement tracks from early age onward. Depending on individual competencies and achievements, German schoolchildren attend separate schools after the 4th or 6th grade (depending on the federal state) already.

Table 3.2: Estimation Results

Parameter	Description	Estimate	S.E.
β	Discount factor	0.971	0.008
σ_a	Standard deviation of the log-normal distribution	0.513	0.003
ν	Preference parameter	6.137	0.013
μ	Good cost to be supported by a household	0.677	0.005
α	Fraction of child-rearing to be supported by women	0.546	0.003
ϕ	Time cost of having children	0.620	0.003
η_1	Fixed cost of children (period 1)	0.187	0.003
δ_m	Time cost for being single (men)	0.321	0.010
δ_f	Time cost for being single (women)	0.106	0.003
$\hat{c}$	Minimum consumption level for procreation	0.461	0.003
$\overline{m}_a$	Average ratio of non-labor income to labor income	1.327	0.005
ϵ	Wage effect of spacing children across time	0.617	0.008
η_2	Fixed cost of children (period 2)	0.013	0.003
ω	Share of randomly matched on marriage market	0.427	0.011

Note: Estimated parameters of the model. Parameters for wages and natural sterility and infertility are set. Standard errors are computed by bootstrapping across different random number seeds. Values rounded.

3.4.5 Decomposition of Childlessness

The model allows decomposing the reasons for childlessness into two main categories: Voluntary childlessness and involuntary childlessness. In the case of voluntary childlessness, individuals optimally decide not to have children. In the case of involuntary childlessness, individuals would like to have children, but are unable to have them. Voluntary childlessness again can be separated into two sub-categories: On the one hand, women (or couples) who's consumption would fall below the minimum consumption level if having children are too poor to have children. Their reason for childlessness is thus "Poverty". On the other hand, women (or couples) can choose to have zero children due to high opportunity costs. The reason for their childlessness is "Optimal". Involuntary childlessness can also be separated into two sub-categories[86]: Some women (or couples) are unable to conceive children in any period for biological reasons. The reason for childlessness of sterile women (or couples) reflects "Sterility". Other women (or couples) are exposed to declining fecundity, namely infertility. They would have been able to have children in period 1, decide to postpone having children to period 2 for economic reasons and end up childless. The reason for childlessness of infertile women (or couples), who decide to postpone their fertility to period 2, is "Postponement".

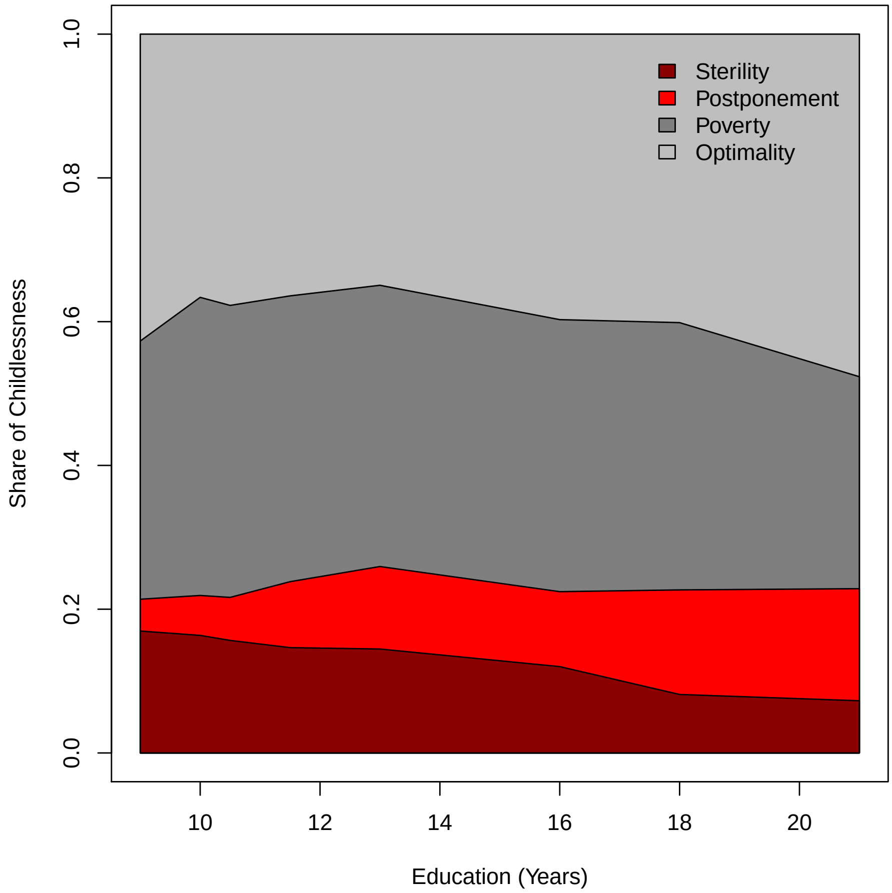
Figure 3.5 and Table 3.3 present the reasons for childlessness (conditional on being childless) for all education groups estimated by the model. The results by marital status are reported in Table B.9 in the Appendix. Within each block, rows sum up to 1. My first finding is that the vast majority of childlessness in Germany is voluntary. Involuntary childlessness explains only about 21% to 26% of childlessness, depending on educational background. Within voluntary childlessness, the share of women, who remain childless due to "Poverty", is declining in education. This is a result of increasing wages. However, the higher wages of highly educated women also make those more likely to remain childless due to opportunity cost ("Optimal"). The results for reasons of involuntary childlessness show large variation. The relative share of women who remain childless due to postponement of children increases monotonically from about 20% (women with basic secondary education, 9 years) to almost 70% for women with a PhD (21 years of education). Thus, "Postponement" is twice as important in explaining childlessness among highly educated women than "Sterility". When investigating the sub-sample of single women, the relative share of involuntary childlessness due to "Postponement" even exceeds 80% for highly educated women. The share of total childlessness within an education group that is a result of "Postponement" can be calculated by multiplying the share of "Involuntary" with the share of "Postponement". Depending on education, this share increases from 4.4% in the case of basic secondary education to 15.6% for women

---

[86] I can also separate childlessness by the time individuals learn about the fact that they will be involuntarily childless. Results are reported in Table B.10 in the Appendix.

with a PhD. Similarly, the share of "Sterility" decreases from 11.6% to 7.2%. I obtain the aggregate effect on the population level by weighting those shares according to the relative size of the education groups in the population. "Postponement" explains 7.6% and "Sterility" explains 15.0% of total childlessness at the population level.

Figure 3.5: Reasons for Childlessness (Baseline)



In the case of voluntary childlessness, the outcome is optimal from an individual's perspective. This is not the case for involuntary childlessness, which results in utility loss. The size of the loss in individual's utility depends on the type of involuntary childlessness, marital status as well as labor and non-labor income. In general, there are two counteracting effects. First, the loss in the number of children directly results in lower utility. Second, the time that is now available for market work (rather than child-rearing) results in more consumption, both directly via the supply of labor and indirectly via the return to experience that increases wages for following periods. I quantify the loss of utility (in terms of equivalent net present value consumption) for some illustrative

Table 3.3: Reasons for Childlessness (Baseline)

			Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.786	0.214	0.457	0.543	0.793	0.207
2	0.781	0.219	0.531	0.469	0.746	0.254
3	0.784	0.216	0.518	0.482	0.724	0.276
4	0.762	0.238	0.522	0.478	0.615	0.385
5	0.741	0.259	0.528	0.472	0.557	0.443
6	0.776	0.224	0.488	0.512	0.535	0.465
7	0.773	0.227	0.481	0.519	0.359	0.641
8	0.771	0.229	0.382	0.618	0.318	0.682

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in baseline. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

examples of the following population groups: (i) a single sterile woman and (ii) a single infertile woman, (iii) a married couple exposed to sterility, (iv) a married couple exposed to infertility.

Single women require a sufficiently large non-labor income, to avoid social sterility and potentially become mothers. Depending on the relative size of labor and non-labor income those single women decide to have a child in period 1 or period 2. The first illustrative example is a single sterile woman with 16 years of education and a non-labor income 47.9% above the average. Optimally, such a woman would choose to have one child in period 1 and zero children in period 2. The change from having one child in period 1 to childlessness results in a loss of lifetime utility equivalent to 22.0% of net present value lifetime consumption. This effect is counteracted by increases in consumption as a result of higher labor market participation. This second effect closes the gap in individual's utility from 22.0% to 4.6% in equivalent net present value consumption. The total loss in utility increases with non-labor income as a higher labor income is needed to offset the loss in utility from having zero children. Increases in education, on the other hand, lower the final gap for a given non-labor income as a result of higher wages and larger returns to experience.

The second illustrative example is a single infertile woman with 16 years of education and a non-labor income 23.4% above the average. This woman would optimally wait until period 2 to have a child and benefit from larger wage growth in period 1. The loss in utility due to the transition from one child in period 2 to zero children is equivalent to a net present value lifetime consumption loss of 14.4%. The counteracting labor supply effect closes the gap in individual utility to 1.2% in equivalent net present value consumption. Compared to sterility, the total effect of infertility is substantially smaller as the loss in utility from the reduced number of children is only experienced for two instead of three periods. Similar to the case of sterility, the total loss in utility increases for small increases in non-labor income and decreases by educational background. Sufficiently large changes in non-labor income, however, will result in children being optimal in period 1 already.

Due to a higher number of children under optimal conditions, the effects of sterility and infertility are substantially larger for married couples. For a marriage in which both partners have 16 years of education, an average non-labor income and where (at least) one partner is biologically sterile, the loss in lifetime utility per person is equivalent to a present value lifetime consumption decrease of 62.1%. The labor supply effect decreases the loss in utility to 25.9% in equivalent consumption. Since married individuals pool their financial resources, this value is the same across genders. The total loss in utility increases with the non-labor income of both partners and decreases with the education. The effect of increases in education is not equal across both genders. Women contribute a larger share of child-rearing, which increases the effect size of the labor supply effect more for women than men.

The same married couple (both 16 years of education and average non-labor income) would experience a loss in total utility equivalent to 5.2% of net present value consumption per individual in the case of biological infertility. The effects are substantially smaller than for sterility, as the couple is only restricted in their period 2 fertility and can have the intended number of children in period 1. The effect of the loss in period 2 children is reduced by the labor supply effect from 21.0% to 5.2% in equivalent consumption.

3.4.6 Heterogeneity between East and West Germany

For the baseline results I use the pooled 2008 and 2012 waves of the German Microcensus, covering Germany in total. In this section, I estimate the model separately for East and West Germany to address (persistent) institutional differences between both former countries. Furthermore, I estimate the model separately for the 2008 and 2012 waves of the Microcensus. The model parameters are displayed in Table 3.4. For readability, the results, including standard errors, are reported in Table B.11 in the Appendix.

Table 3.4: Estimation Results for Subsamples

Parameter	Description	Baseline	West	East	2008	2012
β	Discount factor	0.971	0.954	0.964	0.971	0.994
σ_a	Standard deviation of the log-normal distribution	0.513	0.537	0.500	0.513	0.524
ν	Preference parameter	6.137	6.010	6.129	6.237	6.154
μ	Good cost to be supported by a household	0.677	0.689	0.658	0.677	0.678
α	Fraction of child-rearing to be supported by women	0.546	0.554	0.537	0.546	0.535
ϕ	Time cost of having children	0.620	0.617	0.600	0.620	0.623
η_1	Fixed cost of children (period 1)	0.187	0.198	0.074	0.187	0.192
δ_m	Time cost for being single (men)	0.321	0.346	0.345	0.321	0.331
δ_f	Time cost for being single (women)	0.106	0.105	0.157	0.106	0.103
$\hat{c}$	Minimum consumption level for procreation	0.461	0.417	0.445	0.461	0.462
$\overline{m}_a$	Average ratio of non-labor income to labor income	1.327	1.211	1.344	1.327	1.314
ϵ	Wage effect of spacing children across time	0.617	0.544	0.719	0.617	0.614
η_2	Fixed cost of children (period 2)	0.013	0.005	0.041	0.013	0.010
ω	Share of randomly matched on marriage market	0.427	0.498	0.452	0.427	0.428

Note: Estimated parameters of the model for different data subsets (West Germany, East Germany, 2008 Microcensus and 2012 Microcensus). Parameters for wages and natural sterility and infertility are set. For readability bootstrapped standard errors are reported in table B.11 in the appendix.

Overall, all subsets yield relatively similar results. This is in particular the case for the separate analyis of the 2008 and 2012 waves of the German Microcensus. There are, however, substantial[87] differences between East and West Germany.

There are three different channels through which the exposure to the German Democratic Republic (GDR, East Germany) could have affected fertility behavior for East German women.[88] First, government ideology could change the utility received from children. This would be captured in differences in the preference parameter ν. Second, women were expected to work and not take time off to raise children. Thus, staying at home to raise children could result in a higher wage penalty in East Germany compared to West Germany. Third, socialist ideology aimed to emancipate women in the labor market by providing largely available public childcare. In the model, this is captured by differences in the cost of children, either fixed (η_1, η_2) or variable (ϕ).

---

[87] In the presence of generally very low standard errors in structural estimation, I refrain from using the term “significant” to avoid confusion.

[88] Presented in reverse order of magnitude/importance. However, I acknowledge that there are potentially more that are not captured by the model.

For the preference parameter for children, I find a difference of 0.119 between East and West Germany. Women (and couples) in East Germany obtain a larger utility already from having zero children. However, these differences are small compared to the parameter value (6.010 for West and 6.129 for East Germany). The small difference relative to the parameter value indicates that there are no large effects of government ideology on the preference for children between East and West Germany.[89] I find the effect of spacing children over both periods, a negative wage penalty, to be substantially larger in East Germany. Compared to 0.544 for West Germany, the parameter value increases by 32% to 0.719 in East Germany. This shows that there are larger negative effects of prolonged absence from the labor market in East compared to West Germany. The wage effect may be intensified by the fact that the late reproductive phase of the women in the sample starts around the time of the German Reunification. During this time, individuals in the East had to adapt to the market-based economy of West Germany, which made absence from the labor market even more costly as previously obtained human capital depreciated faster.[90] All those effects jointly result in a 32% larger wage penalty for a long absence from the job market due to child-rearing for East compared to West Germany. For a more short-term microeconometric analysis of the consequences of the fall of the Berlin wall see Chevalier and Marie (2017), who find strong but short-lasting negative fertility responses in East Germany, in particular among higher educated women.

Finally, there is a remarkable difference between East and West Germany in the fixed costs of becoming a mother (η_1 and η_2). While the costs of becoming a mother are relatively constant for East Germany, it decreases substantially for West Germany and even surpasses East Germany. Differences in the variable cost of children (ϕ) are relatively small. Historically, East and West Germany had very different approached to public provision of childcare. While women in West Germany usually dropped out of the labor force for the time they raised their children, women in East Germany continued their career and could rely on largely available public childcare. In fact, the extent to which affordable public childcare was available in East Germany is often seen as a potential role

---

[89] For a childless married West German women, where both spouses have 16 years of education and an average non-labor income, the effect of having the East German ν instead of the West German ν results in a utility increase that is equivalent to a 2.8% increase in net present value consumption.

[90] An additional option can be higher unemployment risk as a result of long absence from the labor market. This effect would also be stronger in combination with the German Reunification.

model for West Germany, even today. For a more detailed investigation of the changes of the fixed cost of becoming a mother, a back-of-the-envelope difference-in-difference calculation of the time cost of the first child is performed in Table 3.5.

Table 3.5: Time Cost for First Child (Differences Analysis)

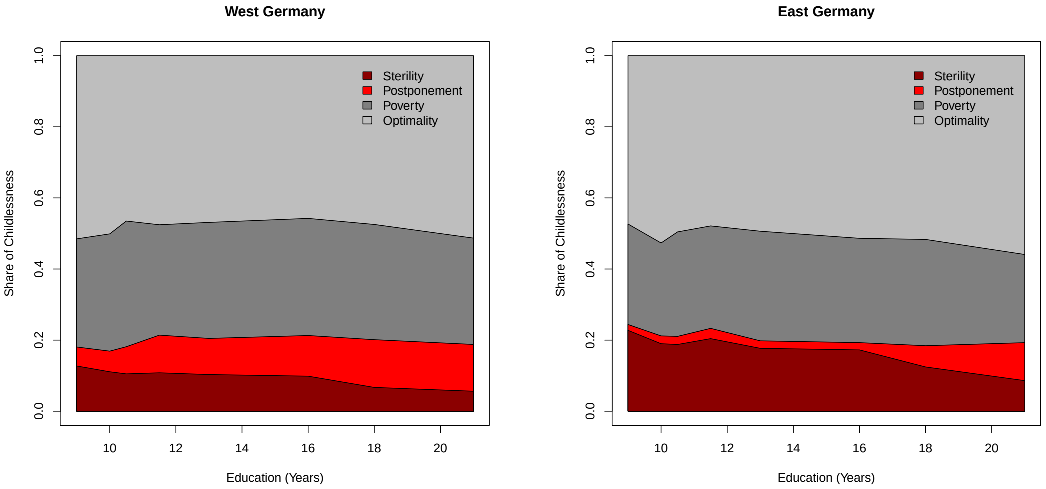
Time	West	East	*Difference*
Before Age 30	0.541	0.396	0.145
After Age 30	0.347	0.363	-0.016
Difference	0.194	0.033	0.161

Note: Full (fixed and variable) time cost of the first child for married women. Values are based on sub-sample estimation results for East and West Germany. Values rounded.

There are several potential reasons for the large decline in the fixed cost of becoming a mother over the lifecycle in West Germany: (i) Increasing efficiency due to age/experience, (ii) expansion of the public provision of childcare, or (iii) increasing support from parents, as those are more likely to reach retirement and are able to provide informal childcare. As a matter of fact, García-Morán and Kuehn (2017) document that some women/couples in Germany locate near their parents or in-laws for informal childcare support.

Unfortunately, this simple calculation does not allow to disentangle the effects of the expansion of public childcare over the observed time from the effect of the provision of informal childcare by relatives, such as parents. However, under two assumptions the joined effect of informal provision of childcare and increases in the publicly availability of childcare can be calculated. First, age-related efficiency gains in the production of children developed in parallel in East and West Germany. Second, due to the large scale availability of public childcare the informal provision of childcare, informal childcare is not of major importance / less common in East Germany. The raw difference in the time required to raise the first child between the two periods is 0.194 for West Germany and 0.033 for East Germany. Attributing the 0.033 to the age effect, leaves a joint effect of 0.161 for increases in the provision of both public and informal childcare for West Germany. This equals 83% of the fixed cost of becoming a mother in period 1.

Figure 3.6: Reasons for Childlessness (West Germany vs. East Germany)



Notes: Subsample Analysis - Reasons for childlessness by womens' education for West Germany (left sub-figure) and East Germany (right sub-figure). Sample restricted to women who are childless.

These differences in the costs of having children are also reflected in the reasons for childlessness in East and West Germany. Then differences are illustrated in Figure 3.6. Table 3.6 and tables B.12 and B.13 in the Appendix provide an overview over the reasons for childlessness by womens' education level. The left block contains the reasons for childlessness for West Germany, the right block for East Germany. The higher time costs of children in West Germany are a large factor for childlessness. The higher costs of children lead to a larger share of voluntary childlessness among most education groups in West Germany Within voluntary childlessness, "Poverty" is (apart from the very low educated) consistently of greater importance in West Germany. Within involuntary childlessness, "Postponement" is of larger importance in West Germany. This is a result of the larger drop in fixed time cost of becoming a mother between period 1 and period 2 for West Germany. Given the same return to experience, the very small difference in the fixed time cost of mother-hood does not trigger as much postponement of parenthood in East Germany. This is illustrated by the larger share of "Postponement" (red) in the left sub-figure of Figure 3.6.

Table 3.6: Reasons for Childlessness (West Germany vs. East Germany)

	West Germany						East Germany					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.819	0.181	0.371	0.629	0.704	0.296	0.756	0.244	0.374	0.626	0.933	0.067
2	0.831	0.169	0.397	0.603	0.656	0.344	0.788	0.212	0.332	0.668	0.896	0.104
3	0.819	0.181	0.432	0.568	0.579	0.421	0.789	0.211	0.372	0.628	0.892	0.108
4	0.786	0.214	0.395	0.605	0.505	0.495	0.767	0.233	0.376	0.624	0.876	0.124
5	0.795	0.205	0.410	0.590	0.504	0.496	0.802	0.198	0.384	0.616	0.894	0.106
6	0.787	0.213	0.419	0.581	0.463	0.537	0.807	0.193	0.364	0.636	0.894	0.106
7	0.799	0.201	0.406	0.594	0.333	0.667	0.816	0.184	0.366	0.634	0.675	0.325
8	0.812	0.188	0.368	0.632	0.300	0.700	0.807	0.193	0.307	0.693	0.446	0.554

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless. Left block for West Germany, right block for East Germany. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

3.5 Counterfactual Simulations

In this section, I use the estimated model parameters to simulate the impact of policy changes and labor market conditions on fertility along the intensive and extensive margin. I use the structural model to simulate the behavior for a sample of 10,000 (potential) couples per education group[91] for counterfactual underlying parameter values. In particular, I simulate changes in the availability of public childcare and changes in the wage penalty for spacing children across time. I make use of the previously obtained results for East and West Germany to simulate the counterfactual states for the implementation of the East German public childcare system and the East German wage penalty to West Germany. Furthermore, I assess how potential future increases in the wage penalty can be counteracted by expansion of public childcare. The model fit of the West German model is displayed in Table B.2 in the Appendix.

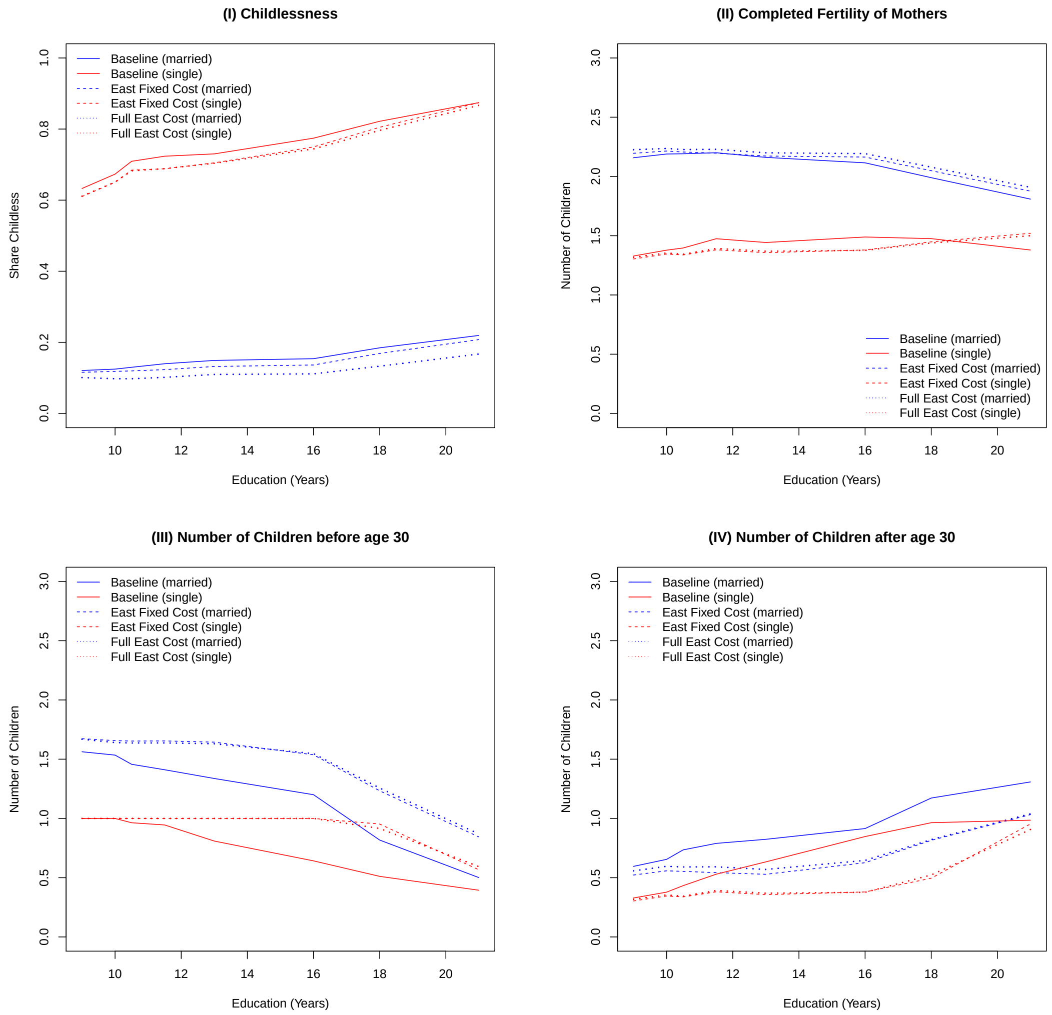
3.5.1 Public Provision of Childcare

For the first counterfactual experiment, I simulate a full application of the East German public provision of childcare to West Germany. I assume that everyone who desires publicly provided childcare is able to obtain it. I further assume that individuals always choose the cheapest childcare option. In period 1, this is the East German fixed (η_1) and variable (ϕ) cost of children. In period 2, this is the West German fixed (η_1) and East German variable (ϕ) cost of children. The results are illustrated in Figure 3.7 and tables B.14 and B.15 in the Appendix. The comparison of the counterfactual experiments with the empirical moments is illustrated in Figure B.3 in the Appendix. The solid line plots

---

[91] With 8 education groups, this results in 80,000 potential couples.

Figure 3.7: Application of the East German Children Production Costs



Notes: Counterfactual Simulation - Simulating the application of the East German children production costs to West Germany. Lines are baseline estimation moments, dashed lines are simulation results for the application of the fixed cost (η_1) in period 1 only, dotted lines are the simulation results for the full application of the East German children production costs (η_1 & ϕ).

the baseline moments. The dashed line plots the results for the application of the fixed cost of motherhood (η_1). The dotted line plots the full application of both fixed (η_1 and variable (ϕ) cost of children.

For the sole implementation of the East German fixed cost of becoming a mother in period 1 (η_1, dashed line), I observe a lower number of childless single women for all education groups but the most highly educated. As a result of the changed composition, the completed fertility for single mothers of all but the most highly educated is lower. Most highly educated single women postpone motherhood to period 2, both in baseline and counterfactual. As a result, I observe very little differences in the rate of highly educated childless single women. However, those highly educated single women, who in counterfactual decide to have their children in period 1 already, increase completed fertility. For married women, I find slightly lower rates of childlessness and higher rates of fertility across all education groups.

When additionally also applying the East German variable cost for children (ϕ), the rate of childlessness is lower for both married and single women across all education groups. For single women, in particular highly educated ones, I find lower rates of childlessness. The completed fertility of highly educated single women is slightly lower compared to the application of only the East German fixed cost of children. This is due to women's transition from single-hood to marriage. For married women, I observe a substantial lower degree of childlessness. The main reason for the differences between the application of only the fixed costs and the application of both fixed and variable costs is that the latter also affects the costs of children from the husbands' labor supply perspective. In the case of a sole reduction in the cost of becoming a mother, men are only affected via consumption and consumption transfers from/to their wife. This makes the childlessness of married women react stronger to changes in the variable cost of children (ϕ), both compared to single women and to only the application of the East German fixed cost of children in period 1 (η_1).

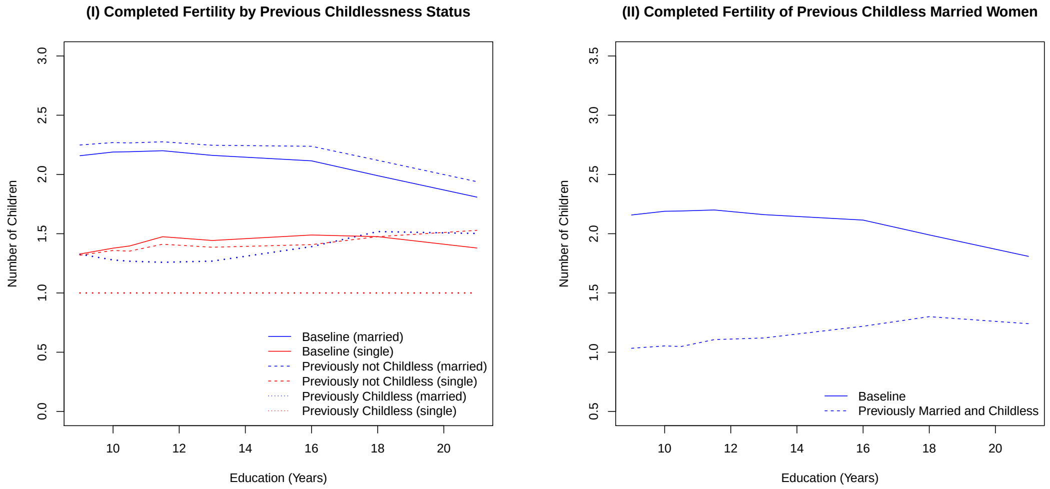
More striking than the differences in the completed fertility, are the differences in the postponement of children. In particular, the education level after which optimal postponement behavior starts increases to about 16 years of education for married women and 18 years of education for single women. The higher number of children in period 1 is offset by a lower number of children in period 2, resulting in little change in the completed fertility of mothers. I find relatively little differences for the shift in inter-temporal allocation of children between both counterfactual scenarios. However, the transition from baseline to counterfactual results in substantial inter-temporal allocation shifts for children.

Next, I investigate the transition from childlessness to motherhood under the counterfactual scenario. I decompose the fertility rates of women, who have children in counterfactual, into "new" mothers and mothers who were already mothers in baseline. Subfigure (I) of Figure 3.8 plots the completed fertility of mothers. The solid line plots the baseline results. Dashed lines illustrate the completed fertility of previously not childless women. Dotted lines illustrate the results for previously childless women. Single women are marked red, married women blue. I observe that previously married women who already had children in baseline display a slightly higher completed fertility following the reduction in childcare cost. Married women with children in counterfactual who were childless in baseline have a completed fertility between 1.3 and 1.5 children, depending on education. Those women exhibit a lower average number of children per mother (conditional on having children), but a higher overall number of children are born as they were previously childless. Compared to baseline, we observe lower completed fertility rates for most single women as a result of some women leaving single-hood into marriage. Single women who were childless at baseline but are single mothers now only have one child, independently of educational background. Single women are constrained in their per period fertility to one child, due to the time constraint. Thus, if previously childless single women decide to have children in one period only, they will automatically have exactly one child.

Sub-figure (II) of Figure 3.8 plots the completed fertility of women who are childless in baseline and married in both the baseline and the counterfactual. This comparison investigates only the impact of the lower costs of children for married women, excluding selection into marriage that changes the composition of the underlying population of married women. The solid line plots the baseline results. The dashed line illustrates mothers who were previously married and childless. I observe an upward sloping completed fertility pattern. If children are considered a normal good, decreases in the relative price, compared to other types of consumption, will result in a larger consumption share of children.

Lastly, I investigate how the full adoption of the East German cost of children affect the reasons for childlessness. The reasons for childlessness are reported in Table 3.7. I find that the lower fixed cost of becoming a mother causes less postponement of children to period 2. This is reflected in the lower relative share of “Postponement” as the reason for childlessness, compared the West German baseline results. Next, I focus on individuals who transition from one reason of childlessness in baseline to either being a

Figure 3.8: Transitions Out of Childlessness



(I) Completed Fertility by Previous Childlessness Status

(II) Completed Fertility of Previous Childless Married Women

Notes: Counterfactual Simulation - Simulating the application of the East German children production costs (η_1, & ϕ) to West Germany. The left figure plots the completed fertility of women by previous childlessness status. Regular lines indicate the baseline results, dashed lines plot previously not childless women and dotted lines plot previously childless women. Single women in the counterfactual simulation are illustrated in red, married women in blue. The right figure plots the completed fertility of women who are married in both baseline and counterfactual were childless in baseline. Regular lines plot the baseline results, dotted lines illustrate previously married childless women.

parent or to another reason for childlessness in counterfactual.[92] The transition shares of previously childless women are displayed in Table 3.8. The reason for childlessness in baseline is reported in rows, the reason for childlessness in counterfactual in columns. Within each block, shares sum up to one. Individuals (or couples) not changing their status in childlessness are displayed on the diagonal. The largest movement, when using the full sample of previously childless women, is from optimal childlessness to not being childless. This effect is largely driven by married women. The effect size of the transition from constrained to not childless is substantially smaller in absolute terms. However, childlessness due to poverty is only a factor for single women in baseline. Weighting the share by the relative size of single compared to married women, effect sizes become roughly similar. Focusing only on individuals who change their status (either in childlessness or the reason for childlessness, right block of Table 3.8), I find that almost 60% of women/couples transition from “Optimal” to not being childless. The second largest group, with almost 30% of all transitions, switches from “Postponement” to not childless. Regarding transitions into involuntary childlessness, I find 1.3% of all transitions to transition to “Sterility” and 4.2% to transition to “Postponement.”

---

[92] Application of both East German fixed cost of becoming a parent in period 1 (η_1) and variable cost of children (ϕ)

Table 3.7: Reasons for Childlessness (East German η_1 / East German η_1 & ϕ)

	East German η_1						East German η_1 & ϕ					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.842	0.158	0.364	0.636	0.837	0.163	0.813	0.187	0.407	0.593	0.809	0.191
2	0.858	0.142	0.391	0.609	0.820	0.180	0.832	0.168	0.451	0.549	0.790	0.210
3	0.858	0.142	0.426	0.574	0.800	0.200	0.839	0.161	0.489	0.511	0.807	0.193
4	0.851	0.149	0.393	0.607	0.805	0.195	0.821	0.179	0.454	0.546	0.784	0.216
5	0.856	0.144	0.408	0.592	0.810	0.190	0.827	0.173	0.474	0.526	0.763	0.237
6	0.848	0.152	0.419	0.581	0.718	0.282	0.823	0.177	0.486	0.514	0.708	0.292
7	0.839	0.161	0.408	0.592	0.449	0.551	0.813	0.187	0.485	0.515	0.476	0.524
8	0.833	0.167	0.369	0.631	0.351	0.649	0.800	0.200	0.432	0.568	0.347	0.653

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual scenarios. Left block for the application of the East German η_1 to West Germany, right block for the application of the East German η_1 and ϕ to West Germany. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table 3.8: Childlessness Transitions (East German η_1 & ϕ for West Germany)

		New Status (All)					New Status (Switchers)		
		Not Childless	Sterility	Postponement	Poverty	Optimal	Not Childless	Sterility	Postponement
Old Status	Sterility	0.000	0.092	0.000	0.000	0.000	0.000	0.000	0.000
	Postponement	0.057	0.000	0.046	0.000	0.000	0.298	0.000	0.000
	Poverty	0.012	0.000	0.000	0.309	0.000	0.061	0.002	0.000
	Optimal	0.112	0.002	0.008	0.000	0.363	0.585	0.011	0.042

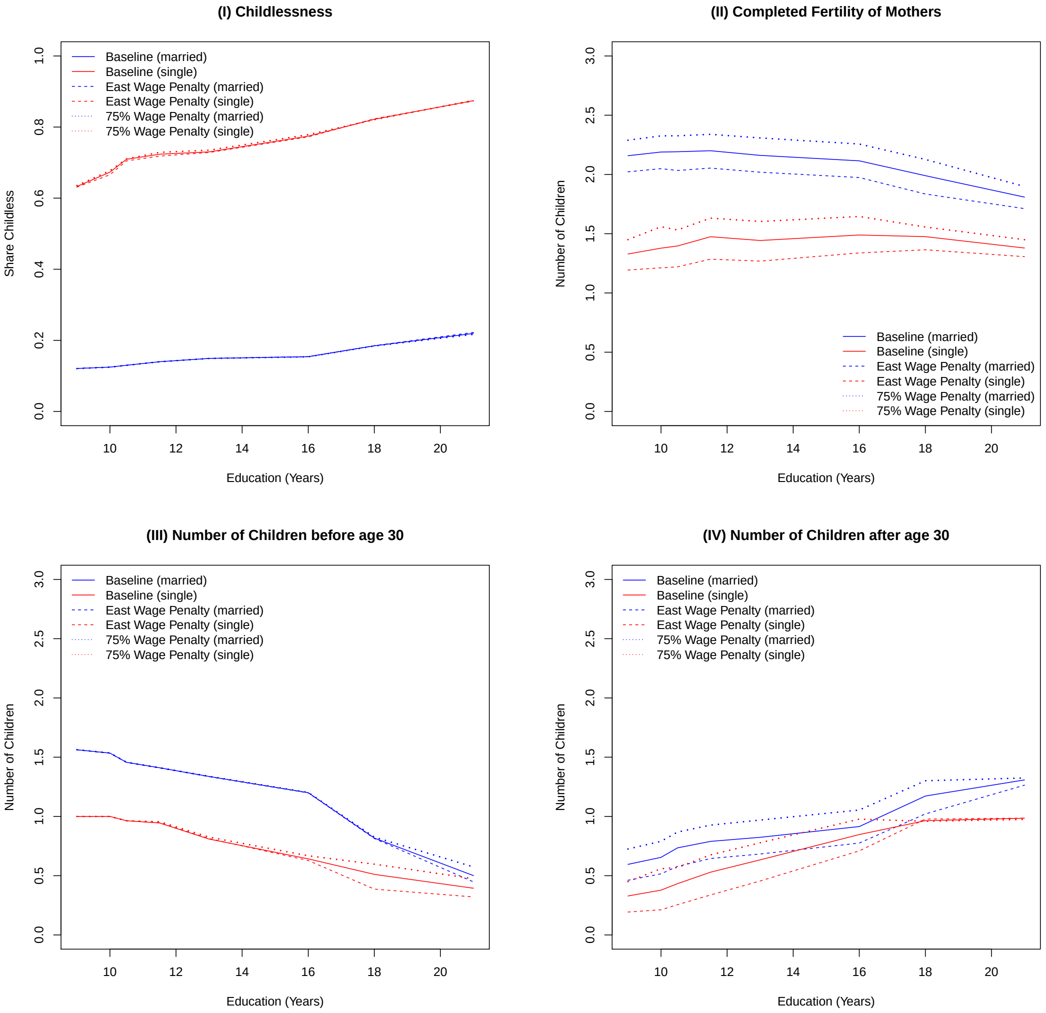
Note: Transitions in the reason for childlessness. Sample restricted to women/couples who are childless in baseline. Old status refers to the reason for childlessness in baseline, new status in the counterfactual. "Switcher" is restricted to women/couples that change their status, either with respect to childlessness or the reason for childlessness. Values rounded.

Summing up, both counterfactual simulations indicate that public provision of accessible childcare affects the timing of children much more than the final number of children per mother. As a result of the much lower costs for children in terms of foregone labor income and experience, a larger fraction of women/couples decides to have children earlier in life. This is counteracted by (almost equally) corresponding lower fertility rates after the age of 30. I find childlessness to decrease for all women, independent of marital status and education. Overall, about 19% of previously childless women change either their reason for childlessness or transition out of childlessness, with the largest share transitioning to parenthood. Calculating the completed cohort fertility for the counterfactual state, weighting the education groups by their respective share in the population, results in a completed cohort fertility of 1.737. This is equivalent to a 13.5% increase in the completed cohort fertility compared to the observed data[93] for the birth cohort of 1966. In the observed data for women born in 1966, the completed cohort fertility in Sweden is 31.0% above the one for Germany. In the counterfactual state, this difference would be reduced by half to 15.4%.

---

[93] Data taken from the Human Fertility Database (www.humanfertility.org)

Figure 3.9: Application of Alternative Wage Penalties to West Germany



Notes: Counterfactual Simulation - Simulating changes in the wage penalty (ϵ). Solid lines are the baseline results moments, dashed lines are simulation results for the application of the East German wage penalty (ϵ), dotted lines are the simulation results for a 25% decrease in the wage penalty (ϵ).

3.5.2 The Wage Effect of Spacing Children across Time

The other major difference between the East and West German sub-sample concerns the wage penalty for having children in both periods, which is the parameter of interest for this counterfactual experiment. The results of changes in the parameter ϵ to West Germany are illustrated in Figure 3.9 and Tables B.18 and B.19 in the Appendix. The comparison of the counterfactual experiments with the empirical moments is illustrated in Figure B.4 in the Appendix. The solid line plots the baseline moments. The dashed line plots the results for the application of the East German wage penalty (ϵ) to West Germany. The dotted line plots the result of a 25% reduction in the wage penalty (ϵ).

The wage penalty affects only individuals who choose to have children in both periods. Provided that there are no changes in the marital status, a decrease in the parameter should only affect fertility rates, leaving the childlessness rates unaffected.[94] The reaction of the childlessness rate to a change in the labor market attachment risk are very small for both married and single women (see Tables B.20, B.21 and B.22). This indicates that the labor market attachment channel does not influence the marriage decision substantially. In addition, there are almost no changes in the reasons for childlessness as indicated by Table B.20 for the full childless population and Table B.21 and Table B.22 in the Appendix for the heterogeneity analysis with respect to marital status.

When applying the East German wage penalty to West Germany, I observe declining fertility rates for both married and single women across all education levels. The effect size is slightly smaller for highly educated women, as those are less likely to space children across time in baseline already. The opposite effect can be observed for the 25% decrease in the wage penalty. For most women the wage penalty of spacing children across affects only the number of children born after age 30. However, the opposite is true for highly educated women, who are more likely to postpone motherhood. As a result of lower costs of spacing children across time, all individuals are more likely to have an additional child in the period in which they would otherwise not have children.

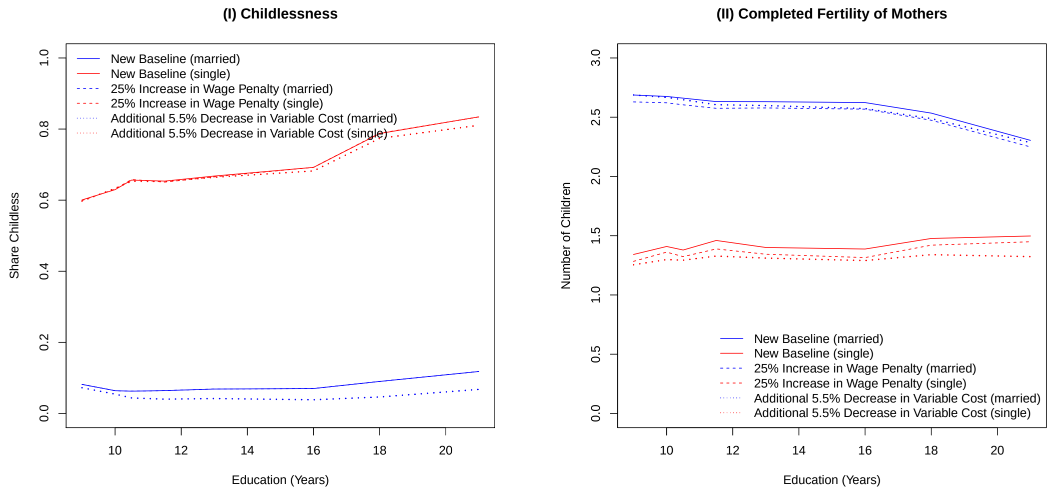
3.5.3 Counteracting the Wage Penalty by Expansion of Public Childcare

In a last counterfactual experiment, I show how increases in the wage penalty of spacing children across time (ϵ) can be counteracted by reductions in the variable cost of children (ϕ). In particular, I assume a 25% increase in the wage penalty (ϵ) and a counteracting 5.5% decrease in the variable cost of children (ϕ). The increase in the wage penalty can come in many forms. Either through discrimination of women spending extended periods of time taking care of their children, or in the form of human capital depreciation. A possible example of human capital depreciation is automation and artificial intelligence, which fundamentally changes the way we work and has the potential to render some

---

[94] In the first period, sterility is the only driver of involuntary childlessness. If sterile, the woman (or couple) does not have children. If not sterile, the women (or couple) will not be childless.

Figure 3.10: Changes in Wage Penalty and Variable Costs of Children



Notes: Counterfactual Simulation - Simulation of a 25% increase in the wage penalty (ϵ) and a counteracting 5.5% reduction in the variable cost of children (ϕ). Regular lines indicates the new baseline simulation, dashed lines illustrate the application of only a 25% increase in the wage penalty (ϵ) and dotted lines indicate an additional 5.5% reduction in the variable cost of children (ϕ).

currently useful human capital obsolete in the future. Not keeping up with the quickly changing work environment and adopting important human capital can negatively affect future wages. The reduction in the variable cost of children can come in many forms that are individual specific, such as investments in the child's human capital in publicly available childcare. The new baseline scenario uses the baseline results for Germany. Furthermore, I apply the East German cost of children and the West German cost of spacing children across time for a more realistic baseline comparison for the future.

The results are illustrated in Figure 3.10. A figure including fertility per period (Figure B.5) and tables indicating the differences per education group (Table B.23 and Table B.24) are in the Appendix. The solid line plots the new baseline moments. The dashed line plots the results for the application of a 25% increase in the wage penalty (ϵ). The dotted line illustrates an additional counteracting 5.5% decrease in the variable cost of children (ϕ).

In line with the previous results of changes in the wage penalty, as documented in Section 3.5.2, the increase in the wage penalty has no influence on childlessness. For the number of children, conditional on being a mother, I observe a parallel downward shift of the completed fertility curve for both married and single women. When additionally applying a 5.5% reduction to the variable cost of children, heterogeneous effects by education and marital status can be observed along both margins of fertility. Childlessness decreases for all education levels, with larger effects for highly educated women, both single and married. The 5.5% reduction in the variable cost of children leads to an increase in completed fertility for married women across all education groups. The effect is largest for very low and very highly educated women. For those two groups, the decrease in variable cost of children almost completely offsets the reduction in completed fertility due to the increase in the wage penalty. For single women, we observe an additional decrease in completed fertility across all education groups. Similar to the observations from previous counterfactuals, this is the result of single women now transitioning out of childlessness to motherhood and from single-hood to marriage.

3.6 Conclusion

This paper presents a structural estimation of fertility and childlessness that includs various potential causes of the observed low fertility rates that Germany experienced since the early 1980s. The structural model parameters are identified using labor market conditions of individuals combined with distinct features of fertility behavior. The research provides novel insights into the interaction of economic and biologic channels in determining childlessness.

The model allows me to decompose the reasons for childlessness into voluntary and involuntary childlessness. Even though voluntary childlessness is the main driving factor for high rates of childlessness, I find that a substantial share of childlessness is involuntary. Women who choose to have children late in life and suffer from decreasing fecundity explain 7.6% of total childlessness. The effect size increases by education from 4.4% for women with only a low level of secondary education to 15.6% for women holding a PhD. I quantify the disutility of childlessness in terms of equivalent consumption and find larger effects for married women compared to single women and for sterility compared to infertility.

I perform a sample split between former East and West Germany to further investigate the impact of institutional differences between those two former states. When looking at the cost of the first child, I find consistently smaller costs of children in East

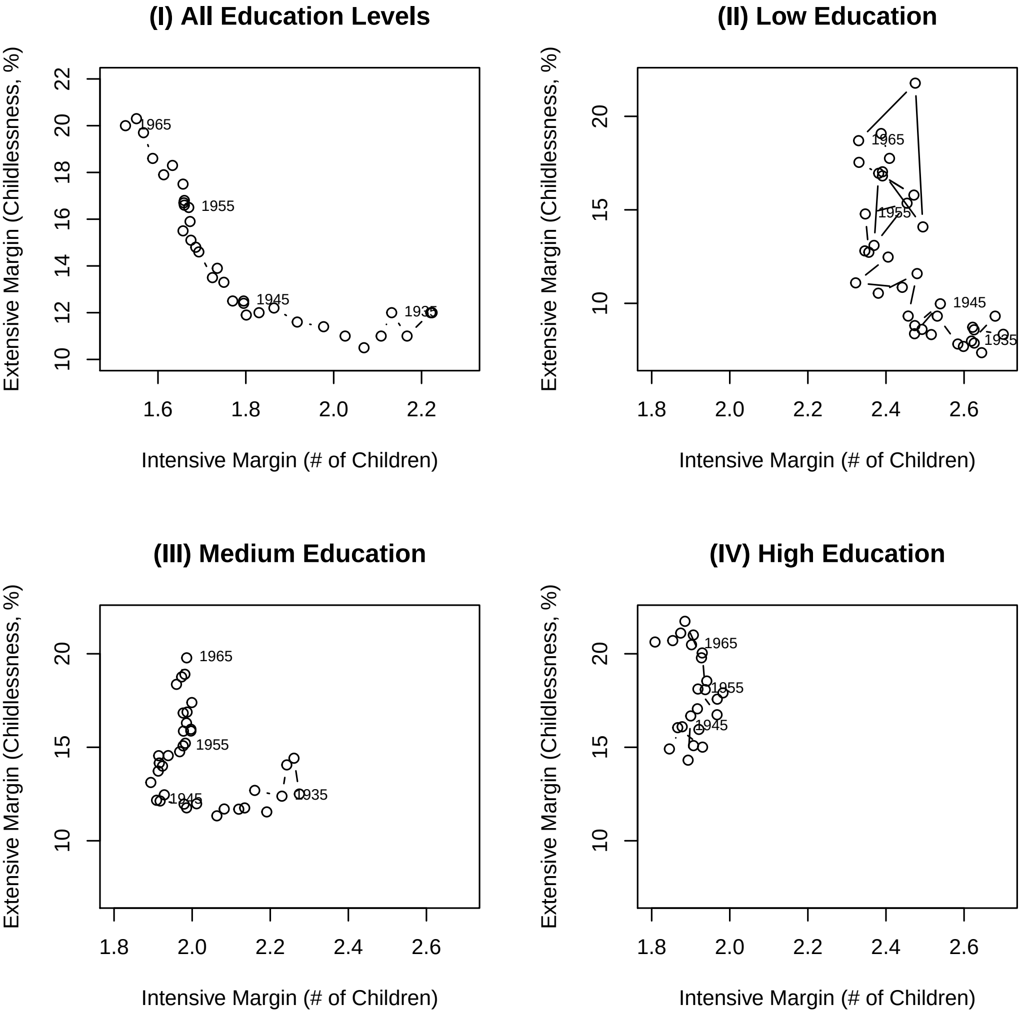
Germany compared to West Germany across both periods. However, the gap between East and West Germany decreases substantially over time, which may be a result of the expansion of the provision of publicly available childcare and/or the availability of informal childcare in West Germany. The long lasting persistent differences between East and West Germany with respect to time cost of children result in higher levels of poverty driven childlessness and involuntary childlessness due to postponement of having children in West Germany.

Lastly, I perform several counterfactual analyses. I show that lowering the costs of children can result in lower rates of childlessness and higher rates of fertility, conditional on having at least one child. However, the inter-temporal allocation of children is much more affected than the final number of children born to mothers. Nevertheless, expansion of public childcare would result in a lower age at first birth of women, a lower number of women who remain childless and a higher completed fertility, conditional on having children. I also show that increases in the negative wage effects of spacing children across time can be counteracted by reductions in the variable costs of children. Those reductions can come in any child-specific human capital investment, such as public provision of after school care that helps children develop their talents and prepare for school.

Appendix B

B.1 Historic Development by Mother's Education

Figure B.1: Fertility along the intensive and extensive Margin - by Education



Notes: Childlessness (y-axis) is defined as the share of the female population that remains without children by age 45. Average Completed Fertility (x-axis) is the total fertility of all women above age 45. Women with a low education level ($\leq$ 9 years of schooling) are plotted black, women with some sort of vocational training (years of schooling $>$ 9 & $<$ 13) are plotted blue and women with a high level of education (years of schooling $\geq$ 13) are plotted red. Due to the low number of women with a high level of education in the birth cohorts before 1945, those cohorts are not plotted for the high education subgroup. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

B.2 Cross Country Comparison for TFR and Childlessness

Table B.1: TFR and Childlessness: Cross Country Comparison

Country	TFR	Childlessness	Data Source
Austria	1.52	0.21	OECD Family Database
Czech Republic	1.69	0.08	
Denmark	1.75	0.13	
Estonia	1.59	0.10	
Finland	1.49	0.21	
Hungary	1.49	0.12	
Japan	1.43	0.27	
Lithuania	1.63	0.12	
Netherlands	1.62	0.18	
Norway	1.62	0.11	
Poland	1.45	0.16	
Portugal	1.37	0.07	
Slovak Republic	1.52	0.12	
Slovenia	1.62	0.12	
Spain	1.31	0.18	
Sweden	1.78	0.12	
United States	1.77	0.12	
Argentina	2.26	0.30	Myong, Park and Yi (2018)
Cameroon	4.64	0.18	
China	1.60	0.08	
Hong Kong	1.19	0.12	
Singapore	0.83	0.24	
Tanzania	4.77	0.09	
Uruguay	1.08	0.27	

Note: For countries where data is obtained from the OECD Family Database, TFR are measured in 2017, whereas childlessness is measured for women born in 1970. For countries where data is obtained from Myong, Park and Yi (2018), childlessness is calculated by multiplying marriage rates with childlessness rates conditional on marital status.

B.3 Wage Regressions

Table B.2: Years of Education by Educational Type

Education Type	Education Title	Years
Secondary Education	Hauptschule	9.0
	Polytech. Oberschule DDR	10.0
	Realschule	10.0
	Fachhochschulereife	12.0
	Abitur	13.0
Tertiary Education	Anlernung	0.0
	Berufsvorbereitungsjahr	1.0
	Lehre	1.5
	Berufsschule	1.5
	Beamtenschule	1.5
	Gesundheit (1 Jahr)	2.0
	Meister	2.5
	Fachschule DDR	2.0
	Fachakademie (Bayern)	2.0
	FH	3.0
	Uni	5.0
	PhD	8.0

Note: Assignment of years of education to educational degrees following the procedure used in the GSOEP.

Table B.3: Descriptive Statistics (GSOEP)

Statistic	N	Mean	St. Dev.
Education (Years)	50,520	12.35	2.63
Experience (Years)	50,520	15.20	7.82
Gross Labor Income (EUR)	50,520	2,317.01	1,540.43
Net Labor Income (EUR)	50,520	1,514.72	963.03
Net Wage (EUR)	50,520	16.42	11.81
Log Wage	50,520	2.66	0.52

Table B.4: Regression Output

	Dependent variable:
	Net Labor Income (log)
Male	0.232^{***}
	(0.002)
Education	-0.075^{***}
	(0.011)
Education(sq)	0.008^{***}
	(0.001)
Education(cu)	-0.0001^{***}
	(0.00002)
Experience	0.039^{***}
	(0.001)
Experience(sq)	-0.001^{***}
	(0.00003)
Experience(cu)	0.00001^{***}
	(0.00000)
Constant	1.991^{***}
	(0.045)
Observations	225,805
R^2	0.332
Adjusted R^2	0.332
Residual Std. Error	0.348 (df = 225797)
F Statistic	$16{,}065.220^{***}$ (df = 7; 225797)
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

B.4 Model Fit: Normalized Differences

Table B.5: Model Fit: Childlessness

Marital Status	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Single Women	1	0.619	0.662	0.473	0.091
	2	0.644	0.709	0.454	0.144
	3	0.681	0.718	0.450	0.083
	4	0.673	0.710	0.454	0.081
	5	0.688	0.675	0.468	0.029
	6	0.734	0.711	0.453	0.052
	7	0.809	0.770	0.421	0.093
	8	0.846	0.812	0.391	0.087
Married Women	1	0.094	0.070	0.255	0.094
	2	0.080	0.103	0.304	0.075
	3	0.084	0.095	0.294	0.037
	4	0.089	0.104	0.305	0.048
	5	0.102	0.098	0.297	0.013
	6	0.108	0.113	0.316	0.016
	7	0.137	0.146	0.353	0.027
	8	0.176	0.160	0.367	0.042

Table B.6: Model Fit: Children before Age 30

Marital Status	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Single Women	1	1.000	1.160	0.924	0.173
	2	1.000	0.996	0.794	0.005
	3	1.000	1.145	0.946	0.153
	4	0.997	0.968	0.885	0.032
	5	0.889	0.938	0.833	0.059
	6	0.745	0.766	0.703	0.029
	7	0.517	0.527	0.735	0.013
	8	0.400	0.407	0.591	0.011
Married Women	1	1.625	1.836	1.081	0.195
	2	1.597	1.719	1.093	0.113
	3	1.584	1.514	0.913	0.076
	4	1.511	1.437	0.954	0.078
	5	1.444	1.322	0.964	0.127
	6	1.370	1.098	0.958	0.284
	7	0.989	0.840	0.922	0.161
	8	0.575	0.632	0.943	0.061

Table B.7: Model Fit: Children after Age 30

Marital Status	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Single Women	1	0.273	0.398	0.642	0.194
	2	0.354	0.366	0.612	0.019
	3	0.348	0.447	0.590	0.168
	4	0.406	0.512	0.688	0.153
	5	0.500	0.486	0.686	0.021
	6	0.667	0.643	0.678	0.034
	7	0.970	0.871	0.697	0.142
	8	0.973	1.149	0.864	0.204
Married Women	1	0.607	0.488	0.761	0.157
	2	0.644	0.528	0.820	0.141
	3	0.669	0.505	0.734	0.225
	4	0.718	0.569	0.776	0.191
	5	0.809	0.651	0.834	0.189
	6	0.850	0.822	0.879	0.032
	7	1.106	1.116	0.945	0.011
	8	1.327	1.400	0.943	0.078

Table B.8: Model Fit: Marriage Rates

Gender	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Women	1	0.920	0.956	0.319	0.111
	2	0.915	0.926	0.390	0.027
	3	0.914	0.951	0.349	0.105
	4	0.912	0.922	0.406	0.025
	5	0.905	0.898	0.428	0.016
	6	0.899	0.874	0.442	0.058
	7	0.876	0.860	0.443	0.038
	8	0.857	0.813	0.457	0.097
Men	1	0.922	0.860	0.418	0.148
	2	0.918	0.836	0.449	0.183
	3	0.908	0.908	0.383	0.002
	4	0.914	0.898	0.403	0.039
	5	0.900	0.865	0.429	0.082
	6	0.900	0.907	0.382	0.018
	7	0.877	0.883	0.396	0.014
	8	0.860	0.914	0.357	0.151

B.5 Additional Baseline Results

Table B.9: Reasons for Childlessness (Baseline)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.786	0.214	0.457	0.543	0.793	0.207	0.996	0.004	0.990	0.010	1.000	0.000	0.208	0.792	0.000	1.000	1.000	0.000
2	0.781	0.219	0.531	0.469	0.746	0.254	0.996	0.004	0.974	0.026	1.000	0.000	0.255	0.745	0.000	1.000	1.000	0.000
3	0.784	0.216	0.518	0.482	0.724	0.276	0.990	0.010	0.955	0.045	1.000	0.000	0.282	0.718	0.000	1.000	1.000	0.000
4	0.762	0.238	0.522	0.478	0.615	0.385	0.993	0.007	0.947	0.053	0.750	0.250	0.387	0.613	0.000	1.000	1.000	0.000
5	0.741	0.259	0.528	0.472	0.557	0.443	0.989	0.011	0.954	0.046	0.714	0.286	0.445	0.555	0.000	1.000	1.000	0.000
6	0.776	0.224	0.488	0.512	0.535	0.465	0.986	0.014	0.887	0.113	0.300	0.700	0.458	0.542	0.000	1.000	1.000	0.000
7	0.773	0.227	0.481	0.519	0.359	0.641	0.983	0.017	0.833	0.167	0.176	0.824	0.635	0.365	0.000	1.000	1.000	0.000
8	0.771	0.229	0.382	0.618	0.318	0.682	0.987	0.013	0.672	0.328	0.188	0.812	0.679	0.321	0.000	1.000	1.000	0.000

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in baseline. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table B.10: Timing of Involuntary Childlessness (Baseline)

	Married Childless Women		Single Childless Women		Married Childless Men	
Education	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
1	0.717	0.283	1.000	0.000	0.656	0.344
2	0.664	0.336	1.000	0.000	0.617	0.383
3	0.631	0.369	1.000	0.000	0.583	0.417
4	0.507	0.493	0.750	0.250	0.479	0.521
5	0.425	0.575	0.714	0.286	0.422	0.578
6	0.352	0.648	0.300	0.700	0.353	0.647
7	0.192	0.808	0.059	0.941	0.211	0.789
8	0.079	0.921	0.062	0.938	0.116	0.884

Note: Reasons for involuntary childlessness. Sample restricted to women/couples who are involuntariy childless. Period refers to the period in which sterility/infertility is realized by individuals. Values rounded.

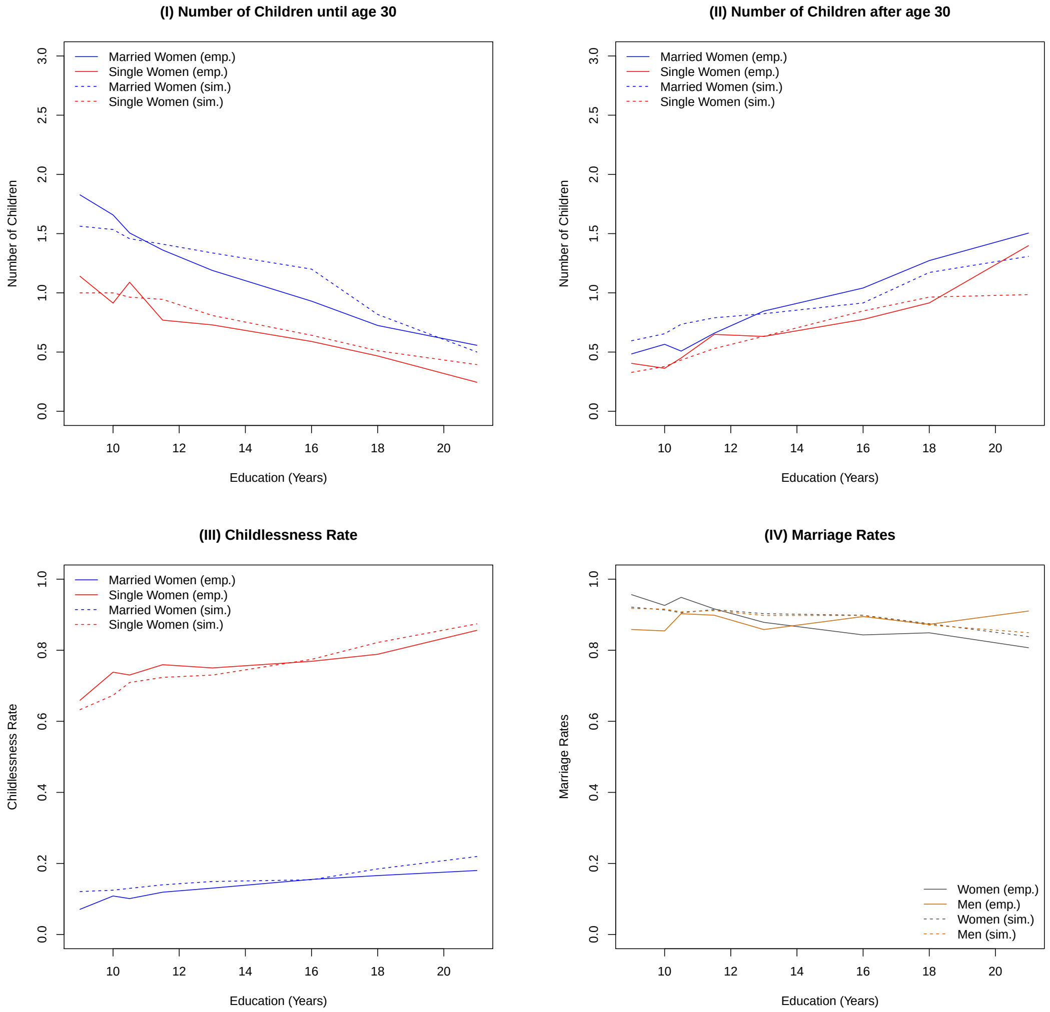
B.6 Additional Sub-sample Results

Table B.11: Estimation Results for Subsamples

Parameter	Description	Baseline	West	East	2008	2012
β	Discount factor	0.971	0.954	0.964	0.971	0.994
		(0.008)	(0.011)	(0.005)	(0.009)	(0.009)
σ_a	Standard deviation of the log-normal distribution	0.513	0.537	0.500	0.513	0.524
		(0.003)	(0.003)	(0.005)	(0.004)	(0.003)
ν	Preference parameter	6.137	6.010	6.129	6.237	6.154
		(0.013)	(0.011)	(0.011)	(0.011)	(0.012)
μ	Good cost to be supported by a household	0.677	0.689	0.658	0.677	0.678
		(0.005)	(0.005)	(0.010)	(0.005)	(0.006)
α	Fraction of child-rearing to be supported by women	0.546	0.554	0.537	0.546	0.535
		(0.003)	(0.004)	(0.005)	(0.004)	(0.008)
ϕ	Time cost of having children	0.620	0.617	0.600	0.620	0.623
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
η_1	Fixed cost of children (period 1)	0.187	0.198	0.074	0.187	0.192
		(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
δ_m	Time cost for being single (men)	0.321	0.346	0.345	0.321	0.331
		(0.010)	(0.010)	(0.010)	(0.010)	(0.011)
δ_f	Time cost for being single (women)	0.106	0.105	0.157	0.106	0.103
		(0.003)	(0.010)	(0.006)	(0.004)	(0.003)
$\hat{c}$	Minimum consumption level for procreation	0.461	0.417	0.445	0.461	0.462
		(0.003)	(0.003)	(0.007)	(0.003)	(0.003)
$\overline{m}_a$	Average ratio of non-labor income to labor income	1.327	1.211	1.344	1.327	1.314
		(0.005)	(0.005)	(0.009)	(0.005)	(0.006)
ϵ	Wage effect of spacing children across time	0.617	0.544	0.719	0.617	0.614
		(0.008)	(0.008)	(0.012)	(0.008)	(0.007)
η_2	Fixed cost of children (period 2)	0.013	0.005	0.041	0.013	0.010
		(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
ω	Share of randomly matched on marriage market	0.427	0.498	0.452	0.427	0.428
		(0.011)	(0.011)	(0.010)	(0.012)	(0.011)

Note: Estimated parameters of the model for different data subsets (West Germany, East Germany, 2008 Microcensus and 2012 Microcensus). Parameters for wages and natural sterility and infertility are set. For readability bootstrapped standard errors are reported in brackets.

Figure B.2: Model Fit for West Germany



Notes: Internal fit of the simulated model for West Germany only. Lines are empirical moments, dashed lines are simulation results. (I) Completed Fertility for married (blue) and single (red) women for different educational groups. (II) Childlessness rate for married (blue) and single (red) women for different education groups. (III) Fertility of mothers until age 30 for married (blue) and single (red) women for different education groups. (IV) Fertility of mothers after age 30 for married (blue) and single (red) women for different education groups. (V) Marriage rates for women (gray) and men (orange) for different education groups. (VI) Divorce rates for women (gray) and men (orange) for different education groups. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Table B.12: Reasons for Childlessness (West Germany, Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.819	0.181	0.371	0.629	0.704	0.296	0.996	0.004	0.988	0.012	1.000	0.000	0.740	0.260	0.000	1.000	0.702	0.298
2	0.831	0.169	0.397	0.603	0.656	0.344	0.993	0.007	0.981	0.019	1.000	0.000	0.748	0.252	0.000	1.000	0.652	0.348
3	0.819	0.181	0.432	0.568	0.579	0.421	0.991	0.009	0.982	0.018	0.833	0.167	0.720	0.280	0.000	1.000	0.574	0.426
4	0.786	0.214	0.395	0.605	0.505	0.495	0.994	0.006	0.959	0.041	1.000	0.000	0.686	0.314	0.000	1.000	0.500	0.500
5	0.795	0.205	0.410	0.590	0.504	0.496	0.990	0.010	0.956	0.044	0.714	0.286	0.693	0.307	0.000	1.000	0.500	0.500
6	0.787	0.213	0.419	0.581	0.463	0.537	0.983	0.017	0.925	0.075	0.231	0.769	0.676	0.324	0.000	1.000	0.470	0.530
7	0.799	0.201	0.406	0.594	0.333	0.667	0.987	0.013	0.844	0.156	0.154	0.846	0.679	0.321	0.000	1.000	0.337	0.663
8	0.812	0.188	0.368	0.632	0.300	0.700	0.992	0.008	0.694	0.306	0.273	0.727	0.674	0.326	0.000	1.000	0.300	0.700

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

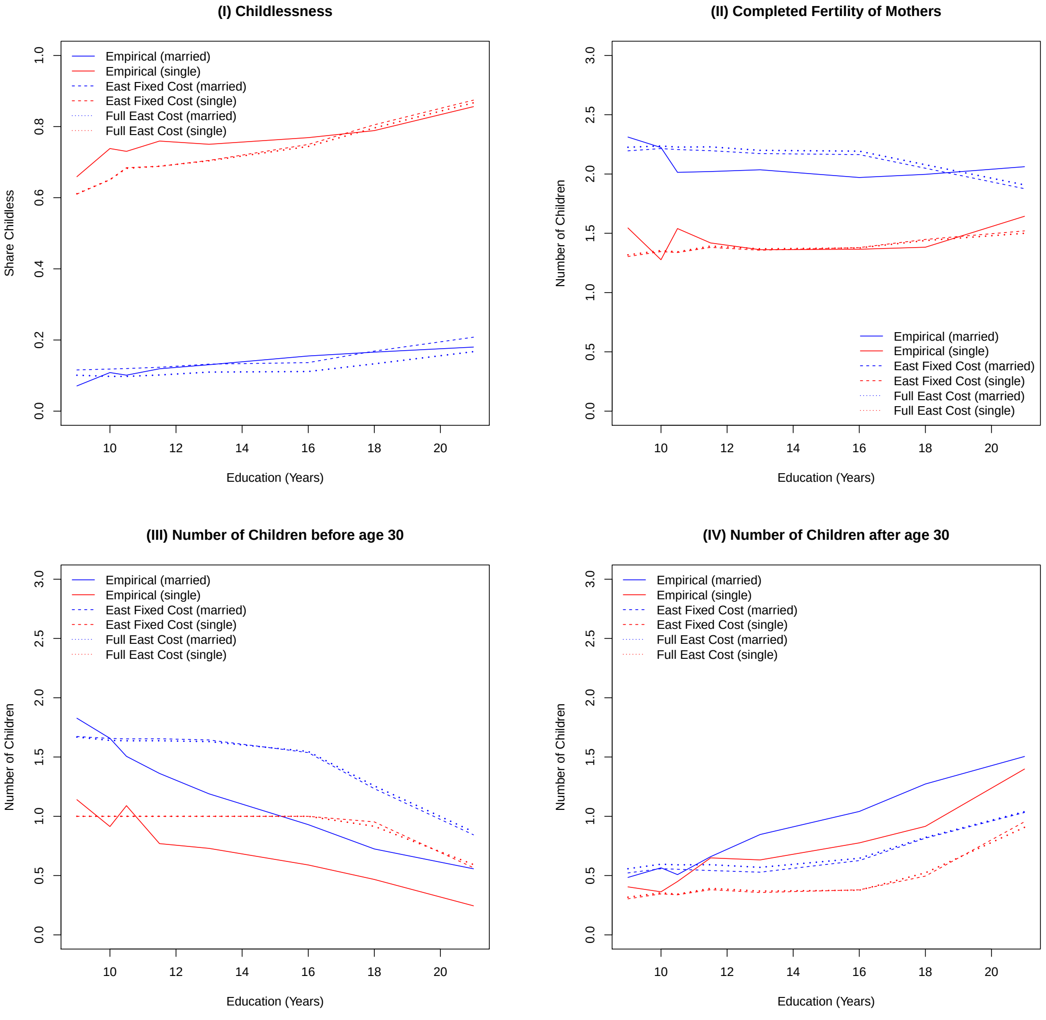
Table B.13: Reasons for Childlessness (East Germany, Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.756	0.244	0.374	0.626	0.933	0.067	0.987	0.013	0.980	0.020	1.000	0.000	0.661	0.339	0.000	1.000	0.931	0.069
2	0.788	0.212	0.332	0.668	0.896	0.104	0.993	0.007	0.975	0.025	1.000	0.000	0.712	0.288	0.000	1.000	0.895	0.105
3	0.789	0.211	0.372	0.628	0.892	0.108	0.991	0.009	0.980	0.020	1.000	0.000	0.702	0.298	0.000	1.000	0.890	0.110
4	0.767	0.233	0.376	0.624	0.876	0.124	0.991	0.009	0.976	0.024	1.000	0.000	0.672	0.328	0.000	1.000	0.875	0.125
5	0.802	0.198	0.384	0.616	0.894	0.106	0.987	0.013	0.981	0.019	1.000	0.000	0.716	0.284	0.000	1.000	0.891	0.109
6	0.807	0.193	0.364	0.636	0.894	0.106	0.995	0.005	0.953	0.047	1.000	0.000	0.723	0.277	0.000	1.000	0.893	0.107
7	0.816	0.184	0.366	0.634	0.675	0.325	0.998	0.002	0.906	0.094	1.000	0.000	0.726	0.274	0.000	1.000	0.674	0.326
8	0.807	0.193	0.307	0.693	0.446	0.554	0.991	0.009	0.743	0.257	0.571	0.429	0.714	0.286	0.000	1.000	0.444	0.556

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in East Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

B.7 Counterfactual Figures and Tables

Figure B.3: **Application of the East German Children Production Costs (vs. Empirical Moments)**



Notes: Counterfactual Simulation - Simulating the application of the East German children production costs to West Germany. Lines are empirical moments, dashed lines are simulation results for the application of the fixed cost (η_1) in period 1 only, dotted lines are the simulation results for the full application of the East German children production costs (η_1 & ϕ). *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Table B.14: Effect of the East German Fixed Cost of Children for West Germany (η_1)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.116	0.118	0.120	0.123	0.132	0.136	0.169	0.208
	vs. Empirical	0.045	0.010	0.019	0.004	0.002	-0.019	0.003	0.028
	vs. Baseline	-0.005	-0.006	-0.010	-0.017	-0.017	-0.018	-0.016	-0.012
Childlessness (single)	Value	0.610	0.650	0.684	0.688	0.705	0.750	0.805	0.874
	vs. Empirical	-0.049	-0.088	-0.046	-0.071	-0.045	-0.019	0.016	0.018
	vs. Baseline	-0.023	-0.023	-0.025	-0.035	-0.025	-0.025	-0.017	-0.000
Fertility (married)	Value	2.196	2.215	2.206	2.197	2.172	2.164	2.049	1.876
	vs. Empirical	-0.116	-0.009	0.192	0.176	0.137	0.193	0.052	-0.186
	vs. Baseline	0.037	0.025	0.015	-0.004	0.011	0.049	0.059	0.067
Fertility (single)	Value	1.304	1.346	1.338	1.381	1.357	1.380	1.448	1.520
	vs. Empirical	-0.241	0.069	-0.202	-0.038	-0.004	0.014	0.066	-0.123
	vs. Baseline	-0.025	-0.033	-0.059	-0.093	-0.086	-0.109	-0.027	0.141

Note: Application of the East German fixed cost of becoming a mother in period 1 (η_1) to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Table B.15: Effect of the East German Cost of Children for West Germany (η_1 & ϕ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.091	0.079	0.083	0.085	0.094	0.098	0.123	0.171
	vs. Empirical	0.020	-0.030	-0.018	-0.034	-0.037	-0.057	-0.043	-0.010
	vs. Baseline	-0.030	-0.046	-0.047	-0.055	-0.055	-0.056	-0.062	-0.049
Childlessness (single)	Value	0.585	0.619	0.646	0.637	0.652	0.681	0.778	0.845
	vs. Empirical	-0.074	-0.119	-0.084	-0.123	-0.099	-0.088	-0.011	-0.011
	vs. Baseline	-0.048	-0.054	-0.063	-0.087	-0.079	-0.094	-0.044	-0.030
Fertility (married)	Value	2.294	2.295	2.296	2.263	2.281	2.279	2.199	1.997
	vs. Empirical	-0.017	0.072	0.282	0.242	0.245	0.309	0.202	-0.065
	vs. Baseline	0.136	0.106	0.105	0.062	0.120	0.164	0.209	0.188
Fertility (single)	Value	1.248	1.299	1.296	1.316	1.303	1.296	1.365	1.429
	vs. Empirical	-0.297	0.023	-0.244	-0.103	-0.058	-0.069	-0.017	-0.215
	vs. Baseline	-0.081	-0.079	-0.100	-0.158	-0.139	-0.193	-0.110	0.049

Note: Application of the East German cost of becoming a mother in period 1 (η) and the variable cost of children (ϕ) to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Table B.16: Reasons for Childlessness (East German η_1 for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.842	0.158	0.364	0.636	0.837	0.163	0.996	0.004	0.992	0.008	1.000	0.000	0.772	0.228	0.000	1.000	0.835	0.165
2	0.858	0.142	0.391	0.609	0.820	0.180	0.993	0.007	0.989	0.011	1.000	0.000	0.788	0.212	0.000	1.000	0.817	0.183
3	0.858	0.142	0.426	0.574	0.800	0.200	0.989	0.011	0.995	0.005	1.000	0.000	0.781	0.219	0.000	1.000	0.794	0.206
4	0.851	0.149	0.393	0.607	0.805	0.195	0.991	0.009	0.986	0.014	1.000	0.000	0.777	0.223	0.000	1.000	0.801	0.199
5	0.856	0.144	0.408	0.592	0.810	0.190	0.993	0.007	0.982	0.018	1.000	0.000	0.780	0.220	0.000	1.000	0.806	0.194
6	0.848	0.152	0.419	0.581	0.718	0.282	0.996	0.004	0.955	0.045	1.000	0.000	0.760	0.240	0.000	1.000	0.715	0.285
7	0.839	0.161	0.408	0.592	0.449	0.551	0.997	0.003	0.876	0.124	0.667	0.333	0.737	0.263	0.000	1.000	0.448	0.552
8	0.833	0.167	0.369	0.631	0.351	0.649	0.994	0.006	0.706	0.294	0.375	0.625	0.707	0.293	0.000	1.000	0.350	0.650

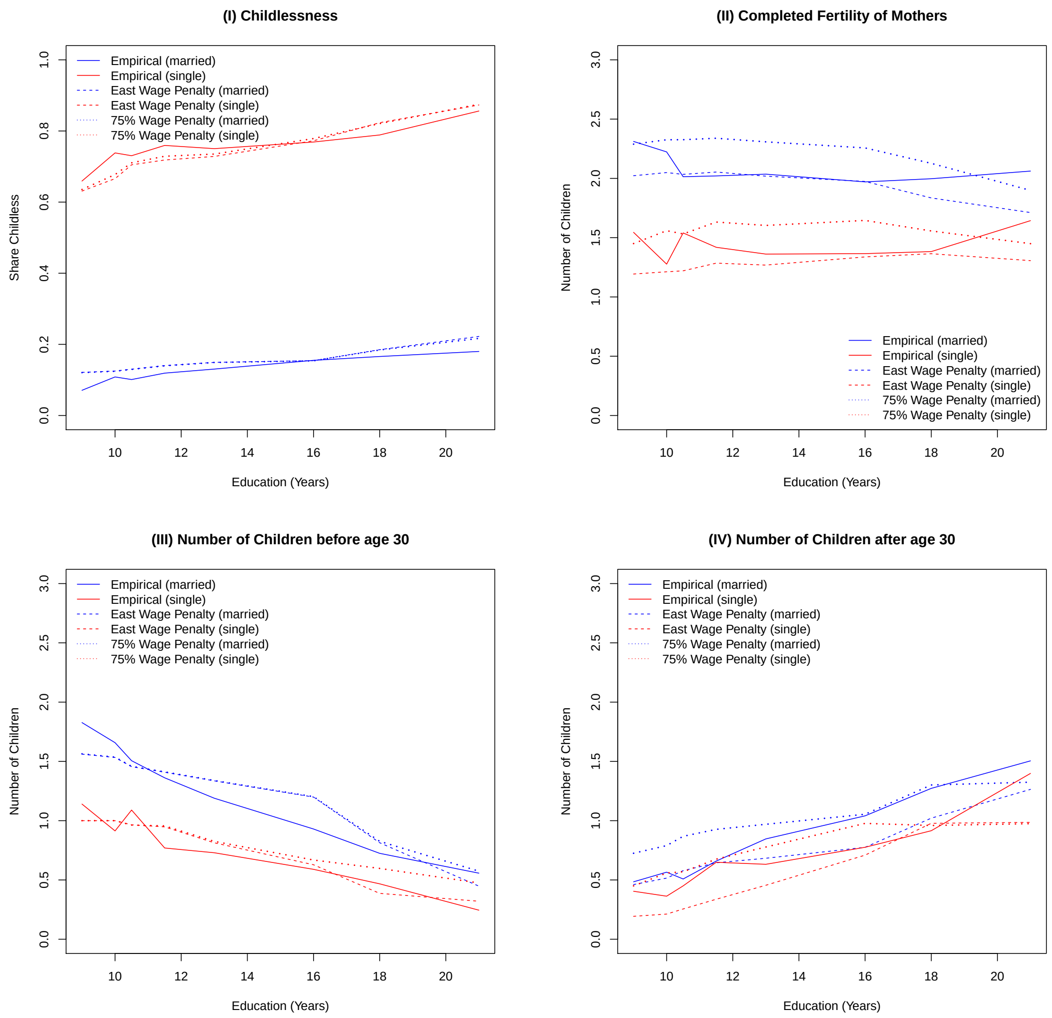
Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of the East German η_1 to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table B.17: Reasons for Childlessness (East German η_1 & ϕ for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.813	0.187	0.407	0.593	0.809	0.191	0.996	0.004	0.991	0.009	1.000	0.000	0.721	0.279	0.000	1.000	0.808	0.192
2	0.832	0.168	0.451	0.549	0.790	0.210	0.993	0.007	0.989	0.011	1.000	0.000	0.733	0.267	0.000	1.000	0.787	0.213
3	0.839	0.161	0.489	0.511	0.807	0.193	0.991	0.009	0.995	0.005	1.000	0.000	0.731	0.269	0.000	1.000	0.803	0.197
4	0.821	0.179	0.454	0.546	0.784	0.216	0.991	0.009	0.986	0.014	1.000	0.000	0.716	0.284	0.000	1.000	0.780	0.220
5	0.827	0.173	0.474	0.526	0.763	0.237	0.992	0.008	0.988	0.012	1.000	0.000	0.716	0.284	0.000	1.000	0.759	0.241
6	0.823	0.177	0.486	0.514	0.708	0.292	0.996	0.004	0.965	0.035	1.000	0.000	0.700	0.300	0.000	1.000	0.705	0.295
7	0.813	0.187	0.485	0.515	0.476	0.524	0.997	0.003	0.898	0.102	0.667	0.333	0.668	0.332	0.000	1.000	0.474	0.526
8	0.800	0.200	0.432	0.568	0.347	0.653	0.993	0.007	0.719	0.281	0.333	0.667	0.619	0.381	0.000	1.000	0.347	0.653

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of the East German η_1 and ϕ to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Figure B.4: Application of Alternative Wage Penalties to West Germany



Notes: Counterfactual Simulation - Simulating changes in the wage penalty (ϵ). Lines are the empirical moments observed in the data, dashed lines are simulation results for the application of the East German wage penalty (ϵ), dotted lines are the simulation results for a 25% decrease in the wage penalty (ϵ) to West Germany. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Table B.18: Effect of the East German Wage Penalty for West Germany (ϵ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.121	0.125	0.130	0.140	0.149	0.154	0.185	0.222
	vs. Empirical	0.050	0.017	0.029	0.021	0.019	-0.001	0.019	0.042
	vs. Baseline	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
Childlessness (single)	Value	0.631	0.666	0.705	0.718	0.728	0.772	0.823	0.873
	vs. Empirical	-0.028	-0.072	-0.026	-0.041	-0.022	0.003	0.035	0.017
	vs. Baseline	-0.002	-0.007	-0.004	-0.005	-0.002	-0.002	0.001	-0.001
Fertility (married)	Value	2.022	2.049	2.034	2.054	2.019	1.974	1.835	1.712
	vs. Empirical	-0.289	-0.174	0.020	0.033	-0.017	0.004	-0.162	-0.350
	vs. Baseline	-0.136	-0.140	-0.158	-0.147	-0.142	-0.141	-0.155	-0.097
Fertility (single)	Value	1.193	1.212	1.220	1.285	1.269	1.338	1.364	1.306
	vs. Empirical	-0.352	-0.065	-0.320	-0.134	-0.093	-0.028	-0.018	-0.337
	vs. Baseline	-0.135	-0.166	-0.176	-0.189	-0.174	-0.151	-0.111	-0.073

Note: Application of the East German wage penalty to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Table B.19: Effect of a 25 % Reduction in the Wage Penalty for West Germany (ϵ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.121	0.124	0.130	0.140	0.149	0.154	0.184	0.217
	vs. Empirical	0.050	0.016	0.029	0.021	0.019	-0.001	0.018	0.037
	vs. Baseline	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.003
Childlessness (single)	Value	0.635	0.677	0.710	0.729	0.735	0.779	0.821	0.875
	vs. Empirical	-0.024	-0.061	-0.020	-0.030	-0.015	0.010	0.032	0.019
	vs. Baseline	0.003	0.004	0.001	0.005	0.005	0.004	-0.001	0.001
Fertility (married)	Value	2.289	2.326	2.326	2.339	2.308	2.257	2.127	1.898
	vs. Empirical	-0.023	0.102	0.312	0.318	0.273	0.286	0.130	-0.163
	vs. Baseline	0.131	0.136	0.135	0.138	0.147	0.142	0.137	0.090
Fertility (single)	Value	1.450	1.559	1.532	1.632	1.603	1.645	1.557	1.449
	vs. Empirical	-0.095	0.282	-0.008	0.213	0.242	0.280	0.174	-0.194
	vs. Baseline	0.121	0.181	0.135	0.157	0.160	0.156	0.081	0.070

Note: Simulation of a 25 % reduction in the wage penalty to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Table B.20: Reasons for Childlessness (East German ϵ / 25 % Reduction in ϵ)

	East Germany ϵ						25% Reduction of ϵ					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.821	0.179	0.378	0.622	0.704	0.296	0.818	0.182	0.366	0.634	0.704	0.296
2	0.832	0.168	0.401	0.599	0.656	0.344	0.830	0.170	0.392	0.608	0.656	0.344
3	0.820	0.180	0.436	0.564	0.579	0.421	0.818	0.182	0.428	0.572	0.579	0.421
4	0.788	0.212	0.402	0.598	0.504	0.496	0.785	0.215	0.394	0.606	0.505	0.495
5	0.797	0.203	0.413	0.587	0.502	0.498	0.793	0.207	0.407	0.593	0.506	0.494
6	0.787	0.213	0.419	0.581	0.462	0.538	0.787	0.213	0.416	0.584	0.466	0.534
7	0.799	0.201	0.407	0.593	0.331	0.669	0.798	0.202	0.406	0.594	0.334	0.666
8	0.809	0.191	0.369	0.631	0.289	0.711	0.816	0.184	0.368	0.632	0.309	0.691

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless. Left block for the application of the East German ϵ to West Germany, right block for the application of 25% reduction of ϵ to West Germany. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table B.21: Reasons for Childlessness (East German ϵ for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.821	0.179	0.378	0.622	0.704	0.296	0.996	0.004	0.988	0.012	1.000	0.000	0.740	0.260	0.000	1.000	0.702	0.298
2	0.832	0.168	0.401	0.599	0.656	0.344	0.993	0.007	0.981	0.019	1.000	0.000	0.748	0.252	0.000	1.000	0.652	0.348
3	0.820	0.180	0.436	0.564	0.579	0.421	0.990	0.010	0.982	0.018	0.857	0.143	0.721	0.279	0.000	1.000	0.573	0.427
4	0.788	0.212	0.402	0.598	0.504	0.496	0.994	0.006	0.960	0.040	1.000	0.000	0.686	0.314	0.000	1.000	0.499	0.501
5	0.797	0.203	0.413	0.587	0.502	0.498	0.990	0.010	0.955	0.045	0.714	0.286	0.693	0.307	0.000	1.000	0.499	0.501
6	0.787	0.213	0.419	0.581	0.462	0.538	0.982	0.018	0.922	0.078	0.214	0.786	0.676	0.324	0.000	1.000	0.470	0.530
7	0.799	0.201	0.407	0.593	0.331	0.669	0.985	0.015	0.840	0.160	0.125	0.875	0.679	0.321	0.000	1.000	0.337	0.663
8	0.809	0.191	0.369	0.631	0.289	0.711	0.992	0.008	0.691	0.309	0.250	0.750	0.668	0.332	0.000	1.000	0.290	0.710

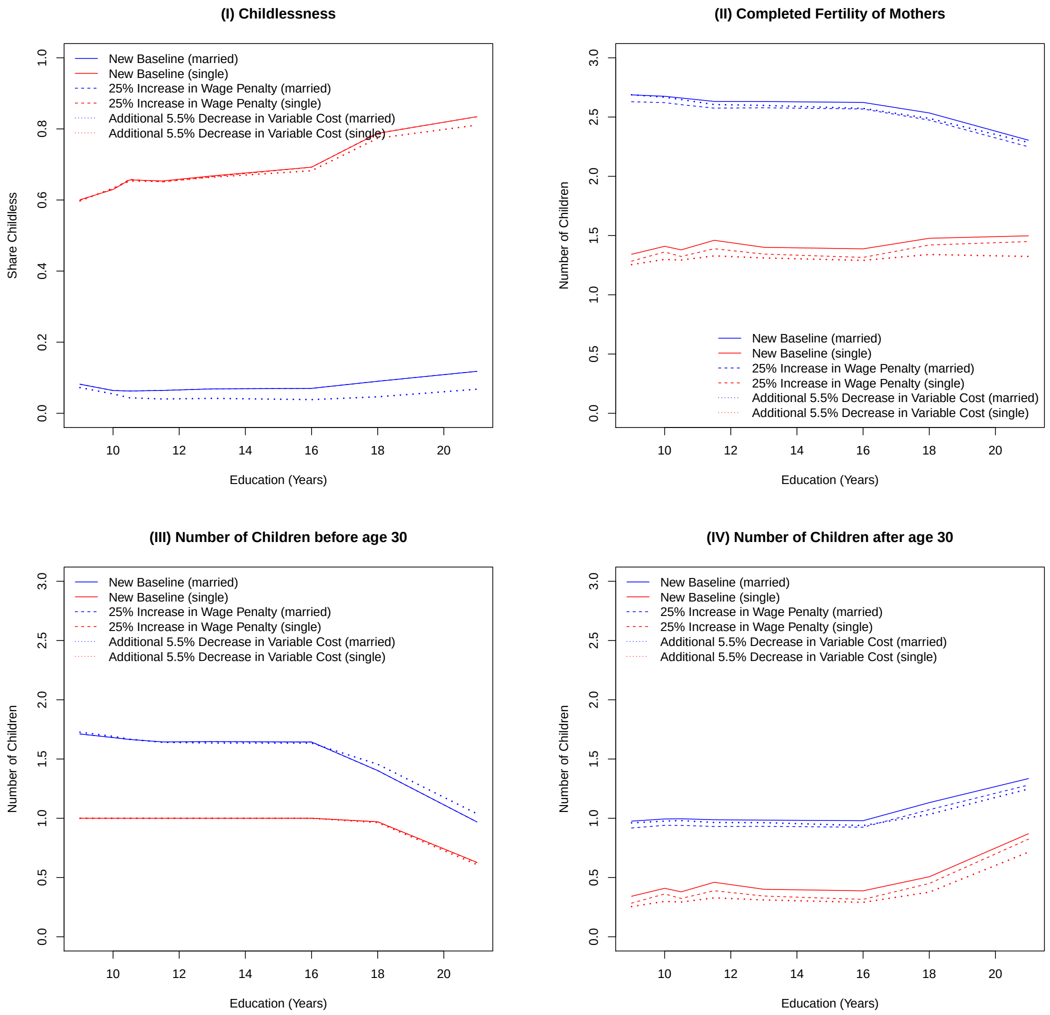
Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of the East German ϵ to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table B.22: Reasons for Childlessness (25 % Reduction in ϵ & ϕ for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement	Voluntary	Involuntary	Poverty	Optimal	Sterility	Postponement
1	0.813	0.187	0.407	0.593	0.809	0.191	0.996	0.004	0.991	0.009	1.000	0.000	0.721	0.279	0.000	1.000	0.808	0.192
2	0.832	0.168	0.451	0.549	0.790	0.210	0.993	0.007	0.989	0.011	1.000	0.000	0.733	0.267	0.000	1.000	0.787	0.213
3	0.839	0.161	0.489	0.511	0.807	0.193	0.991	0.009	0.995	0.005	1.000	0.000	0.731	0.269	0.000	1.000	0.803	0.197
4	0.821	0.179	0.454	0.546	0.784	0.216	0.991	0.009	0.986	0.014	1.000	0.000	0.716	0.284	0.000	1.000	0.780	0.220
5	0.827	0.173	0.474	0.526	0.763	0.237	0.992	0.008	0.988	0.012	1.000	0.000	0.716	0.284	0.000	1.000	0.759	0.241
6	0.823	0.177	0.486	0.514	0.708	0.292	0.996	0.004	0.965	0.035	1.000	0.000	0.700	0.300	0.000	1.000	0.705	0.295
7	0.813	0.187	0.485	0.515	0.476	0.524	0.997	0.003	0.898	0.102	0.667	0.333	0.668	0.332	0.000	1.000	0.474	0.526
8	0.800	0.200	0.432	0.568	0.347	0.653	0.993	0.007	0.719	0.281	0.333	0.667	0.619	0.381	0.000	1.000	0.347	0.653

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of a 25% reduction in ϵ to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Figure B.5: Changes in Wage Penalty and Variable Cost of Children (all plots)



Notes: Counterfactual Simulation - Simulation of a 25% increase in the wage penalty (ϵ) and a counteracting 5.5% reduction in the variable cost of children (ϕ). Regular lines indicates the new baseline simulation, dashed lines illustrate the application of only a 25% increase in the wage penalty (ϵ) and dotted lines indicate an additional 5.5% reduction in the variable cost of children (ϕ).

Table B.23: Effect of a 25% Increase in Wage Penalty for Germany (ϵ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.082	0.064	0.063	0.064	0.069	0.070	0.090	0.118
	vs. Baseline	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Childlessness (single)	Value	0.599	0.631	0.658	0.651	0.666	0.692	0.788	0.834
	vs. Baseline	-0.002	0.002	0.002	-0.003	-0.002	0.000	0.001	-0.000
Fertility (married)	Value	2.629	2.622	2.605	2.575	2.578	2.568	2.474	2.249
	vs. Baseline	-0.058	-0.053	-0.056	-0.057	-0.053	-0.055	-0.060	-0.055
Fertility (single)	Value	1.284	1.361	1.323	1.388	1.344	1.315	1.420	1.449
	vs. Baseline	-0.058	-0.048	-0.056	-0.071	-0.057	-0.072	-0.057	-0.049

Note: Application of a 25% increase in the wage penalty for Germany.Germany is the new baseline with East German cost for children in period 1 (η_1) and West German wage penalty (ϵ). VS.-rows are calculated by subtracting the new baseline simulation results from the counterfactual results. Values rounded.

Table B.24: Additional Effect of a counteracting 5.5% decrease in Variable Cost of Children (ϕ) for Germany

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.072	0.054	0.044	0.040	0.042	0.038	0.046	0.068
	vs. Baseline	-0.009	-0.010	-0.019	-0.024	-0.027	-0.032	-0.044	-0.050
Childlessness (single)	Value	0.597	0.633	0.653	0.652	0.664	0.682	0.774	0.811
	vs. Baseline	-0.003	0.004	-0.003	-0.001	-0.004	-0.010	-0.014	-0.024
Fertility (married)	Value	2.688	2.667	2.647	2.606	2.598	2.573	2.489	2.285
	vs. Baseline	0.000	-0.008	-0.013	-0.026	-0.033	-0.050	-0.046	-0.019
Fertility (single)	Value	1.255	1.299	1.293	1.328	1.311	1.290	1.340	1.324
	vs. Baseline	-0.087	-0.111	-0.086	-0.131	-0.090	-0.097	-0.137	-0.174

Note: Application of a in 25% increase in the wage penalty and a counteracting 5.5% decrease in the variable cost of children for Germany. Germany is the new baseline with East German cost for children in period 1 (η_1) and West German wage penalty (ϵ). VS.-rows are calculated by subtracting the new baseline simulation results from the counterfactual results. Values rounded.

B.8 Optimization Routines

The model parameter are estimated using a tree stage estimation procedure. First, a set of initial values of size 500,000 is drawn from the complete solution space for each parameter and the model is evaluated using this initial grid. Second, - based on the results from step one - a genetic (global optimization) algorithm is run using the best combinations of values from step one as starting values. The second step is used in order to find the area in the parameter space in which the global maximum lies. The final parameter values are obtained using the (local) Powell Optimization (PO) routine. Estimation steps one and two are performed at the Leibniz Supercomputing Centre of the Bavarian Academy of Science and Humanities (LRZ), while the last step (PO-Optimization) is performed on a local machine. All optimization routines have standard implementations in R, which I use. However, I have adjusted the genetic algorithm package in order to work with Rmpi communication based parallelization between computing nodes on the Leibniz Supercomputing Centre of the Bavarian Academy of Science and Humanities (LRZ).

B.8.1 Genetic Algorithm

The genetic algorithms R-package “GA” provides a valuable and flexible toolbox for general-purpose stochastic optimization of binary and real-valued functions. Genetic algorithms are stochastic optimization routines that work by mimicking biological evolution and natural selection. At the end of each iteration of the optimization the fittest individuals survive. Additional biological mechanisms of evolution, such as crossover between surviving individuals and random mutation are applied when generating the new population for the next round from the surviving population of the last round. Thus, GA’s provide a powerful general purpose optimization strategy for complex problems where first order conditions are not available. GA is robust against local extrema and can thus be used in a setting where the existence of multiple local extrema can not be ruled out. Unfortunately, GA’s are - similar to the biological evolution of life - relatively slow and thus require high computational cost and time until convergence is achieved.

B.8.2 Powell Optimization Algorithm

The R-package “powell” provides the R implementation of the Unconstrained Optimization by Quadratic Approximation (UOBYQA) Algorithm, originally developed under Fortran by Michael J. D. Powell (Powell, 2002). Powell’s UOBYQA Algorithm is an iterative, numerical and derivative free optimization algorithm that minimizes the objective function within a trust region by constructing and minimizing a quadratic model at each iteration step.

B.9 Identification

In this section, I illustrate the identification of the structural model parameter. I use 64 moments along 8 dimensions to identify my 14 model parameter. In the following I change each structural model parameter individually, leaving the remaining parameter constant to illustrate how changes in one parameter affect the simulated moments.

B.9.1 μ and $\bar{m}_a$

Increases in the public household good (μ) as well as decreases in the mean of the non-labor income decrease the available consumption in the household. Figure B.6 plots the response of the simulated moments for a 20% increase in μ (dashed line / triangles) and a 20% decrease in $\bar{m}_a$. Both parameter influence childlessness and marriage rates in roughly the same way. However, the number of children born to single women, both before and after age 30, is affected differently by both parameters across education levels, which allows for parameter identification.

B.9.2 δ_f and δ_m

δ_f and δ_m affect both marriage rates as well as childlessness and the inter-temporal allocation of children of single women. Figure B.7 plots the response of the simulated moments for a 20% increase in δ_f (dashed line / triangles) and a 20% decrease in δ_m. The model parameter can be identified as both parameters affect both childlessness and the inter-temporal allocation of children for single women differently across education levels.

Furthermore both parameter increase childlessness for single women but have different effects on marriage rates.

B.9.3 ϕ, η and η_2

The time cost of children ϕ and η affect both childlessness and the number of children born in each period. Figure B.8 plots the response of the simulated moments for a 20% increase in ϕ (dashed line / triangles) and a 20% decrease in η. The structural parameter affect childlessness differently by marital status and education level. The same is true for the number of children born before and after age 30 of the mother. This allows for model parameter identification.

The fixed time cost of children η and η_2 affect the number of children born in each period and the inter-temporal allocation of children. Figure B.9 plots the response of the simulated moments for a 20% increase in η (dashed line / triangles) and a 20% decrease in η_2. The parameter are identified via their different effect on the number of children per period by education group.

B.9.4 ν and β

The preference parameter allowing for zero children (ν) and the discount rate (β) enter the utility function directly. While the preference parameter is constant across periods and education groups, the discount rate affects individuals differently by education level due to the return to experience which depends on individuals education level. While both changes in parameter values have effects going in the same direction for childlessness and marriage rates, the effects differ for the number of children born before and after age 30 both by marital status and by education level. Figure B.10 plots the response of the simulated moments for a 20% increase in ν (dashed line / triangles) and a 20% decrease in β.

B.9.5 $\hat{c}$ and σ_a

Increases in the minimum consumption level for procreation ($\hat{c}$) and decreases the standard deviation of the non-labor income affect marriage rates in a similar way (yet of different sign). At the same time, both changes in parameter values decrease childlessness for married women across almost all education levels in a non-linear way. Furthermore, both parameter affect childlessness and the number of children born in each period in a substantially different way across marital status and education background. Figure B.11 plots the response of the simulated moments for a 20% increase in $\hat{c}$ (dashed line / triangles) and a 20% decrease in σ_a.

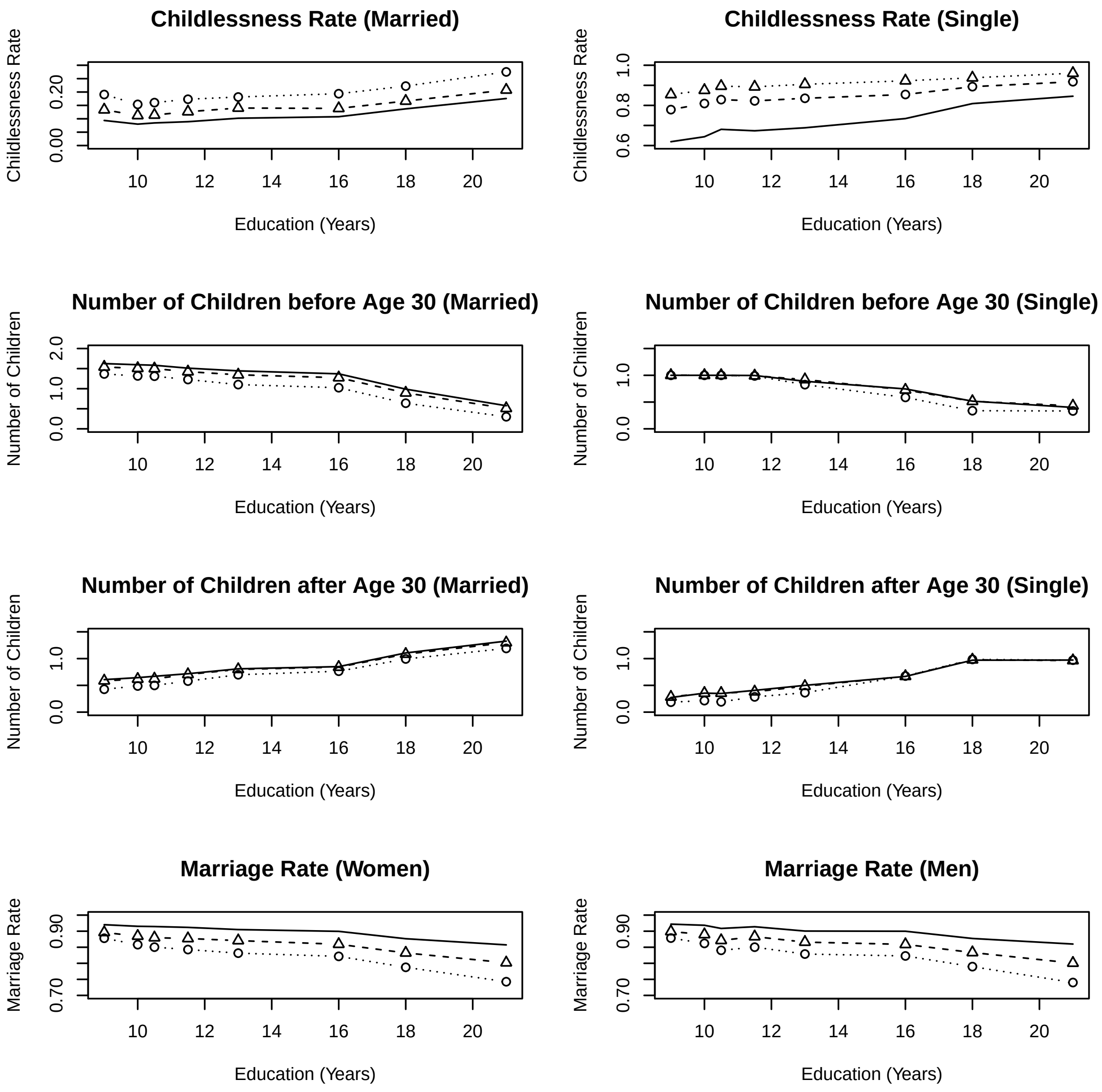
B.9.6 ω and ϵ

The level of assortative matching on the marriage market ω overall shows little effects compared to the negative wage effect of long term child-rearing ϵ. While ω mainly affects childlessness of single women and marriage rates, ϵ affects the timing of children in a way that strongly depends on mothers educational background and marital status. Furthermore, marriage rates of men are affected differently by education level. Figure B.12 plots the response of the simulated moments for a 20% increase in ω (dashed line / triangles) and a 20% decrease in ϵ.

B.9.7 α

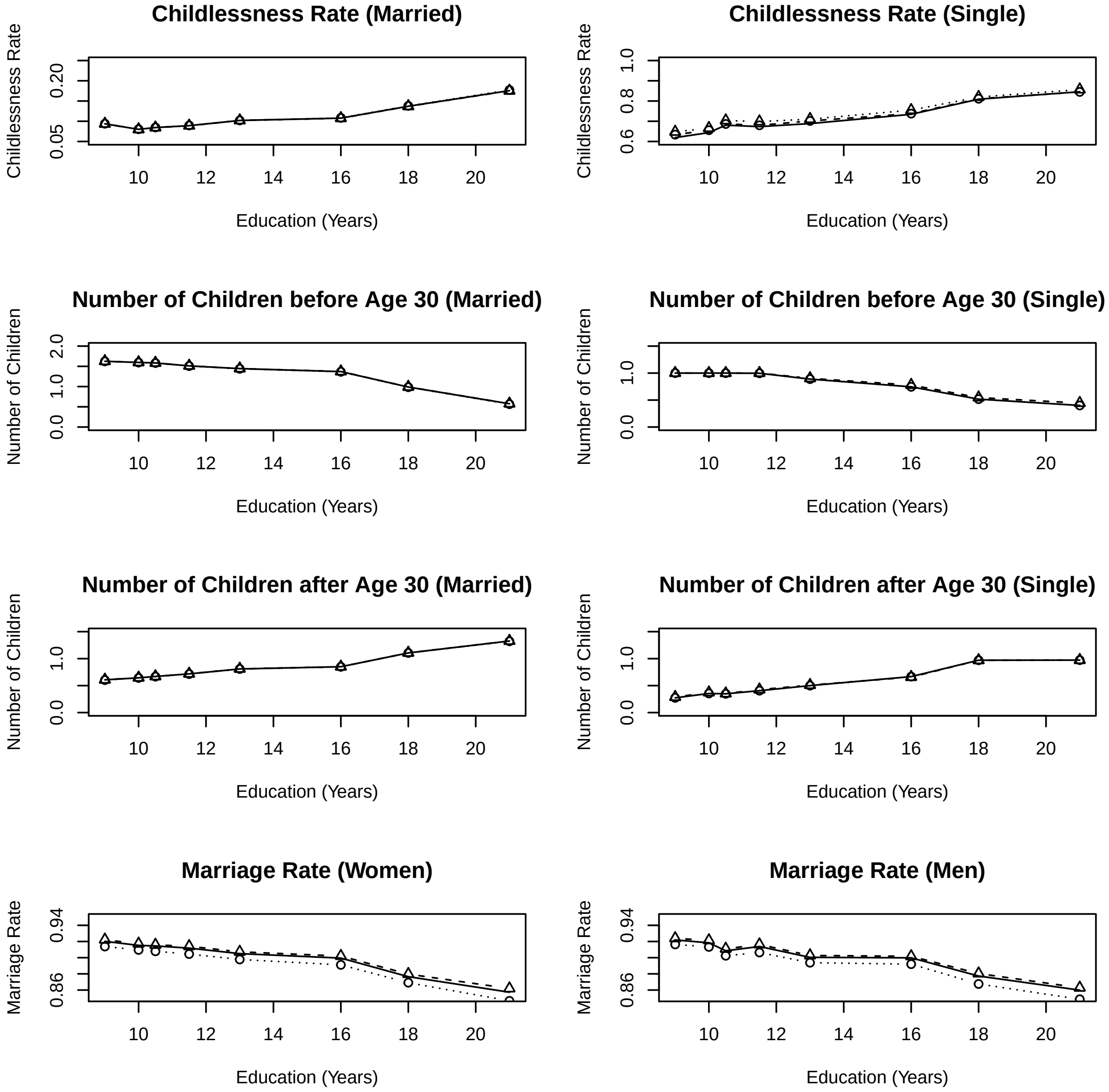
The share of child rearing provided by the husband only affects the fertility behavior of married couples and marriage rates. The extend to which α affects the optimal conditions depends on the relative income of both spouses, which varies by education level. In particular the number of children born after age 30 show heterogeneity in effect size by education level which allows for parameter identification. Figure B.13 plots the response of the simulated moments for a 20% increase in α (dashed line / triangles) and a 20% decrease in α.

Figure B.6: Identification of μ & $\bar{m}_a$



Notes: Identification of μ & $\bar{m}_a$ - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in μ. Dotted lines/circles symbolize a 20% decrease in $\bar{m}_a$.

Figure B.7: Identification of δ_f & δ_m


Childlessness Rate (Married)

Childlessness Rate (Single)

Number of Children before Age 30 (Married)

Number of Children before Age 30 (Single)

Number of Children after Age 30 (Married)

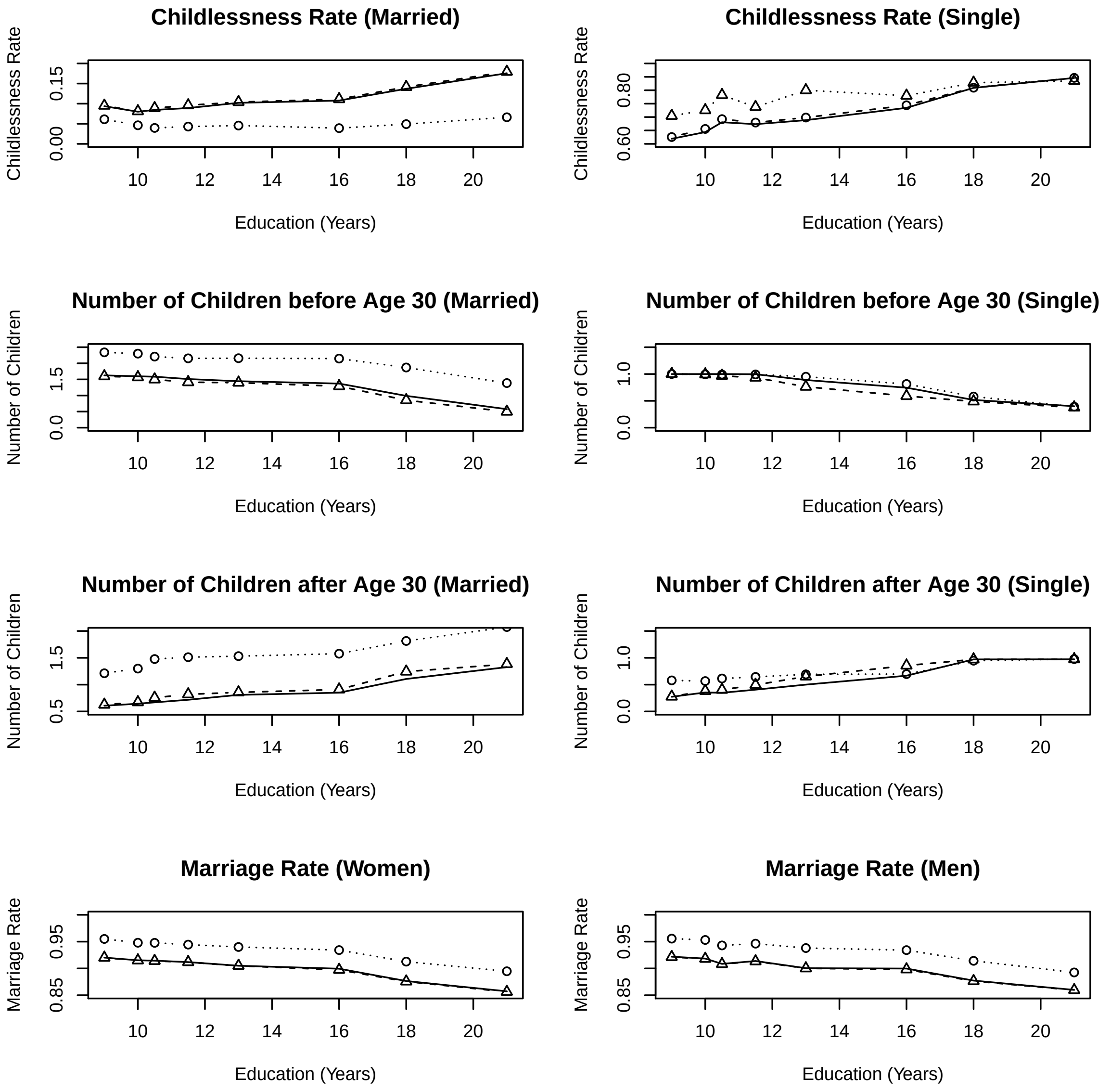
Number of Children after Age 30 (Single)

Marriage Rate (Women)

Marriage Rate (Men)

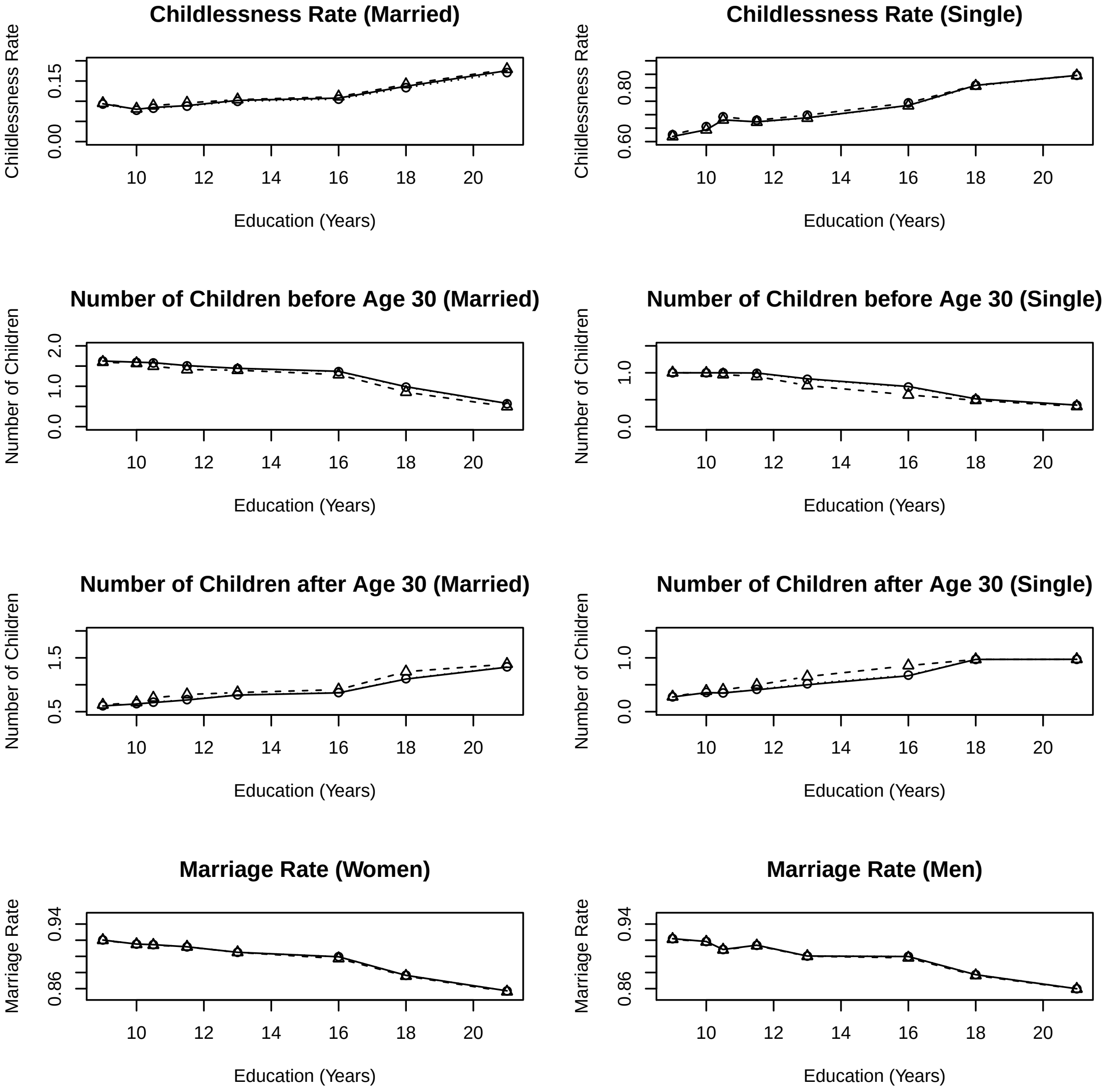
Notes: Identification of δ_f & δ_m - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in δ_f. Dotted lines/circles symbolize a 20% decrease in δ_m.

Figure B.8: Identification of ϕ & η



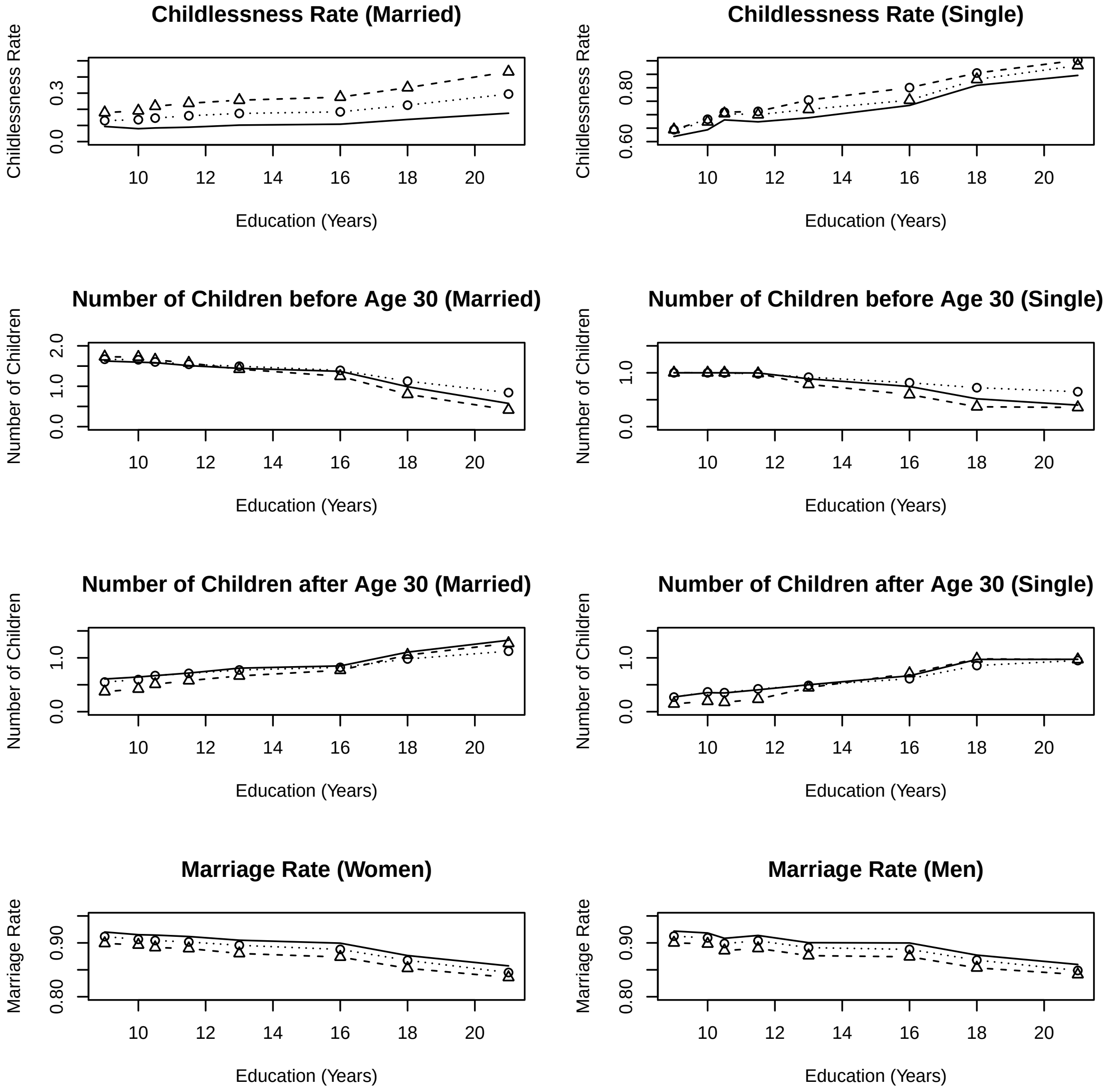
Notes: Identification of ϕ & η - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in ϕ. Dotted lines/circles symbolize a 20% decrease in η.

Figure B.9: Identification of η & η_2



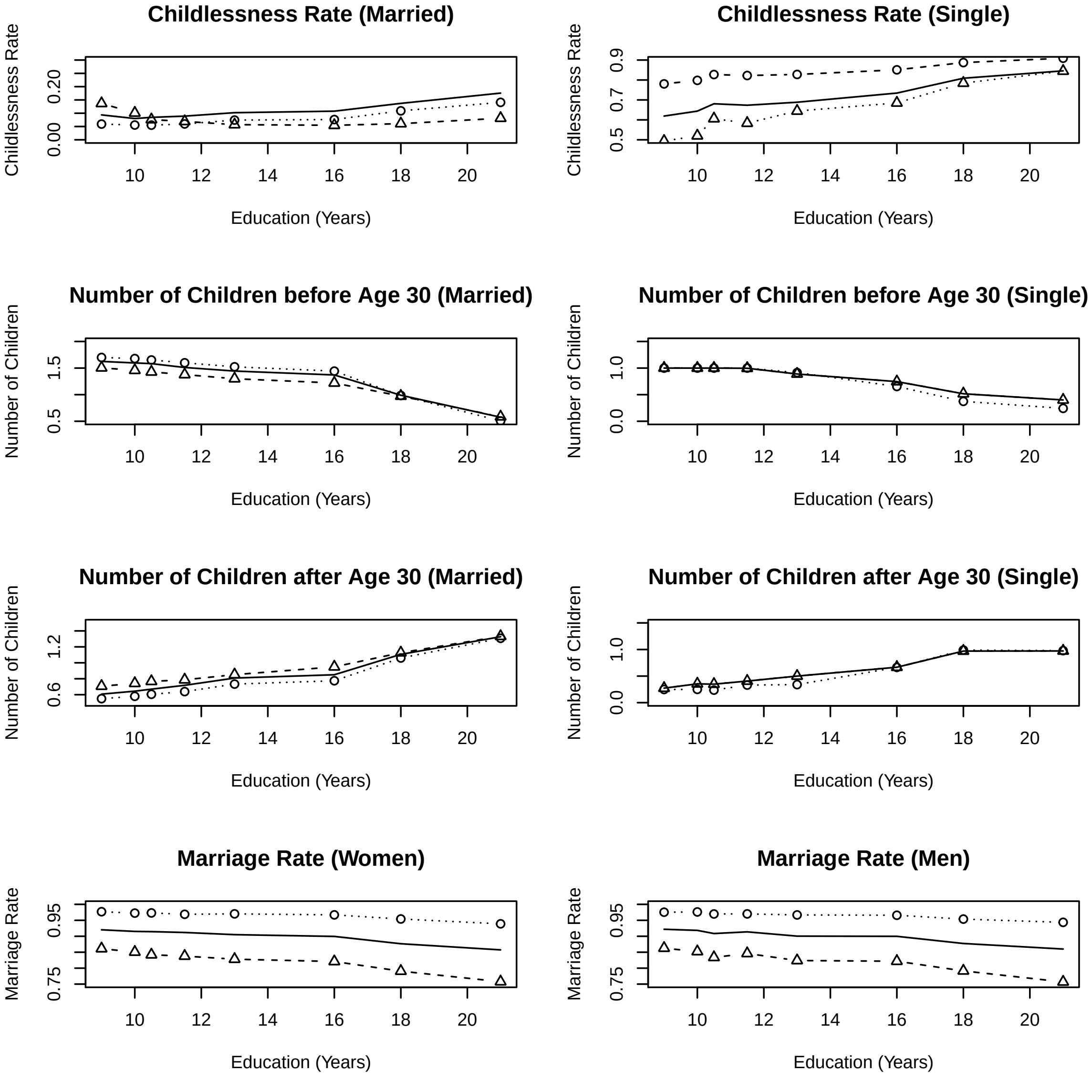
Notes: Identification of η & η_2 - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in η. Dotted lines/circles symbolize a 20% decrease in η_2.

Figure B.10: Identification of ν & β



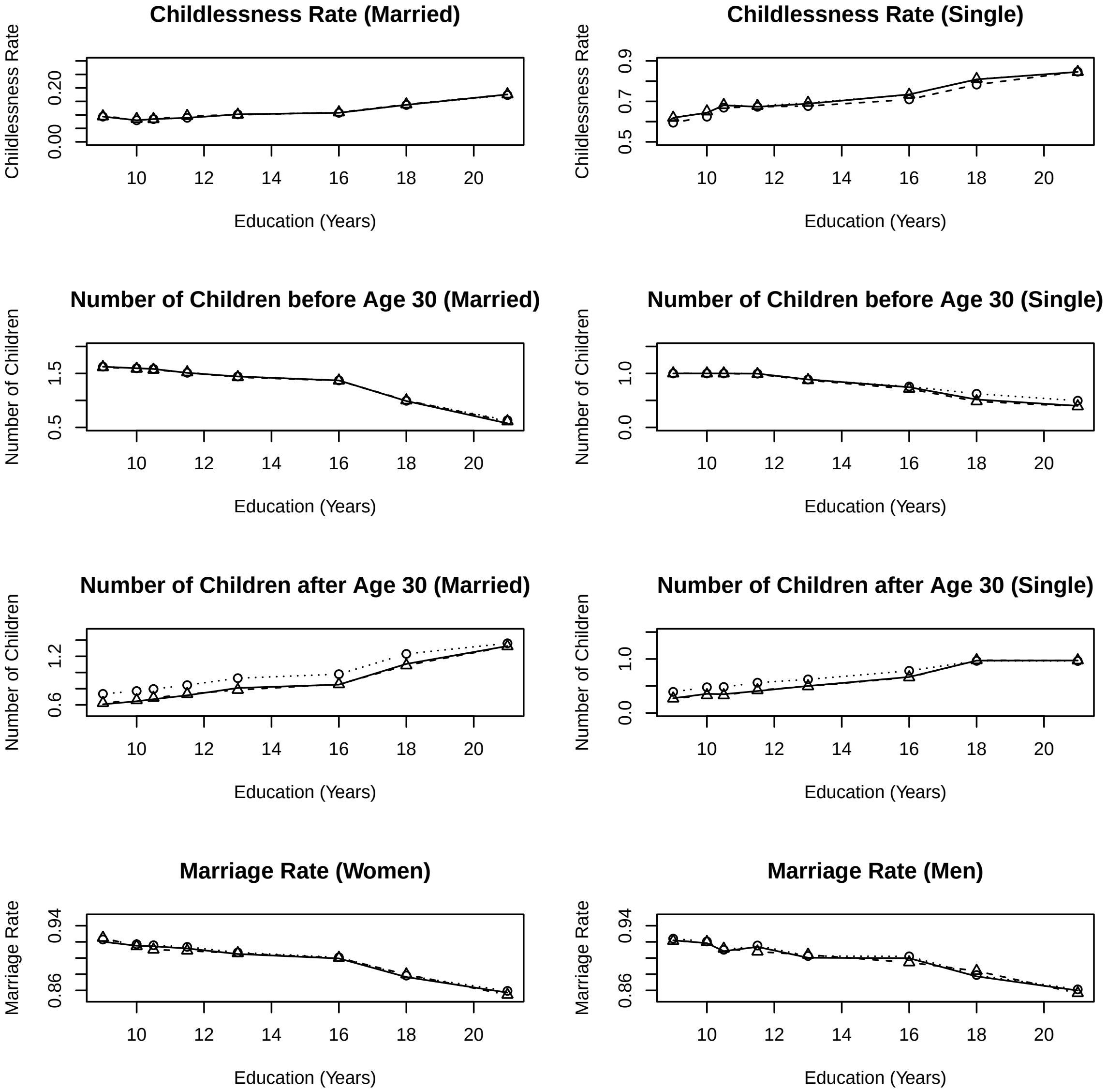
Notes: Identification of ν & β - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in ν. Dotted lines/circles symbolize a 20% decrease in β.

Figure B.11: Identification of $\hat{c}$ & σ_a



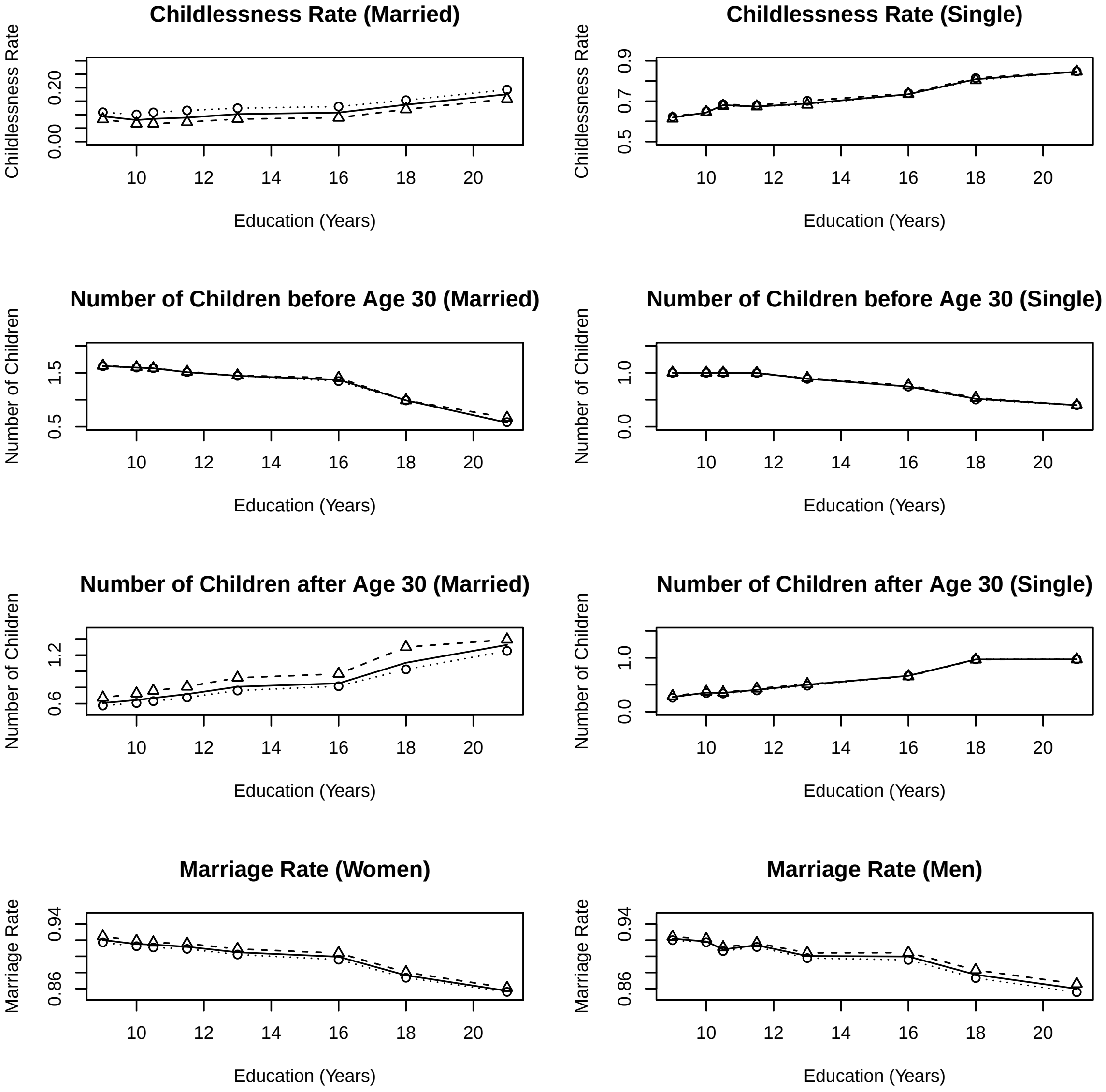
Notes: Identification of $\hat{c}$ & σ_a - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in $\hat{c}$. Dotted lines/circles symbolize a 20% decrease in σ_a.

Figure B.12: Identification of ω & ϵ



Notes: Identification of ω & ϵ - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in ω. Dotted lines/circles symbolize a 20% decrease in ϵ.

Figure B.13: Identification of α



Notes: Identification of α - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in α. Dotted lines/circles symbolize a 20% decrease in α.

Chapter 4

Marriage and Divorce: The Role of Labor Market Institutions

This chapter is joint work with Bastian Schulz from Aarhus University.

4.1 Introduction

Living in a union with another individual has many benefits. Besides companionship and mutual affection, there is arguably an economic dimension to partner choice and household formation. Economies of scale can be realized by joint consumption (Browning et al., 2013). Moreover, the partner's time endowment, employed either in home production or through the labor market, can provide utility for multiple household members.[95] Labor supply is a joint decision due to implications for the whole household (Chiappori, 1992; Chiappori et al., 2002). Thus, marriage and labor markets interact (Grossbard-Shechtman, 1984).

In addition to its effect on current consumption, the spouse's employment and income stream may also provide insurance during times of economic hardship, e.g. prolonged unemployment. This form of risk pooling, however, does not exclusively take place within households. In many countries, the social insurance system provides a substitute for within-household insurance: with good unemployment insurance coverage one does not need to rely on one's spouse. The role of the family and partnership formation (or dissolution) decisions, therefore, depend on the institutional environment. It influences *marital surplus*, that is, the economic rents that are gained and shared by individuals who form a union.[96]

In this paper, we empirically study the household insurance channel, its interaction with the generosity of the public unemployment insurance system, and implications for marriage formation and stability.[97] We estimate marital surplus using the transferable utility marriage market matching model of Choo and Siow (2006). Suppose unemployment benefits are generous such that there is no need for within-household insurance against unemployment. This increases marital surplus and, therefore, leads to more marriages and higher marital stability. If unemployment benefits are low, for example due

---

[95] The traditional specialization of one individual in market work while a second individual focuses on home production can be understood as a policy that maximizes joint household utility in this setting (Becker, 1981).

[96] In equilibrium models of the marriage market, the marital surplus governs marriage formation and marital stability, see Goussé et al. (2017) and Gayle and Shephard (2019) for two recent examples.

[97] In principle, all of our arguments also apply to unmarried cohabitation and same-sex couples. The nature of our data, however, forces us to focus on legally married heterosexual couples in this paper.

to means-testing against the partner's income, shocks have to be absorbed within the household to a larger extent, lowering marital surplus.

Means testing, a common feature of many social insurance systems, makes it costly in expectation to marry a partner who is exposed to high unemployment risk. We study a large-scale institutional reform in Germany that changed the rules of means testing and, thus, the generosity of unemployment insurance for couples. In January 2003, the first part of the comprehensive German labor market reforms, the so-called "Hartz reforms", was implemented.[98] One specific element of the reform was a tightening of means testing exemptions, implying a sharp increase in the need for within-household insurance during a period of very high unemployment risk. In 2003, the German unemployment rate stood at 10% with an increasing trend.

We identify the effect of this labor market reform on marital surplus and stability in a differences-in-differences framework under the assumption that interethnic marriages, that is, marriages with one German spouse and one spouse of foreign nationality, were more exposed to unemployment risk as compared to marriages with two German spouses. We find support for this identifying assumption in German social security data.[99] We find that the labor market reform had a sizable negative impact on the marital surplus of interethnic marriages in Germany. Accordingly, the intermarriage rate of German men and women declined by about 30% between 2003 and 2008. This feedback effect of the German labor market reforms on the marriage market, and on interethnic marriages in particular, constitutes and important finding of high policy relevance. Interethnic marriages can be an important vehicle for the integration of migrants (Adda et al., 2019; Azzolini and Guetto, 2017). An institutional environment that makes this kind of marriage relatively unattractive may therefore hinder the success of migration policy.

An important confounding factor that we have to take into account to identify the effect of the labor market reform is the Eastern expansion of the European Union (EU) in May 2004. The EU expansion granted the right to live and work in any EU country to citizens of eight Eastern European countries, Malta, and Cyprus (the EU10 countries).

---

[98] Named after the chairman of the commission that worked out the reform package, Peter Hartz, who was at that time director of human resources at Volkswagen. We provide more details in Section 4.2.

[99] Caucutt et al. (2018), who investigate racial differences in marriage market outcomes in the US, make a similar identification argument related to the unemployment and incarceration rates of black men.

Most member states opened their labor markets straight away. Germany and Austria, however, implemented a seven-year transitional period during which free movement of workers for citizens of the new member states was only gradually introduced.

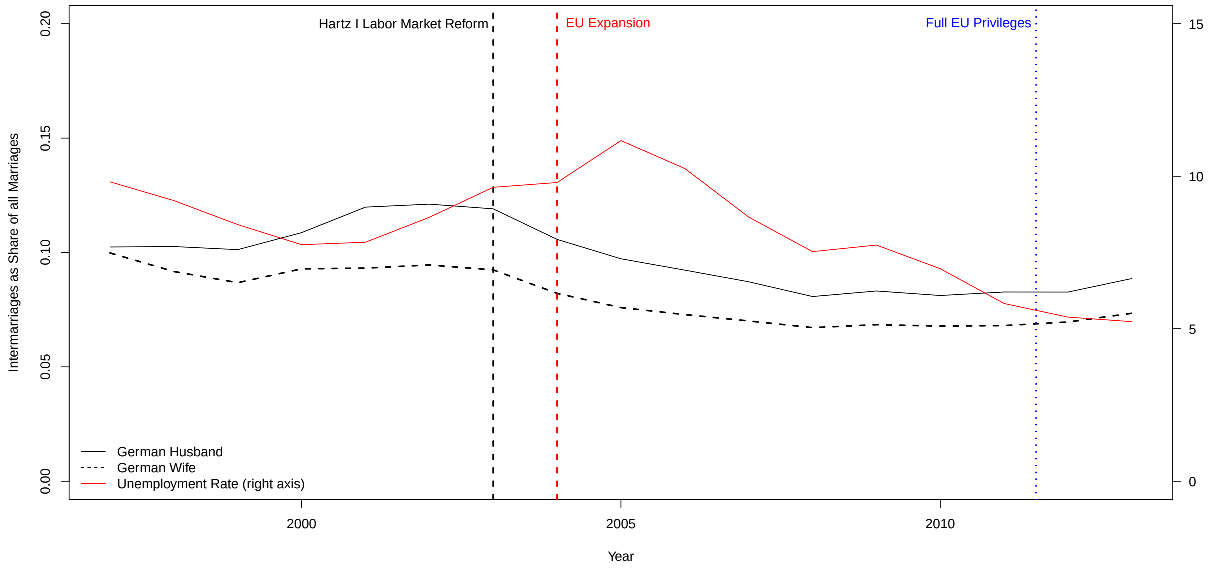
It is likely that the EU expansion had by itself an impact on the German marriage market, similar to what Adda et al. (2019) find in the Italian context. From a theoretical perspective, the marital surplus of interethnic marriages between Germans and citizens of the new EU member states was negatively affected by the EU expansion. The reason is that marrying a German citizen was in principle no longer necessary to obtain the right to reside and work in Germany. Due to the gradual opening of the German labor market, however, one would expect to find a smaller effect in Germany as compared to Italy, a country that immediately granted full labor market access.

We control for the effect of the EU expansion on marital surplus and stability in a double differences-in-differences setting. That is, we estimate the effect of the EU expansion conditional on the impact of the aforementioned labor market reform using a second set of treatment and control groups. We compare marriages of Germans with a EU10 spouses (treatment group) with marriages of Germans with natives of countries outside Europe (nonEU, control group). Taking into account the effect of the labor market reform, we find no statistically significant effect of the EU expansion on marital surplus and stability of interethnic marriages. For the German case, this finding seems reasonable,

The main sources of micro data we use in this study are the German marriage and divorce registers. Between 1997 and 2013, we observe all legal marriages and divorces in Germany that were formed or dissolved with daily precision and a rich set of covariates. We are not aware of any other research paper in the literature on marriage market and family economics that uses these data. As complementary data sources, we use the German Microcensus, the largest household survey in Europe, and linked employer-employee data drawn from the social security registers at the German Federal Employment Agency.

Figure 4.1 depicts the development of the German intermarriage rates between 1997 and 2013 using the marriage register, along with the unemployment rate, to highlight the interaction of marriage market outcomes and unemployment risk. Intermarriage rates evolve almost in parallel for men and women. The level of the marriage rate is always

Figure 4.1: Intermarriage Rates in Germany



Notes: The black dashed vertical line indicates the year in which the Hartz I Reform became effective (2003), the red dashed vertical line marks the year in which the EU expansion took place (2004). *Data*: RDC of the Federal Statistical Office and Statistical Offices of the Federal States, Marriage Registry, 1997-2013, own calculations. The unemployment rate is extracted from OECD data.

higher for German men marrying foreign women as compared German women marrying foreign men, so men are more likely to marry a partner of foreign nationality. Note that, after increases around the year 2000, the German intermarriage rates essentially became flat. This was a period of rising unemployment in Germany. The unemployment rate increased from 7.8% in 2001 to a maximum of 11.2% in 2005. The negative correlation between intermarriage and unemployment rates in this time period suggests a potential link between marriage market decisions and labor market conditions, which is what we study in this paper. Note that once the “Hartz I” labor market reform had been implemented (black dashed line), intermarriage rates started to fall for both German men and women. The negative trend was hardly affected by the EU expansion (red dashed line) and intermarriage rates only started increasing again around the year 2011, when the German unemployment rate had reached a historical low.

There is a large literature in family economics on the long-run interaction between marriage and labor markets, see Greenwood et al. (2016), Chiappori et al. (2018), and Greenwood et al. (2017) for a survey of this literature. The steep increase of female educational attainment and labor force participation in most developed economies after World War II has been a revolution according to Goldin (2006) and was without doubt a source of enormous economic growth. Our paper complements this literature by providing evidence for short-run interactions between marriage and labor markets, identified through interethnic marriages and institutional change. Other papers have documented that unemployment, especially male unemployment, is associated with an increase in the divorce rate.[100] Also, we know that marriage and divorce rates are negatively correlated with the unemployment rate over the business cycle.[101] Regarding the interaction of social insurance systems and marriage, Persson (2020) finds that the elimination of survivor insurance in Sweden affected marriage formation, divorces and the degree of assortativeness on the marriage market. Lastly, there is also a relatively large literature (Basu, 2015; Dribe and Nystedt, 2015; Furtado and Theodoropoulos, 2009; Kantarevic, 2005; Meng and Gregory, 2005; Meng and Meurs, 2009) on intermarriage and labor outcomes with mixed results.

In a related paper, Adda et al. (2019) show that intermarriage rates in Italy have been falling relative to the increasing number of foreign residents since the eastern expansions of the EU in 2004 and 2007.[102] Large groups of immigrants received immediate and full access to the Italian labor market. Adda et al. (2019) argue that lower intermarriage rates between Italians and foreigners after the expansions reflect that marrying an Italian spouse was no longer necessary to gain labor market access in Italy. Thus, if immigrants react to obtaining labor market access by marrying among themselves to a larger extent rather than natives of the host country, the labor market access of immigrants might paradoxically interfere with their integration in the host country instead of fostering it.

We find no significant effect of the EU expansion on interethnic marriages in Germany, conditional on the effect of the earlier labor market reform.[103] There are two main differences between Italy and Germany to consider in this context. First, labor market access for citizens of the countries that joined the EU in 2004 and 2007 was restricted in Germany until 2011.[104] Thus, the channel highlighted in Adda et al. (2019) (an Italian

---

[100] See Jensen and Smith (1990), Hansen (2005), and Amato and Beattie (2011) among others.

[101] See Schaller (2013), González-Val and Marcén (2017), and González-Val and Marcén (2018) among others.

[102] The 2007 expansion admitted Bulgaria and Romania to the European Union, which is of special importance in the Italian context due to the geographic proximity.

[103] We cannot identify what the EU expansion's effect would have been in the counterfactual scenario absent the labor market reform. We do find, however, that the expansion's effect on marital surplus is negative and significant (as in, Adda et al., 2019) if we estimate the EU effect in isolation.

[104] Even though it is debatable how much bite those restrictions had, see Section 4.2.

spouse was no longer necessary to obtain labor market access in Italy) should be much weaker in Germany. Second, Germany has a very different history of receiving migrants as compared to Italy and intermarriages have been relatively common for a long period of time. While large-scale immigration is a relatively new phenomenon in Italy[105], Germany has experienced sizable inflows of migrants since guest worker programs started in the 1950s/60s. During the 1990s and 2000s, the period we study in this paper, the share of residents without German citizenship was stable at around 8–9% of the population, a level that Italy did not reach until 2013.[106] Adda et al. (2019) report an intermarriage rate among newly formed marriages of below 3% for Italian men with foreign wives and around 1% for Italian women with foreign husbands in 1996, the first year of their data. In Germany, about 10% of all new marriages in 1997, the first year of our data, were intermarriages. This high baseline level of intermarriages in Germany might make the EU expansion "shock" quantitatively less important.

Our finding of a significant and quantitatively important negative effect on the marital surplus of interethnic marriages in Germany as a result of the labor market reform, however, leads to a conclusion similar in spirit to Adda et al. (2019): if natives react to labor market reforms by marrying each other rather than foreigners, paradoxically, reforms that are intended to lower the unemployment rate might interfere with the integration of foreigners, at least in the short-run.

The remainder of our paper is structured as follows. Section 4.2 describes the institutional background and Section 4.3 our data. Section 4.4 reviews the Choo and Siow (2006) marriage market matching model that we use to estimate marital surplus. Section 4.5 takes the model to the data and presents our empirical strategy with the main results. Section 4.6 provides a concluding discussion of the findings.

---

[105] As Adda et al. (2019) report, the share of foreign residents in Italy had been below 2% during the 1990s and started increasing during the 2000s. It reached around 9% in 2013.

[106] The share increased from 3% in 1967 to around 8% by the time of reunification. After the period of relative stability between 8–9%, the share surpassed 10% in 2014 and stood at more than 13% by the end of 2018. The recent increase is mainly related to prolonged recessions in Southern Europe and the inflow of refugees. All numbers are according to the federal statistical office.

4.2 Institutional Background

Our empirical analysis builds on a distinct change to the institutional environment in which individuals decide who to marry or stay married to in Germany. The change was a specific element of the so-called *Hartz reforms*, a comprehensive labor market reform package that was worked out by a commission chaired by Peter Hartz, who was at that time director of human resources at Volkswagen. The commission's work took place during the first half of 2002 and results were presented to the public on August 16, 2002. The Hartz reforms consisted of four reform packages that came into force consecutively. The reform packages were designed to increase labor demand (Hartz I and II), matching efficiency (Hartz III), and labor supply (Hartz II and IV).[107]

We focus on the Hartz I reform package, which came into force on January 1, 2003. The reform package was passed in parliament only shortly before, on December 23, 2002. Anticipation effects that would influence marriage-related decisions can thus expected to be minimal. As it was mainly designed to increase labor demand, the most prominent policy changes in the package liberalized temporary employment and subcontracted labor in Germany. Less prominently, however, Hartz I also severely tightened exemptions from household-level means-testing in the long-term unemployment benefits system, thereby increasing the extent to which spouses have to insure each other against unemployment.

Traditionally, the German social security system featured three types of transfers. The first transfer, unemployment benefits[108], is a social insurance benefit that replaces 60 to 67% of the previous net salary. It is not means-tested. Prior to 2005, the duration varied between 12 and 36 months depending upon age and work history. Since 2008, the duration of these benefits has been restricted to 12 months for workers below the age of 50.[109] Upon exhaustion of unemployment benefits, a second transfer, unemployment

---

[107] Hartz I, liberalized temporary employment and subcontracted labor in addition to the changes to means testing. Hartz II introduced subsidies for one-person companies ("Me-inc"), reformed marginal employment legislation by introducing new forms of tax-exempt part-time employment (so-called mini and midi jobs), and made it easier for firms to lay off workers. Hartz III reorganized the Federal Employment Agency to improve the process of offering suitable jobs to unemployed workers. Hartz IV heavily reformed the unemployment benefit system, mainly by shortening the duration of unemployment benefits and merging long-term unemployment assistance with means-tested social assistance.

[108] "Arbeitslosengeld" in German. The "Hartz IV" reform renamed it to "Arbeitslosengeld I" in 2005.

[109] For older workers, it is 15 months below 55, 18 months below 58, and then 24 months.

assistance[110], followed prior to 2005. Unemployment assistance claims had to be renewed yearly, but receipt was not time-limited otherwise. This transfer was tax-financed and amounted to 53 to 57% of the last net salary. It was, however, means-tested against the partner's income for both married and cohabitating individuals.[111] The threshold above which the partner's income reduced transfer entitlements was lowered substantially by the Hartz reforms.

From January 1 2003, the Hartz I reform lowered the partner-income threshold by more than 60% from 520 to 200 Euros per year of age with a maximum of 13000 Euros. This is the primary reform cutoff we exploit in our empirical analysis. Two years later, Hartz IV effectively set the means-testing threshold to zero when the long-term unemployment assistance program was discontinued. From January 1 2005, only tax-financed social benefits, traditionally the third and lowest tier of transfer payments in the German social security system, were available for unemployed individuals who exhausted their primary unemployment benefits. These social benefits[112] are strictly means-tested and additional sources of income, including the partner's income, are counted against benefit entitlements from the first Euro.

4.3 Data and Descriptive Evidence

4.3.1 Marriage and Divorce Registers

The marriage and divorce registers, MR and DR in the following, cover the universe of marriages and divorces in Germany. Data access is provided through the Research Data Centers (FDZ) of the statistical offices of the German federal states. The marriage and divorce registers are two separate sources of process-generated micro data that originate from the German civil registry offices and divorce courts, respectively. Both data sources contain information on legally registered marriages of different-sex couples only. Although

---

[110] "Arbeitslosenhilfe" in German.

[111] From 2001 onward, the partner's income above a threshold of 520 Euros per year of age of the partner was taken into account. The maximum value of the exemption was 33800 Euros for partners of age 65 and above.

[112] "Arbeitslosengeld II" or simply "Hartz IV" in colloquial German.

same-sex couples could form a civil union in Germany starting in 2001, these unions are not included in the marriage and divorce registers.[113]

Both data sets are organized at the level of the couple and contain information on the birth dates of both spouses, the date of marriage, and, in the DR, the date of divorce. Additionally, the data contain various covariates including religion and citizenship of both spouses, place of residence, number of children (before marriage and at the time of divorce), as well as who filed for divorce and the court's ruling. There is no information about education or other indicators of socioeconomic status.

Due to strict German data protection legislation, it is illegal to link the MR and DR registers at the level of the individual couple. Thus, we first use the MR data only and study marriage formation at the couple level. We estimate marital surplus based on the Choo and Siow (2006) transferable utility model of marriage-market matching, introduced in Section 4.4. To this end, we combine the flow of new marriages observed in the MR with stocks of unmarried individuals for different nationalities and age groups obtained from the German Microcensus (MC, described below).

To study marital stability and the incidence of divorce, we need to link the MR and the DR data. We do so by counting in both data sets the number of marriages in cells formed by the marriage date in quarterly terms and the nationality of both spouses. We can then merge both data sets at the quarter-nationality-nationality level to estimate survival models for different types of marriages that were formed before and after the institutional change.

The marriage and divorce data are organized as separate yearly files. We have access to all waves from 1991–2013 (MR) and 1995–2013 (DR). A few federal states did not report data prior to 1997, so we start our analysis in 1997 and merge the single yearly files for marriages and divorces into one data set, respectively. We clean the yearly MR and DR files from missing and inconsistent observations, that is, we remove duplicates, observations with missing marriage and birth dates, and marriages formed outside Germany. The latter should be removed for conceptual reasons because the two spouses matched on a different marriage market. Furthermore, marriages formed outside of Ger-

---

[113] Same-sex marriages were fully legalized in Germany only in 2017.

Table 4.1: Number of Marriages by Nationality and Gender

Nationality	Men	Women
German	6,090,937	5,978,700
EU15 (w/o Germany)	121,023	83,040
Poland	13,380	81,368
Turkey	100,981	55,487
EU10 (w/o Poland)	1,446	15,644
Romania	4,214	24,472
Former Yugoslavia	5,184	33,647
Rest of the World	255,304	313,680
Total	6,626,083	6,626,083

Data: German Marriage Registry, 1997–2013. EU15 (w/o Germany) countries are Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom. EU10 (w/o Poland) countries are Cypress, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Slovakia and Slovenia.

many were not recorded before 2008.[114] Furthermore, we disregard cases in which one of the individuals' birth date implies an age at marriage below 18. Most of these marriages were formed abroad, although this was a legal possibility in Germany during our period of observation.[115]

Table 4.1 shows the distribution of nationalities in the new marriages we observe between 1997–2013 for men and women, respectively. We observe a total of 6,626,083 marriages. Roughly 6 million of these marriages have at least one spouse with German nationality. The largest groups of non-Germans who get married in Germany are citizens of the other EU15 member states, Turkish men, and Polish women. Interestingly, the numbers of Turkish women and Polish men, respectively, are much smaller. For most nationalities, the foreign spouse is more often the wife. Exceptions are EU15 and Turkey, for which the number of husbands is higher. Marriages in which at least one spouse is non-European ("Rest of the World" in Table 4.1) also make up a significant share of all observed marriages in Germany.

---

[114] Marriages formed abroad represent only 0.15% of all marriages after 2008. Some descriptive information on marriages formed abroad can be found in Appendix C.1.

[115] Before 2017, it was in legal in Germany to form marriages in which there is one adult spouses and the other is between 16 and 18 years old. However, this type of marriage needed to be approved by a family court.

Table 4.2: Number of Marriages by Nationality Combination and Age

		Wife German	Wife EU15 (w/o Germany)	Wife Polish	Wife Turkish
Husband German	Mean Age Husband	35.82	36.18	37.40	30.34
	Mean Age Wife	32.91	33.21	31.08	26.37
	Difference	2.91	2.96	6.32	3.97
	N	5,587,615	52,736	70,377	29,429
Husband EU15 (w/o Germany)	Mean Age Husband	35.89	30.92	35.62	30.16
	Mean Age Wife	32.87	27.83	28.90	26.54
	Difference	3.02	3.09	6.72	3.62
	N	82,425	22,331	2,585	1,002
Husband Polish	Mean Age Husband	30.32	29.27	33.01	30.00
	Mean Age Wife	29.68	29.76	29.72	27.46
	Difference	0.64	-0.49	3.29	2.54
	N	9,236	79	3,747	13
Husband Turkish	Mean Age Husband	27.94	27.23	32.46	27.17
	Mean Age Wife	27.79	26.24	27.55	24.51
	Difference	0.14	0.99	4.91	2.67
	N	71,014	1,754	1,077	21,929

Data: German Marriage Registry, 1997 - 2013. Total number of observations for the shown sub-sample 5,957,349.

Table 4.2 provides a closer look at the marriage data by showing the number of observations for all combinations of the four most numerous (groups of) nationalities: German, EU15, Polish, and Turkish. It also shows the mean ages of both spouses along with the mean age difference. Marriages where none of the spouses is a German citizen are rare. They constitute less than 1% of the total number of marriages for the subsample in Table 4.2. 0.36% are marriages among Turkish citizens. In 8.2% of all marriages, at least one spouse is German. There are slighty more marriages between German women and foreign men than there are between German men and foreign women. However, German men who marry a non-German woman are on average older compared to German-German couples, although they are much younger in case the wife is Turkish. German women who marry a non-German man are on average younger compared to German-German couples, and much younger in case the husband is Turkish.

Age differences between men and women are almost always positive, that is, the husband is on average older than the wife in almost all nationality combinations. We observe a slightly negative average age difference for couples of EU15 women and Polish men, but this estimate is likely noisy due to the small subsample. The largest average age differences exist between Polish women and German or EU15 men. In these marriages, the woman is on average more than 6 years younger than the man. This is more than twice the unconditional average age gap of about 3 years in our sample. Overall, the descriptive evidence from the MR data points towards substantial differences in marriage market matching behavior across the different nationalities present in the German marriage market.

For the empirical analysis, we follow the marriage market matching model by Choo and Siow (2006), which uses the number of marriages relative to the number of available singles (see Chapter 4.4). To comply with the German data protection law, we can only extract these single stocks for groups that are sufficiently large. This criterion is met for citizens of Germany, EU15 (excluding Germany), Poland, Turkey, EU10 (excluding Poland), Romania, former Yugoslavia, and “Rest of the World”. We use the age groups 18-25, 26-32, 33-39, 40-46, 47-54, and 55-68. Finally, we merge the number of marriages obtained from the MR with the single stocks obtained from the German Microcensus.

4.3.2 The German Microcensus

The German Microcensus (MC) is an annual survey that delivers representative statistics on the German population and labor force. Data access is provided through the Research data centers (FDZ) of the statistical offices of the German federal states. The MC samples 1% of the population, consisting of all persons legally residing in Germany.[116] It is the largest household survey in Europe. Participation is mandatory[117] and only a subset of questions can be answered on a voluntary basis.

In the survey, one household member responds for all individuals living in the household, including the spouse, children, and other cohabitants if applicable. The survey program of the MC consists of a set of core questions that remains the same in each wave, covering general demographic and socioeconomic characteristics like marital status, education, employment status, individual and household income, among many other

---

[116] The MC survey design relies on single-stage stratified cluster sampling. The primary sampling units are artificially delimited districts with a number of neighboring buildings. All households residing in these buildings are interviewed (principal residence). Since 1990 the average number of buildings has been 9, the targeted number of individuals is 15. Larger buildings are subdivided.

[117] According to the German Microcensus law, non-response may be fined.

things. In addition to that, every yearly wave has a special topic on which specific questions are asked.

We select all individuals between 18 and 68 years of age who live in private households.[118] For the period after German reunification (1993–2013), this MC sample is representative of a roughly constant population of about 53 million individuals.[119] 47% are men and 53% women. 72% of men and 64% of women are married. The average labor force participation rates are 62% for men and 46% for women.[120]

For the questions we seek to answer in this paper, the MC data alone would be insufficient, however. For married individuals, they contain only the year of marriage, so the length of marital spells can only be calculated imprecisely. Also, this information is no longer collected since a redesign in 2005. Finally, the MC is not a panel data set, so studying at the individual level how marriage and divorce behavior has changed in connection with the institutional reforms considered in this paper is not possible.

Instead, we use the MC data to identify the respective populations of singles out of which new marriages are formed, by nationality and age. To this end, we select all adult individuals of ages 18 to 68 who live in private households as singles, either alone or with cohabitants. This includes never-married, divorced, and widowed individuals. We use the age groups 18-25, 26-32, 33-39, 40-46, 47-54, and 55-68. We compute the single stocks for the following nationalities/nationality groups for which we have sufficient numbers of observations in the MC: Germany, EU15 (excluding Germany), Poland, Turkey, EU10 (excluding Poland), Romania, and former Yugoslavia. Moreover, we form a residual group of nationalities denoted "Rest of the World".

4.3.3 Sample of Integrated Labour Market Biographies

The Sample of Integrated Labour Market Biographies (SIAB) is an administrative data set provided by the Research Data Center (FDZ) of the Institute for Employment Research (IAB) at the German Federal Employment Agency. We use these data to test a

---

[118] The MC also samples individuals who are in the military and live in barracks.

[119] Extrapolated from information on 8,426,756 surveyed individuals using sample weights. The average number of observations per wave is 443,513. The population increases somewhat after reunification and reaches a maximum of almost 55 million people in 2007. Afterwards it starts declining.

[120] The participation-age profiles are hump-shaped. In the 2006 MC wave, participation for men is highest in the age bracket 35-39 (88%) and the maximum for women (77%) is reached for ages 40-44.

central assumption of our empirical analysis: interethnic marriages were disproportionately affected by the labor market reform. The idea is that non-German workers face a higher risk of becoming unemployed. They and their partners are thus more affected by the tightening of means-testing thresholds in the unemployment insurance system.

The SIAB data cover a 2% random sample of the German social security registers. One observation in the data corresponds to a time period (spell) with at least one of the following characteristics: (i) employment subject to social security (in the data since 1975), (ii) marginal part-time employment (in the data since 1999), (iii) benefit receipt[121], (iv) officially registered job-seekers at the German Federal Employment Agency or (planned) participation in programs of active labor market policies (in the data since 2000). We observe these (un)employment spells with daily precision.

(Un)employment Spells end either by a change of employment status, employer or always at the end of calender year. The duration variable (tenure) is the accumulated time from the beginning of employment. We are interested in estimating conditional rates of job loss (firings/quits) and job finding (hirings). To identify the rate of job loss, we count transitions from employment into unemployment and from employment into inactivity. Transitions from unemployment into employment, both full and part time, identify the job finding rate. Changes from full to part-time employment (and vice versa) and transitions between employers are treated as continuous employment. The SIAB data also include information about, among other things, gender, nationality (German, non-German), regional identifiers, and education.[122]

To estimate the effect of the labor market reform on marital surplus below, we use a differences-in differences strategy and divide individuals into treatment and control groups according to their nationality, based on the idea that unemployment risk is higher for workers with an immigrant background and, thus, the treatment intensity of the reform is higher for interethnic marriages. The SIAB data allows us to formally test this identifying assumption. To this end, we estimate labor market transition probabilities

---

[121] According to the German Social Code: SGB III since 1975 and SGB II since 2005, The introduction of SGB II was part of the implementation of the Hartz IV reform.

[122] The education variable in German social security data suffers from missing values and inconsistencies, essentially because misreporting has no negative consequences. We impute missing and inconsistent observations using the methodology proposed by Fitzenberger et al. (2006). We use five levels of education: Lower secondary education without/with vocational training, higher secondary education without/with vocational training and tertiary education (University, University of Applied Sciences).

Table 4.3: Labor Market Hazard Rates

	Transitions into Unemployment				Transitions into Employment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
German	-0.130***	-0.144***	-0.184***	-0.199***	0.025**	-0.025***	-0.005	-0.052***
	(0.012)	(0.011)	(0.010)	(0.010)	(0.010)	(0.009)	(0.008)	(0.008)
	[0.878]	[0.866]	[0.832]	[0.820]	[1.025]	[0.975]	[0.995]	[0.949]
Female	-0.191***	-0.125***	-0.188***	-0.116***	-0.161***	-0.143***	-0.160***	-0.143***
	(0.009)	(0.008)	(0.010)	(0.008)	(0.011)	(0.011)	(0.010)	(0.010)
	[0.826]	[0.882]	[0.829]	[0.890]	[0.851]	[0.867]	[0.852]	[0.867]
N	1,857,659	1,857,659	1,857,659	1,857,659	1,232,908	1,232,908	1,232,908	1,232,908
Stratified by Education	✓	✓	✓	✓	✓	✓	✓	✓
Year FE		✓		✓		✓		✓
Region FE			✓	✓			✓	✓

Notes: robust standard errors (clustered by region) in parentheses. Hazard rates reported in square brackets.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

conditional on gender and nationality (German, non-German). We do not observe marital status in the SIAB data. Additionally, we stratify by education. To test whether non-natives face a higher unemployment risk in Germany, both in terms of transitions into unemployment and duration, we estimate Cox proportional hazard models (Cox, 1972).

This Cox model assumes a baseline hazard that is common to both employed and unemployed individuals along with a log-linear function of covariates.[123] With stratification, the five different education groups are allowed to have different baseline hazards.[124]

We calculate hazard rates for transitions into unemployment and into new employment out of unemployment. Table 4.3 presents the results. The covariates of interest are nationality and gender of the employed/unemployed individuals. Columns (1)–(4) of table 4.3 present the hazard rates for job loss (transitions into unemployment) and columns (5)–(8) present the hazard rates for job findings (transition into employment). We find that the hazard of transitioning from employment into unemployment is significantly higher for non-natives as compared to Germans. Thus, as we conjectured, non-natives

---

[123] The hazard rate for transitions out of and into unemployment after a number of days, d, with the vector of covariates Z is denoted $h(d, Z)$. γ indicates the vector of coefficients to be estimated and $\lambda(d)$ the baseline hazard and v is an error term. Thus, the hazard model can be specified as $h(d, Z) = \lambda(d) \cdot \exp(\gamma' Z) \cdot v$.

[124] Separate Cox models for each education group are estimated with stratification under the assumption that coefficients are the same across strata and that each education group has its own baseline hazard for job loss and job findings, respectively. As education is unobserved in the marriage and divorce data, we also estimate hazard rates without stratification, see Table C.2 in the Appendix. The conclusions are unchanged.

face a higher risk of becoming unemployed. Our preferred specification includes both year and labor market region fixed effects, see columns (4) and (8). German nationals have a job loss hazard rate that is 20% lower than the respective hazard rate for workers without German citizenship, who are thus on average more likely to lose their jobs. For transitions into employment, the hazard rate of Germans is 5% lower than the hazard rate for foreigners. Thus, workers without German citizenship find new jobs out of unemployment quicker than Germans, their unemployment duration is on average shorter. An explanation for this finding are lower reservation wages, for example due to lower unemployment benefit entitlements or because for some nationalities continued employment is a necessary requirement for residence status.[125]

Note that the estimated hazard rates reflect differences between Germans and a diverse group of individuals without German citizenship. One would expect that labor market transition probabilities vary greatly across individuals of different foreign nationalities. For example, citizens of other EU15 countries face no legal barriers to employment in Germany and unemployment benefit entitlements can be transferred across countries. Thus, they might be more comparable to German workers in terms of labor market attachment than workers from non-EU countries are. The hazard rate differences we find can therefore be interpreted as a lower bound for the differential exposure to labor market risk for workers without German or EU15 citizenship.

Finally, women are 12% less likely to become unemployed and about 14% less likely to move into employment according to our preferred specification. That is, women are on average employed longer, but it takes them longer to find a new job out of unemployment. Thus, the need for additional insurance after the reform might be higher for women.

4.4 Theory

To formally investigate how changes to labor market institutions affect decisions in the marriage market, we rely on a marriage market matching model that lends us structure. Choo and Siow (2006) derive a simple non-parametric estimator of the *marriage surplus*,

---

[125] Selection also plays a role: upon job loss, some foreign workers might simply leave the German labor market and return to their home country, so we don't observe those individuals transitioning back into employment.

using a static matching model with transferable utility between spouses in the spirit of Becker (1973, 1974). Choo and Siow (2006) generate the market demand for marriages using the extreme-value logit random utility model of McFadden (1974), which yields characteristic functional forms.

4.4.1 Marriage Surplus

The marriage surplus reflects the gains from marriage for both partners, and those gains may change systematically in response to changes in the institutional environment. The marriage surplus is calculated using market clearing conditions and, thus, depends on the relative numbers of married and single individuals of a particular type.

The independent utility of a type i man g married to a type j women is given by equation 4.1.[126] It consists of a systematic gross return ($\tilde{\alpha}_{ij}$) that depends on the particular type combination, a systematic utility transfer from the man to the women (τ_{ij}) and an independently and identically distributed random variable with a type I extreme-value distribution (ϵ_{ijg}). Thus, the systematic gain from marrying a type j for a type i man is given by $\tilde{\alpha}_{ij} - \tau_{ij}$.

$$V_{ijg} = \tilde{\alpha}_{ij} - \tau_{ij} + \epsilon_{ijg} \tag{4.1}$$

Symmetrically, for a female of type j the systematic gain from marrying a type i man is denoted $\tilde{\gamma}_{ij}$. Following the notation of Choo and Siow (2006) the sign of the utility transfer (τ_{ij}) is positive for women. A male (female) individual g will choose the type of the marriage partner type j (i) according to

$$V_{ig} = \max_{j}\{V_{i0g}, ..., V_{ijg}, ..., V_{iJg}\}. \tag{4.2}$$

Following McFadden (1974) and assuming a large number of men and women, this translates into a quasi-demand function for type i, j marriages demanded by type i men:

---

[126] In our empirical implementation, type i and j are a combination of nationality and age. See Section 4.5 for more details.

$$\begin{aligned}\ln \mu^d_{ij} &= \ln \mu^d_{i0} + \tilde{\alpha}_{ij} - \tilde{\alpha}_{i0} - \tau_{ij} \\ &= \ln \mu^d_{i0} + \alpha_{ij} - \tau_{ij}, \end{aligned} \tag{4.3}$$

where $\alpha_{ij} = \tilde{\alpha}_{ij} - \tilde{\alpha}_{i0}$ is the systematic gross return to a type i man for a type i, j marriage relative to being unmarried. Symmetrically, the supply of type i, j marriages by women j is given by:

$$\ln \mu^s_{ij} = \ln \mu^s_{0j} + \gamma_{ij} + \tau_{ij}. \tag{4.4}$$

In equilibrium—when all $I \times J$ submarkets of the marriage market clear—the joint surplus generated by a marriage between a type i man and type j woman can be calculated by adding equations (4.3) and (4.4). The utility transfers between both spouses cancel out and only the two systematic components, α_{ij} and γ_{ij}, remain:

$$\ln \mu_{ij} - \frac{\ln \mu^d_{i0} + \ln \mu^s_{0j}}{2} = \frac{\alpha_{ij} + \gamma_{ij}}{2}, \tag{4.5}$$

so the joint surplus for both partners consists solely of the systematic gains from marriage. The LHS of equation (4.5) can be rewritten as

$$\Phi_{ij} = \ln \left(\frac{\mu_{ij}}{\sqrt{\mu_{i0}\ \mu_{0j}}} \right). \tag{4.6}$$

Choo and Siow (2006) refer to this expression as the *marriage market matching function*: the number of marriages between type i men and type j women is given by μ_{ij} in the numerator. It is scaled by the the number of single men and single women of the same type, μ_{i0} and μ_{0j}, in the denominator, so the expression is scaled by the observed population vectors. Intuitively, the total systematic gain (surplus) to marriage per partner for any i, j pair can be expected to be high if we observe many i, j marriages relative to the respective single populations.

For a constant marriage surplus Φ_{ij}, a percentage increase in the stock of available singles of a particular type (μ_{i0} and μ_{0j}) should result in a percentage increase of marriages that include this particular type (μ_{ij}). Consequently, changes in the marriage surplus are deviations from this constant relationship between marriages and single stocks.[127] Thus, any inflow of singles of a certain type should—in case the systematic factors underlying the marriage surplus did not change—result in a proportional increase of marriages that include this particular type.

4.4.2 Reform Effects on Marital Surplus

The labor market reform we consider in this paper lowered the generosity of social insurance in case of prolonged unemployment. The need to self-insure within the household increased. Thus, the systematic component of the marriage surplus changed, assuming that married individuals take into account that they may have to support their partner.

From the male perspective, the reform affected both $\tilde{\alpha}_{ij}$ and $\tilde{\alpha}_{i0}$ in the model. On the one hand, the lower generosity of social insurance reduced $\tilde{\alpha}_{i0}$ and thus increased incentives to get married due to the need for additional insurance through a partner. On the other hand, stricter means testing decreased $\tilde{\alpha}_{ij}$, the gains from being married, because of the larger need to support the partner in case of unemployment. From the female perspective, the reform affected $\tilde{\gamma}_{ij}$ and $\tilde{\gamma}_{i0}$ in the same way.

The net effect of the changes to both model objects is a priori unclear. We evaluate it empirically in Section 4.5 by exploiting the reform-induced variation in observed marriage rates and the estimated surplus for different types of individuals.

Note that, according to the model, utility transfers, τ_{ij}, do not matter for marital surplus and, thus, do not have to be observed to study the reform's effect on marital surplus. In theory, however, they are part of an important adjustment mechanism. Utility transfers change relative gains to marriage for both partners by transferring resources to one partner at the expense of the other. For example, the loss of systematic gains from marriage for a certain type of women may have to be compensated by men through a larger transfer to keep the marriage preferable to singlehood for both partners. If increasing the transfer sufficiently is infeasible, a lower number of marriages of that particular type i, j, and, potentially, more divorces (which are not modeled here) would be the consequence.

---

[127] Implicitly, the marriage surplus is always defined relative to the value of being single. Thus all changes that affect both the value of being single as well as the value of being married to the same extend will not alter the marriage surplus.

4.4.3 Expected Gains to Entering the Marriage Market

In addition to the marriage surplus, the Choo and Siow (2006) model also provides functional forms for the expected gains to marriage that can be computed directly from the data. The labor market reform arguably also affected gains to entering the marriage market for both genders, due to the aforementioned insurance considerations. Thus, we will also study how these gains evolved over time in conjunction with the institutional changes in the labor market.

Starting from the demand for marriages, equation (4.3) above, the expected value of entering the marriage market for a type i man g before all individual realizations of ϵ_{ijg} is

$$\mathbb{E}V_{ig} = c + \tilde{\alpha}_{i0} + \ln\left(\frac{m_i}{\mu_{i0}^d}\right), \tag{4.7}$$

where c is a constant and $\tilde{\alpha}_{i0}$ the gains from being single of this particular type. The value of entering the marriage market is proportional to the log of the number of type i men who enter the marriage market, m_i, divided by the number of type i men who remain single. The last term can thus be interpreted as the expected gains to entering the marriage market for type i men, denoted

$$Q_i = \ln\left(\frac{m_i}{\mu_{i0}^d}\right). \tag{4.8}$$

By symmetry, the expected gains to enter the marriage market for women are

$$Q_j = \ln\left(\frac{f_j}{\mu_{0j}^s}\right), \tag{4.9}$$

where f_j is the number of type j women who enter the marriage market.

4.5 Empirical Analysis

4.5.1 Taking the Model to the Data

Using the Choo and Siow (2006) model, one can compute the marriage surplus from a single cross section of data. Our data has a time dimension, so we adapt this approach by calculating the marriage surplus annually using the flow of new marriages relative to the number of available singles in that particular year. Essentially, this measures the flow out of singlehood.[128]

In the data, we interpret the individual types i and j of men and women as a combination of age and nationality. Thus, we let $\hat{\Phi}(f_{a,n}, m_{a,n})_t$ denote the estimated surplus of a marriage between a man of age a and nationality n and a woman of age a and nationality n in year t in our data. We estimate it using equation (4.6):

$$\hat{\Phi}\left(f_{a,n}, m_{a,n}\right)_t = \ln\left(\frac{\mu(f_{a,n}, m_{a,n})_t}{\sqrt{\mu(0, f_{a,n})_t \; \mu(m_{a,n}, 0)_t}}\right), \tag{4.10}$$

where the marriage surplus in any particular year t depends on the observed numbers of females $f_{a,n}$ and males $m_{a,n}$ of a certain age a and nationality n who get married, $\mu(f_{a,n}, m_{a,n})_t$, relative to the geometric average of the available singles of the same types, $\mu(0, f_{a,n})_t$ and $\mu(m_{a,n}, 0)_t$. The more new marriages we observe for given population vectors, the higher is the estimated marriage surplus for this particular age-nationality combination. As our data inputs, we use observed new marriages in the MR data and single stocks in the MC data for six age groups (18-25, 26-32, 33-39, 40-46, 47-54, 55-68) and eight nationalities (Germany, EU15 (excluding Germany), Poland, Turkey, EU10 (excluding Poland), Romania, former Yugoslavia, Rest of the World) as explained in Section 4.3.

Moreover, we estimate the gains to entering the marriage market for both men ($\hat{Q}_{m_n}$) and women ($\hat{Q}_{f_n}$) of all nationalities n (irrespectively of age, for brevity) according to equations (4.8) and (4.9), respectively:

$$\hat{Q}_{f_n} = \ln\left(\frac{f_n}{\mu(0, f_n)_t}\right), \; \hat{Q}_{m_n} = \ln\left(\frac{m_n}{\mu(0, m_n)_t}\right). \tag{4.11}$$

The numerator in both expressions represents the total number of women and men by nationality, respectively. The denominators ($\mu(0, f_n)_t$, $\mu(0, m_n)_t$) represent the respective numbers of singles. We approximate the total numbers of all male and female individuals

---

[128] This approach is also used by Adda et al. (2019), who estimate the Choo and Siow (2006) model using Italian census data.

in the marriage market by adding to the number of singles from the MC the number of individuals for which we observe a marriage in the same year.[129]

4.5.2 Trends on the Marriage Market

Figure 4.2 plots the estimated marriage surplus for different nationality combinations of spouses over time. We focus on marriages where at least one partner is German. To increase visibility, we separately show the surplus for marriages in which both partners are German (black line) one spouse is an EU15 citizen (blue line), one spouse is an EU10 citizen (orange line). We pool all other nationalities in the "Rest" (of the world) category (gray line).

From 1998 until the announcement date of the labor market reform (black dashed line), we observe a slow but steady decline in marriage surplus for all combinations of spouses. Afterwards, trends diverge. We observe a steep decline in the estimated surplus for marriages in which one partner is of EU10 or "Rest of World" type.[130] According to our hypothesis, these marriages were disproportionately negatively affected by the reform due to higher unemployment risk. Conversely, the marriage surplus for German couples and between Germans and EU15 citizens, arguably the groups with lower unemployment risk, increases slightly.

It is challenging to isolate the marriage market impact of the labor market reform in January 2003 due to the Eastern enlargement of the EU. Ten new member states joined in May 2004 (red dashed line in Figure 4.2) and this was anticipated. For citizens of these countries, marrying a German was no longer necessary to obtain access to the German labor market following the enlargement.[131] Thus, the EU expansion could have had an impact on the marriage market in itself, as argued by Adda et al. (2019) in the Italian context. To take this confounding factor into account, we control for the EU expansion

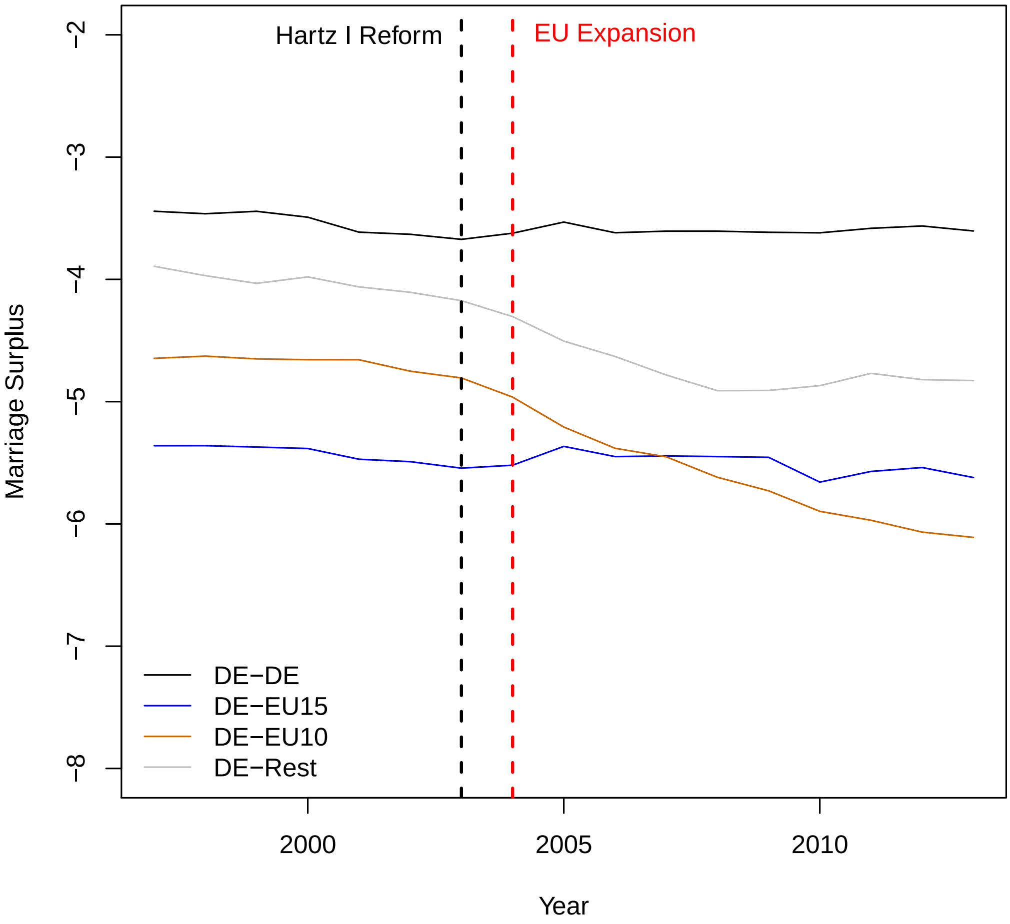
---

[129] This is only an approximation since the MC data is survey-based and individuals could potentially get married in the same year after reporting in the survey that they are singles. The numbers of individuals might thus be somewhat upward biased due to double counting.

[130] By far the largest group of EU10 immigrants are Poles. Figure C.1 in the Appendix separates the surplus of German-Polish marriages and German-Other-EU10 marriages, The trend is broadly the same, the decrease somewhat less steep for Poles.

[131] Although access to the German labor market for migrants from the new EU member states was initially restricted.

Figure 4.2: Development of Marital Surplus over Time

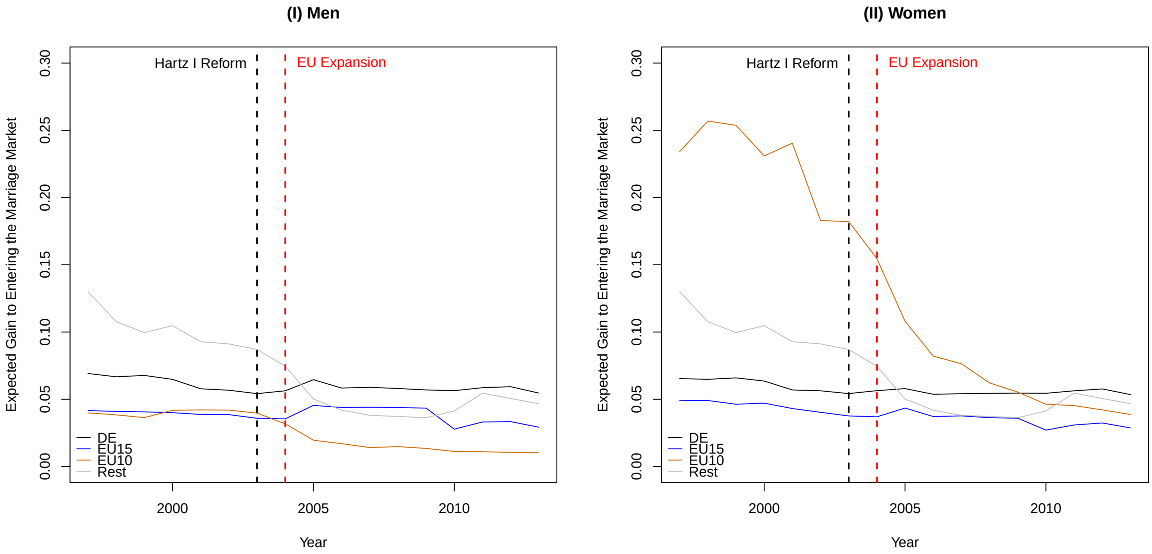


Notes: Marriage surplus for marriages where at least one spouse is German by nationality of the non-German spouse. The black dashed vertical line indicated the year in which the labor market reform became effective, the red dashed vertical line marks the year 2004 in which the EU expansion took place. *Data*: RDC of the Federal Statistical Office and Statistical Offices of the Federal States, Marriage Registry, survey year(s) 1997-2013, own calculations.

in our main analysis by using separate treatment and control groups to isolate its effect in our differences-in-differences setup.

In Figure 4.2, the trends described above did not change around the date of the EU expansion. On the contrary, the divergence between German/German-EU15 and German-EU10/German-Rest marriages became more pronounced. The surplus of marriages between Germans and between Germans and EU15 citizens continued to increase before flattening out in 2005. EU10 citizens were directly affected by the EU expansion and, accordingly, their marriage surplus with Germans decreased at a steeper rate as compared to German-Rest marriages, especially after 2007. This makes intuitive sense: arguably, the surplus from marrying a German for EU10 citizens reflected to some extent

Figure 4.3: Expected Gains to Entering the Marriage Market



Notes: Expected gains to entering the marriage market for men (left sub-figure) and women (right sub-figure).

the obtainment of a residence permit and labor market access before 2004. Due the EU expansion, this part of the marital surplus was erased.

The declining marriage surplus for interethnic marriages with non-EU15 spouses is also reflected in the estimated expected gains to entering the marriage market, see Figure 4.3, which plots these gains for men (left sub-figure) and women (right sub-figure). Recall that, according to Equation 4.11, the estimated gains of marriage only depend on the total number of individuals relative to singles of any particular type. As before, they are shown for German men/women in black, for EU15 men/women in blue, for EU10 men/women in orange and gray for all remaining nationalities.

Notably, the gains to marriage decrease more substantially for foreign women than for foreign men and this is mainly driven by EU10 women, who had very high gains in the beginning of our sample that rapidly decreased thereafter. This is in line with the fact that we observe relatively many women from Poland and other EU10 countries who get married in Germany as compared to men from these countries, recall Table 4.1. For EU10 men the gains are essentially flat before the labor market reform, decrease in 2003/2004, and reach another relatively stable level. Rest-of-the-world men's and women's gains are very similar. They start decreasing before the reform, but the negative trend accelerates in 2003–2005.

Table 4.4: Treatment and Control Groups

Type of Marriage	"Hartz" Treatment (Jan 01, 2003)	EU Treatment (May 01, 2004)	"Hartz"-Effect	Controls (EU-Effect)
German-German	No	No	Control	—
German-EU15	No	No	Control	—
German-EU10	Yes	Yes	Treatment	Treatment
German-nonEU	Yes	No	Treatment	Control

4.5.3 Reform Effects on Interethnic Marriage Formation

In this empirical section, we aim to illustrate the effect of a mayor institutional change that affected the German marriage market. The institutional change is the labor market reform in 2003. We run an empirical specification including difference-in-difference terms to estimate the effect of the institutional change on the treated population. Furthermore, we extensively control for the 2004 EU expansion. We restrict our sample to marriages where at least one spouse is German. Table 4.4 illustrates the treatment and control groups for the evaluation of the labor market reform (see Column 4), and the control variables that control for the EU expansion in 2004 (see Column 5), which may also have affected the marriage surplus for a sub-group of the non-native population.

The Labor Market Reform: The labor market reform increased the need to self-insure within the marriage in case of unemployment, which is more likely for interethnic marriages as non-natives have a higher unemployment risk compared to natives. This is causing a decrease in the demand of interethnic marriages from natives, as the marriage with a non-native spouse becomes riskier. As a result, we expect fewer interethnic marriages relative to the single stocks, which will result in a lower marriage surplus. For the difference-in-difference specification, we compare marriages formed between spouses where both have unrestricted labor market access (German, EU15) with marriages where the non-native spouse had worse labor market access (Polish, Turkish, Romanian, other EU-2004, former Yugoslavia, Rest of the World) before and after the date the law became effective. Thus, the variable *Hartz* takes on the value of 1 for marriages where the non-native partner is not from a EU member country[132]. The variable $PostHartz$ takes on the value of 1 for marriages formed after January 1, 2003.

Empirical Specification: Formally, we estimate the effect of the labor market reform using a differences-in-differences specification:

$$\begin{aligned}\Phi_{c_h,c_w,a_h,a_w,t} = \beta_1 \times Hartz_{c_h,c_w} + \beta_2 \times PostHartz_t + \beta_3(Hartz_{c_h,c_w} \times PostHartz_t) \\ + \gamma X_{c_h,c_w,t} + \alpha_t + \delta_c + u_{c_h,c_w,a_h,a_w,t}, \quad (4.12)\end{aligned}$$

where c_h and c_w are country of origin for husband and wife. a_h , a_w and t represent age of husband, age of wife and year, respectively. α_t and δ_c are time and country of non-German spouse fixed effects. $\Phi_{c_h,c_w,a_h,a_w,t}$ is the marriage surplus for a particular combination of age and country of origin for both partners in a given year t. Standard errors $u_{c_h,c_w,a_h,a_w,t}$ are at the level of the marriage surplus, which depends on the combination of age and nationality of both spouses in each year. $X_{c_h,c_w,t}$ is a vector of control variables that extensively controls for the 2004 EU expansion that may have also affected the marriage surplus at approximately the same time. A detailed analysis of this vector of control variables is discussed in Section 4.5.4. The coefficients of interest for the treatment effect on the treated of the labor market reform is β_3.

4.5.3.1 Main Results

We quantify the effect illustrated in Figure 4.2 using the empirical model captured in Equation 4.12. The baseline estimation results are presented in Table 4.5. Columns 1 and 2 include all marriages where at least one spouse is German. Columns 3 & 4 and 5 & 6 present the results for the sub-samples where the husband or wife are German, respectively. Columns 1, 3 and 5 include year and nationality of the non-German spouse fixed effects, whereas columns 2, 4, and 6 additionally control for age fixed effects of both spouses. The difference-in-difference coefficients of interest for the effect of the labor market reform on the treatment group are $Hartz \times PostHartz$. Robust standard errors are reported in parentheses.

---

[132] The analysis focuses on marriages with at least one German spouse.

Table 4.5: Baseline Results for Marriage Formation

Dependent Variable	Marriage Surplus					
	All Marriages		German Husband		German Wife	
Hartz x PostHartz	-0.441^{***}	-0.473^{***}	-0.370^{**}	-0.443^{***}	-0.519^{***}	-0.535^{***}
	(0.119)	(0.106)	(0.154)	(0.133)	(0.157)	(0.137)
Constant	-6.237^{***}	-6.055^{***}	-6.275^{***}	-6.498^{***}	-6.191^{***}	-5.987^{***}
	(0.144)	(0.154)	(0.169)	(0.194)	(0.167)	(0.191)
Year, Nation FE	✓	✓	✓	✓	✓	✓
Age FE (both)		✓		✓		✓

Notes: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The baseline specification for the full sample shows a 0.44 log point decrease in the gains of marriage for marriages formed between a native and a non-EU15 spouse as a reaction to the ‘labor market reform. The specification controls for year fixed effects and nationality of the non-German spouse fixed effects. Year fixed effects control for the generally declining marriage rates in Germany, while the nationality fixed effects control for any confounding factors that are specific to marriage formation with particular nationalities. The results are a clear indication that the labor market reform negatively influenced interethnic marriage formation and, thus, had a substantial negative influence on the integration of immigrants into society. In particular, existing barriers on the labor market that already made interethnic marriages riskier than marriages between spouses where both partners had full labor market access were intensified through the reforms.

After additionally controlling for age fixed effects of both spouses, the effect size slightly increases in magnitude to -0.473. We estimate the model separately for marriages where the husband is German and where the wife is German. We find larger negative effects of the labor market reform for marriages where the husband is non-native compared to when the wife is non-native. The results for the sub-sample analysis are consistent with classic gender roles in Germany, where the husband is often seen as the main breadwinner. Since the husbands’ income is relatively speaking more important for the total household income, the effect sizes are larger for marriages where the husband is exposed to the labor market reform treatment.

Interethnic marriages are often interpreted as a sign of integration of ethnic minorities and immigrants into society. By negatively affecting the interethnic marriage rates, these unintended consequences of the labor market reform post a serious threat to social integration of immigrants, who already face more difficulties on the labor market. In fact, given the literature on labor market outcomes of immigrants[133] that result from interethnic marriage formation, these reforms may have substantially hurt immigrants labor market participation though the marriage formation channel as well.

4.5.4 EU Expansion & Robustness Checks

4.5.4.1 2004 EU Expansion

The importance of institutional factors in marriage formation has already been investigated by other studies. Adda et al. (2019) for example study the effect of the EU expansion on interethnic marriage formation in Italy and find that the EU expansion negatively influenced interethnic marriage formation. Germany differs from Italy in some crucial dimensions, which make a similar analysis more complicated. First, Germany had a substantial share of non-natives in the total population even before the EU expansion took place in 2004. Second, following the 2004 EU expansion, Germany did not grant full labor market access to citizens from newly entering countries. Nevertheless, the EU expansion may have substantially influenced marriage formation even in the case of Germany, which is why we control for the EU expansion extensively in previously reported regressions. In this subsection, we will further investigate the estimated parameter values of these control variables and compare them to the values obtained by Adda et al. (2019).

Institutional Background: The European Union (EU) is a political and economic union currently consisting of 28 member states (as of August 2019). Initially consisting of 12 member countries[134] (Maastricht Treaty, effective November 1, 1993), the EU was expanded in multiple steps. In 1995, Austria, Finland and Sweden joined the EU. In 2004, the largest expansion round admitted Cyprus, Malta, and eight Eastern European

---

[133] See for example: Basu (2015); Dribe and Nystedt (2015); Furtado and Theodoropoulos (2009); Kantarevic (2005); Meng and Gregory (2005); Meng and Meurs (2009)

[134] Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the United Kingdom.

countries to the EU: the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia. In 2007, Bulgaria and Romania followed and Croatia joined in 2013.

The main objective of the EU is the development of a common internal market. This is achieved through common policies that ensure free movement of people, goods, services, and capital. Citizens of any EU member state have the right to live and work in any of the other member states, under the same conditions as the native citizens of that particular country. Following the 2004 EU expansion, the old member states (EU15) and new member states (EU10) negotiated a transitional period of up to 7 years in which labor movement was restricted in order to "protect" the labor market of the old member states.[135] Some countries, such as the UK and Italy (Adda et al., 2019), opened their labor market immediately, whereas other countries, such as Germany and Austria, restricted the inflow of workers until all limitations were lifted in 2011. This had a sizable effect on the direction of migration flows.

The main difference between Germany and Italy is that citizens of the new EU member states, as the case of the Poles illustrates, already had legal ways of working in Germany before the EU expansion. Even with labor market access restrictions, arguably, those ways continued to exist. While in Italy labor markets access changed, in exaggeration, from completely closed to completely open almost instantly, in Germany labor market access changed much more gradually until all restrictions were lifted in 2011.[136]

Theoretical considerations: For the effect of the 2004 EU expansion, let's follow the example of a German man and an EU10 woman. After the EU expansion, the EU10 woman no longer hat to marry a German husband to obtain access to the German labor market. This is reflected in a lower value of $\tilde{\gamma}_{ij}$. In addition, the EU10 woman had labor market access also as a single woman, which increased $\tilde{\gamma}_{i0}$. Both changes lower the gains to marriage for this particular type of i, j marriage. The German potential husband

---

[135] There was a fear that the EU expansion would lead to a large scale migration of lower wage workers from newly admitted countries to old member countries, with substantial labor market consequences.

[136] Between 2007 and 2009, when unemployment rates started to fall, Germany began granting labor market access to migrants in specific occupations, for example, IT specialists, engineers and medical doctors, and to college graduates seeking employment in their field of study. These exemptions from the initial restrictions and the bilateral agreements show that the German labor market was in fact not completely inaccessible.

can offset this lower value of marriage by a larger transfer ($\tau_{i,j}$) to the potential wife whenever feasible. However, when this change in transfer may become too large, other types of marriages become more attractive, leading to fewer particular type i, j marriages in equilibrium.

One issue with the EU expansion is that some countries (including Germany) only slowly introduced full access of new EU citizens to the German labor market. While services and self employed work could freely be provided, regular employment was initially restricted and restrictions were lifted in a staggered fashion. Important for the understanding of the marriage surplus, it is important to understand the parameter values (e.g. $\tilde{\gamma}_{ij}$) as an expected gain over the lifetime. Simply speaking, both spouses discount all future (potential) benefits from a certain type of marriage.

Empirical Specification: Following the EU expansion, it was no longer necessary to marry a native in order to get access to the German labor market for citizens of EU10 states. This is causing a decrease in the demand for interethnic marriage from the immigrants. As a result, we expect fewer interethnic marriages relative to the single stocks, which will result in a lower marriage surplus. For the difference-in-difference specification, we compare interethnic marriages where the non-native spouse is from a country that joined the EU in 2004 with marriages where the non-native spouses is from a country that was not affected by the EU expansion. The resulting effect is conditional on the labor market reform effect, which precedes the EU expansion. Thus, we compare marriages formed between Germans and new EU members with marriages formed between Germans and never EU members. Conditional on the labor market reform effect, we compare marriages where the non-native spouse is from a Post-Hartz-New-EU country (EU10) to marriages where the non-native spouse is from a Post-Hartz-Non-EU country (Turkey, Romania, former Yugoslavia, Rest of the World). Since the data, in particular the single stocks taken from the MC, is only available on an annual basis, all marriages formed in 2004 will be counted as part of the treatment group.[137]

Results of the EU Expansion: For the investigation of the control variables for the 2004 EU expansion, let's illustrate the control parameters (previously $\gamma X_{c_h,c_w,t}$). The

---

[137] Traditionally relatively few marriages are formed during the winter month in Germany.

additional difference-in-difference coefficient (see Equation 4.13) of interest is $NewEU \times PostEU$ for the effect of the EU expansion. The treatment and control group of the difference-in-difference specification are illustrated in Column 4 of Table 4.4. The results for the control variables are reported in Panel A of Table 4.6. Robust standard errors are reported in parentheses.

$$\begin{aligned}\Phi_{c_h,c_w,a_h,a_w,t} = \beta_1 \times Hartz + \beta_2 \times PostHartz + \beta_3(Hartz \times PostHartz) \\ + \beta_4 \times NewEU + \beta_5 \times PostEU + \beta_6(NewEU \times PostEU) \\ + \alpha_t + \delta_c + u_{c_h,c_w,a_h,a_w,t}, \quad (4.13)\end{aligned}$$

Contrary to Adda et al. (2019) for the case of Italy, we do not find significant effects of the EU expansion on interethnic marriages in Germany. Throughout all specifications and sub-samples, we find negative coefficients. However, apart from one single specification that is significant to the 10% level, all specifications do not indicate statistical significance. Consequently, we find the large negative effect of the labor market reform to overshadow the EU expansion effect for the case of Germany.

To illustrate the importance of the labor market reform effect, in particular when assessing the effect of the EU expansion on interethnic marriages in Germany, we run the difference-in-difference specification above without including the labor market reform effect. The results are reported in Panel B of Table 4.6. Using the miss-specification, we find a significant and negative effect of the EU expansion on interethnic marriages in Germany. Without prior knowledge about the labor market reform and the effect on interethnic marriages that result from it, one might conclude that the EU expansion had a negative effect on interethnic marriages also in the case of Germany.

4.5.4.2 Availability of Singles

The framework by Choo and Siow (2006), see Equation 4.12, assumes that a percentage increase in the available number of singles results in a percentage increase in the number of marriages for a constant value of the gains to marriage. Thus, the marriage surplus can change for two reasons: (i) underlying factors that fundamentally change the attractive-

Table 4.6: Baseline Results for the EU Expansion

Dependent Variable	Marriage Surplus					
	Panel A: Baseline Control for EU Expansion					
	All Marriages		German Husband		German Wife	
NewEU x PostEU	-0.107	-0.167^{*}	-0.222	-0.201	-0.072	-0.157
	(0.103)	(0.093)	(0.161)	(0.142)	(0.114)	(0.100)
	Panel B: Without Labor Market Reform Coefficients					
	All Marriages		German Husband		German Wife	
NewEU x PostEU	-0.223^{**}	-0.291^{***}	-0.334^{**}	-0.334^{**}	-0.251^{**}	-0.341^{***}
	(0.101)	(0.092)	(0.159)	(0.141)	(0.111)	(0.099)
	Controls (Both Panels)					
Year, Nation FE	✓	✓	✓	✓	✓	✓
Age FE (both)		✓		✓		✓

Notes: Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

ness of a certain combination of spouses and (ii) mechanically due to a larger availability of spouses of such type. So far, the main focus has been on the former, ignoring the latter.

In the robustness check, we include the number of available singles (log) to the main specification in order to control for the purely mechanical effect of the larger availability of the particular type of single in the population. This is in particular important as we compute the marriage surplus from the stock of available singles and the flow of marriages. A sudden inflow of singles decreases the marriage surplus instantly, whereas the flow of marriages can realistically be expected to react with a certain lag. Table 4.7 provides an overview of the robustness check when step-wise adding the available female (log) and male singles (log) of the particular type of marriage formed.

For the effect of the labor market reform in the full sample, we find relatively little differences compared to the baseline specification when step-wise adding the single stocks of both spouses.[138] The size of the coefficient in the main specification is -0.441. When

---

[138] Given that the marriage surplus function proposed by Choo and Siow (2006) already controls for population vectors, these little changes when adding the single stocks are a good check for the validity of the marriage surplus function.

Table 4.7: **Robustness Checks for Marriage Formation**

Dependent Variable	Marriage Surplus								
	All Marriages			German Husband			German Wife		
Hartz x PostHartz	-0.411^{***}	-0.456^{***}	-0.438^{***}	-0.255	-0.373^{**}	-0.258^{*}	-0.518^{***}	-0.697^{***}	-0.681^{***}
	(0.119)	(0.119)	(0.120)	(0.157)	(0.153)	(0.157)	(0.149)	(0.156)	(0.148)
log(female singles)	-0.123^{***}		-0.049	-0.290^{***}		-0.289^{***}	-2.208^{***}		-2.180^{***}
	(0.010)		(0.047)	(0.090)		(0.090)	(0.096)		(0.100)
log(male singles)		0.124^{***}	0.076		0.422^{***}	0.421^{**}		0.580^{***}	0.532^{***}
		(0.010)	(0.046)		(0.164)	(0.164)		(0.059)	(0.057)
Constant	-4.564^{***}	-7.930^{***}	-6.606^{***}	-2.323^{*}	-12.031^{***}	-8.072^{***}	23.969^{***}	-14.101^{***}	16.315^{***}
	(0.198)	(0.198)	(1.261)	(1.220)	(2.219)	(2.612)	(1.309)	(0.815)	(1.609)
Year, Nation FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

including the single stocks of both husband and wife, the effect slightly decreases to -0.438.

Regarding heterogeneity by gender of the German spouse, we find the effect of the labor market reform to be significant for marriages where either the husband or the wife are German. The size of the effect as well as the significance level, however, seem to be larger for marriages where the wife is German. The effect of the EU expansion on interethnic marriages becomes significant for marriages where the wife is German, once controlling for the number of available singles.

The issue of a large inflow of new singles is more of a concern for the EU expansion, as the EU expansion allowed free movement of citizens. However, for the coefficient size and significance of the EU expansion control variables, we find no substantial change when controlling for single stocks.

A different issue linked to the number of available singles is that changes in the availability of foreign singles could also affect the marriage decision of individuals. This issue is also stressed by Adda et al. (2019). In our setting, however, the large inflow of individuals only occurs after the labor market reform following the EU expansion, for which we control for extensively.

4.5.5 The Effect on Interethnic Marriage Stability

After illustrating the effect of the labor market reform on the marriage surplus for interethnic marriages, we follow those marriages over time and check for their marriage stability. As a result of the effects of the institutional changes, selection into marriage changed, confounding any estimation results. Nevertheless, a descriptive empirical investigation of marriage stability provides interesting insights, as marriage stability affects population dynamics.

In a first step, we graphically show how marriage stability changed following the introduction of the labor market reform. We focus on the largest group of immigrants that was affected by the institutional change.[139] In a second step, we quantify the effect of the institutional change using a cox proportional hazard model on the full dataset.[140]

4.5.5.1 Kaplan Meier Plots

We plot the Kaplan Meier hazard rates for German-Polish couples around the cutoff date to graphically analyze marriage stability. We use these descriptive illustrations to compare marriages formed one year before the cutoff with marriages formed one year after the cutoff date. For the case of the labor market reform - years 2002 and 2003 - both are unaffected by the EU expansion, so we observe only differences in the divorce hazard due to the labor market reform. The different separation hazards are captured in Figure 4.4.

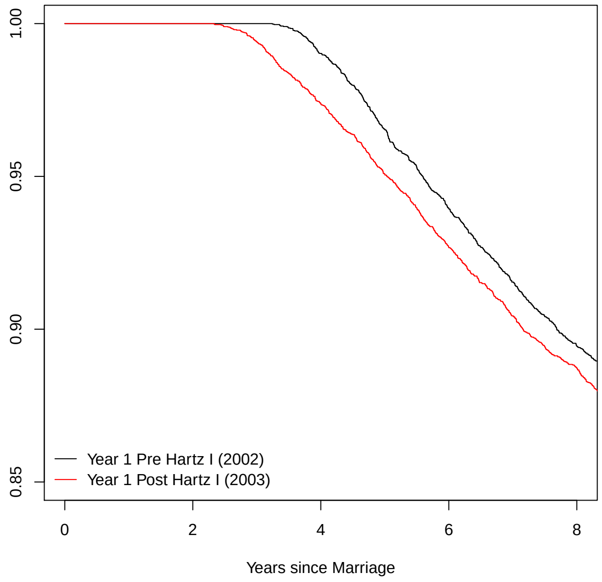
The Kaplan Meier hazard of divorce of the after reform year (red) is parallel shifted below the divorce hazard of marriages formed before the reform (black). The lower survival rate indicates that marriages formed after the cutoff have a higher separation rate than marriages formed before the cutoff. Regarding heterogeneity by gender of the German spouse, we find the effect of the labor market reform to apply roughly equally to marriages where the husband or the wife are German (Table C.2 in the Appendix).

---

[139] Technically, the largest non-EU15 group would be Turks. However, given that the guest worker programs for Turks started in the 1960's, many of the individuals that are recorded as Turks are 2nd or 3rd generation immigrants who always lived in Germany.

[140] In order to comply with the German data protection laws, the number of marriages per quarter are obtained from the universe of marriages and then matched to the universe of divorces.

Figure 4.4: Divorce Hazard of German-Polish Marriages (Kaplan Meier Plots)



The black line plots the Kaplan Meier hazard rates for the pre-year. The red line plots the Kaplan Meier hazard rates for the post-year. *Data*: RDC of the Federal Statistical Office and Statistical Offices of the Federal States, Marriage Registry, survey year(s) 1997-2013, own calculations. Sample restricted to include only German-Polish marriages.

However, marriages where the husband is Polish seem to be affected more by the labor market reform than marriages where the husband is German.

4.5.5.2 Survival Models

A major shortcoming of the illustrative Kaplan-Meier plots in Figure 4.4 is that the differences in divorce hazards are only conditional on the two investigated groups. All other possibly important factors, such as the labor market, are absent. In particular, the introduction of the ‘labor market reform affected both marriages formed before and after the law was introduced. The law effectively made both types of marriages more “risky” through the more restrictive application of means testing in unemployment assistance. The only difference between those two groups depicted in the Kaplan-Meier plots above is, that the post-introduction group was aware of the changed law before marriage formation and the pre-introduction group was not.

We estimate the identical difference-in-difference specification we used to identify the effect of the policy change on marriages rates in a Cox proportional hazard setting to overcome this issue. In this setting, the hazard rated (d,Z) indicates the divorce hazard of the marriage after d years and the vector of covariates (Z). γ indicates the vector of coefficients and $\lambda(d)$ the baseline divorce hazard common to all marriages. The coefficients of interest are $Hartz \times PostHartz$, which compares marriages where one partner is non-native before the reform with marriages of that type after the reform. As before, we extensively control for the effects of the EU expansion. The results are presented in Table 4.8.

Column 1 of Table 4.8 illustrates the results for the difference-in-difference hazard rates without taking year fixed effects into account. The results indicate that the divorce hazard for marriages that are treated by the labor market reform increases by 9% following the introduction of the reform. The issue with this specification is, that it ignores year-specific situations that contributed to the separation of marriages. Such situations could be related to the labor market situation. In fact, the introduction of the labor market reform has substantially changed the importance of labor market situations for partnerships.

Column 2 presents the results when adding year fixed effects to the specification. Once controlling for year fixed effects, the effect of the labor market reform becomes negative, resulting in a divorce hazard below one. This means, that marriages where one spouse is from a non-EU15 country have a lower separation rate after the introduction, when controlling for year specific factors in the divorce decision.

Column 3 presents the results when stratifying by divorce year. In this setting, every divorce year has it's own baseline hazard, which captures year specific factors that may influence the baseline hazard. Similar to the results reported in column 2, we find a divorce hazard below 1, indicating a lower divorce hazard of interethnic marriages following the labor market reform.

Columns 2 and 3 support the hypothesis that the remaining interethnic marriages that are formed after the labor market reform became effective are positively selected. In the estimation of the marriage surplus, we have shown that the marriage surplus dropped as a result of the introduction of the labor market reform. The marriages that are formed despite the drop in marriages relative to the respective population shares are more stable than marriages of the same type formed before the change in law became known and effective. The introduction of the labor market reform resulted in fewer but

Table 4.8: Divorce Hazard - Diff-in-Diff Estimates

Dependent Variable	Duration until Divorce								
	All Marriages			German Husband			German Wife		
Hartz x PostHartz	0.089^{***} (0.010) [1.093]	-0.306^{***} (0.009) [0.736]	-0.456^{***} (0.010) [0.634]	-0.085^{***} (0.016) [0.919]	-0.388^{***} (0.016) [0.678]	-0.453^{***} (0.016) [0.636]	0.178^{***} (0.012) [1.195]	-0.280^{***} (0.012) [0.756]	-0.475^{***} (0.012) [0.622]
Divorce Year FE		✓			✓			✓	
Stratified by Divorce Year			✓			✓			✓
Observations	6,592,292	6,592,292	6,592,292	6,417,362	6,417,362	6,417,362	6,431,657	6,431,657	6,431,657
R^2	0.022	0.262	0.186	0.022	0.257	0.184	0.023	0.260	0.186

Notes: Robust standard errors in parenthesis. Hazard rates in square brackets.
* p<0.1, ** p<0.05, *** p<0.01

more stable interethnic marriages. We confirm the same trends for the sub-samples of marriages where the husband is German and where the wife is German. There is always a large drop in the divorce hazard once controlling for year fixed effects or stratifying by divorce year.

The effect of the labor market reform in the spirit of Choo and Siow (2006) is essentially a transition to a new equilibrium. We would expect an initial large jump shortly after the introduction and then an effect size that slightly increases in size as more and more individuals become aware (or fully comprehend) the effects of the institutional change. Furthermore, we would expect marriage formation to react stronger over time as marriage logistics typically require some planning, which generally take some time. To test this hypothesis, we interact the dummy of the $Hartz$ dummy with dummies for the first and all subsequent years after the introduction of the labor market reform. The results are reported in Table 4.9. Indeed, we observe an initial large jump followed by a slightly increasing effect size for subsequent years throughout all specifications.

4.6 Conclusion

In this paper, we empirically investigate the importance of the household insurance channel in marriage formation and stability. The analysis is performed in the specific context of the transferable utility marriage market matching model proposed by Choo and Siow (2006). We exploit a distinct legal change in the institutional environment in which marriages are formed, namely the so called "Hartz reforms" in 2003, to identify the ef-

Table 4.9: Divorce Hazard - Treatment Years

Dependent Variable	Duration until Divorce								
	All Marriages			German Husband			German Wife		
Hartz	0.135*** (0.005) [1.145]	0.183*** (0.005) [1.201]	0.172*** (0.005) [1.188]	0.038*** (0.009) [1.039]	0.100*** (0.009) [1.105]	0.094*** (0.009) [1.099]	0.177*** (0.007) [1.194]	0.219*** (0.007) [1.245]	0.210*** (0.007) [1.234]
Hartz x 1 year post Hartz	0.682*** (0.015) [1.978]	1.142*** (0.015) [3.133]	1.269*** (0.015) [3.557]	0.483*** (0.026) [1.621]	0.971*** (0.026) [2.641]	1.134*** (0.026) [3.108]	0.802*** (0.019) [2.230]	1.207*** (0.019) [3.343]	1.304*** (0.019) [3.684]
Hartz x 2+ years post Hartz	0.762*** (0.011) [2.143]	1.617*** (0.011) [5.038]	1.901*** (0.012) [6.693]	0.643*** (0.020) [1.902]	1.475*** (0.020) [4.371]	1.771*** (0.020) [5.877]	0.829*** (0.014) [2.291]	1.650*** (0.014) [5.207]	1.897*** (0.014) [6.666]
Divorce Year FE		✓			✓			✓	
Stratified by Divorce Year			✓			✓			✓
Observations	6,592,292	6,592,292	6,592,292	6,417,362	6,417,362	6,417,362	6,431,657	6,431,657	6,431,657
R^2	0.001	0.174	0.005	0.000	0.169	0.002	0.001	0.172	0.003

Notes: Robust standard errors in parenthesis. Hazard rates in square brackets.
* p<0.1, ** p<0.05, *** p<0.01

fect. As a result of the reform, marriages where one partner had a substantially larger unemployment risk became more risky and, thus, less attractive. This affected in particular interethnic marriages, as non-natives have a substantially larger unemployment risk compared to natives.

We find a significant and quantitatively important negative effect on the marital surplus of interethnic marriages in Germany as a result of the labor market reform. Our interpretation of the results are similar to the findings of Adda et al. (2019): if natives react to labor market reforms by marrying each other rather than foreigners, paradoxically, reforms that are intended to lower the unemployment rate might interfere with the integration of foreigners, at least in the short-run.

By following these interethnic marriage over time and investigating their marriage stability, we find that interethnic marriages formed after the introduction of the labor market reforms are more stable compared to interethnic marriages formed before the reform. Our interpretation of these findings is that the labor market reform resulted in fewer, but better selected interethnic marriages. The interethnic marriages formed after the reform became effective are more able to absorb economic shocks within marriage, resulting in fewer divorces.

Interethnic marriages are often seen as a measure of social integration. Thus, institutional changes directly influenced integration of immigrants, which can have large long run implications. The interpretation of the net effect on social integration of immigrants depends on the relative importance of the number of interethnic marriages versus the stability and duration of interethnic marriages in the assessment. While this is of substantial importance in social science, this is beyond the scope of this analysis and subject to future research.

Appendix C

C.1 Marriages Formed Abroad

From 2008 onward, the German marriage registers include an indicator for marriages formed outside of Germany (“Auslandsehen”). In addition to German nationals who get married outside of Germany and register their marriage at home, this category also includes two other forms of marriages: (i) marriages of refugees or stateless individuals who reside in Germany and (ii) marriages formed in Germany by foreigners under the jurisdiction of a foreign country, for instance in case the marriage is conducted at an embassy in Germany. According to this definition, marriages formed abroad make up only about 0.15% of all marriages in the data between between 2008–2013. Table C.1 presents the number of marriages formed abroad by nationality of the spouse we observe between 2008–2013.

Table C.1: Number of Marriages formed Abroad by nationality of the non-German spouse (selection)

Partner	German	EU15	Pol	TUR	EU10	Romania	Former Yugoslavia	Rus	Rest
German Husband	8,619	296	182	173	96	38	69	587	5,442
German Wife	8,619	428	20	528	9	5	71	65	3,315

Data: German Marriage Registry, 2008 - 2013. Total Number of Observations: 20,117

C.2 Additional Plots and Tables

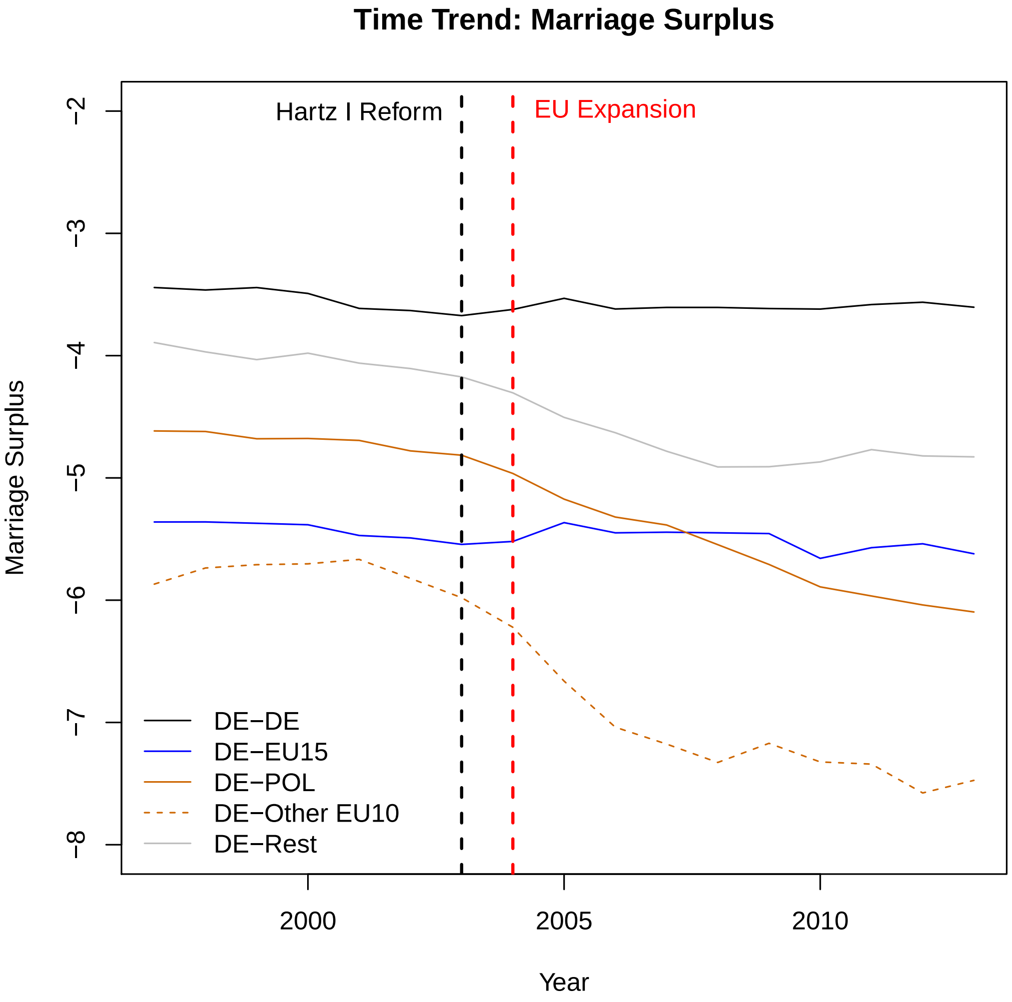
Table C.2: Labor Market Hazard Rates (Stratified by Education)

	Employment Duration (Firings)				Unemployment Duration (Hirings)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
German	-0.168***	-0.098***	-0.225***	-0.151***	0.100***	0.054***	0.069***	0.028***
	(0.013)	(0.011)	(0.011)	(0.010)	(0.010)	(0.009)	(0.008)	(0.007)
	[0.845]	[0.907]	[0.799]	[0.860]	[1.105]	[1.055]	[1.071]	[1.028]
Female	-0.178***	-0.123***	-0.174***	-0.115***	-0.158***	-0.139***	-0.156***	-0.138***
	(0.009)	(0.008)	(0.010)	(0.009)	(0.011)	(0.011)	(0.010)	(0.010)
	[0.837]	[0.884]	[0.804]	[0.891]	[0.854]	[0.870]	[0.856]	[0.871]
Year FE		✓		✓		✓		✓
Region FE			✓	✓			✓	✓
Observatons	1,957,289	1,957,289	1,957,289	1,957,289	1,343,678	1,343,678	1,343,678	1,343,678
Firings / Hirings	1,218,625	1,218,625	1,218,625	1,218,625	1,086,943	1,086,943	1,086,943	1,086,943

Robust standard errors (clustered by region) in parentheses

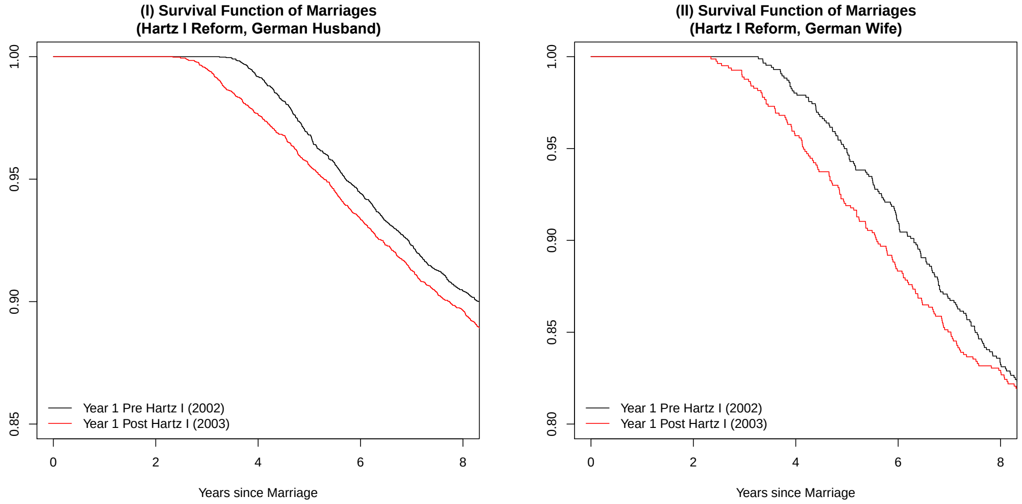
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure C.1: Pre-Trend of Marriage Surplus - POL vs. Other EU-10



Notes Marriage surplus for marriages where at least one spouse is German by nationality of the non-German spouse. The black dashed vertical line indicated the year in which the "Hartz I" Reform became effective, the red dashed vertical line marks the year 2004 in which the EU expansion took place. *Data*: RDC of the Federal Statistical Office and Statistical Offices of the Federal States, Marriage Registry, survey year(s) 1997-2013, own calculations.

Figure C.2: Kaplan Meier Plots for “Hartz” Reform (DE-POL, by Gender)



The black line plots the Kaplan Meier hazard rates for the pre-“Hartz”-reform year (left plot: German husband, right plot: German wife). The red line plots the Kaplan Meier hazard rates for the post-“Hartz”-reform (left plot: German husband, right plot: German wife). *Data*: RDC of the Federal Statistical Office and Statistical Offices of the Federal States, Marriage Registry, survey year(s) 1997-2013, own calculations. Sample restricted to include only German-Polish marriages.

Bibliography

Adda, Jèrôme, Christian Dustmann, and Katrien Stevens (2017) "The Career Costs of Children," *Journal of Political Economy*, Vol. 125, No. 2, pp. 293 –328.

Adda, Jérôme, Paolo Pinotti, and Giulia Tura (2019) "There's More to Marriage than Love: The Effect of Legal Status and Cultural Distance on Intermarriages and Separations."

Alfani, Guido (2013) "Plague in seventeenth-century Europe and the decline of Italy: an epidemiological hypothesis," *European Review of Economic History*, Vol. 17, No. 4, pp. 408–430.

Alfani, Guido and Marco Bonetti (2019) "A survival analysis of the last great European plagues: The case of Nonantola (Northern Italy) in 1630," *Population Studies*, Vol. 73, No. 1, pp. 101–118.

Alfani, Guido and Matteo Di Tullio (2019) *The Lion's Share: Inequality of the Fiscal State in Preindustrial Europe*, Cambridge, United Kingdom: Cambridge University Press.

Alfani, Guido and Tommy E. Murphy (2017) "Plague and Lethal Epidemics in the Pre-Industrial World."

Alfani, Guido and Marco Percoco (2019) "Plague and Long-Term Development: the Lasting Effects of the 1629-30 Epidemic on the Italian Cities," *Economic History Review*, Vol. 72, No. 4.

Bibliography

Amato, Paul R. and Brett Beattie (2011) "Does the unemployment rate affect the divorce rate? An analysis of state data 1960-2005," *Social Science Research*, Vol. 40, No. 3, pp. 705–715.

Ayyadurai, Saravanan, Linda Houhamdi, Hubert Lepidi, Claude Nappez, Didier Raoult, and Michel Drancourt (2008) "Long-term persistence of virulent Yersinia pestis in soil," *Microbiology*, Vol. 154, pp. 2865—-2871.

Azzolini, Davide and Raffaele Guetto (2017) "The impact of citizenship on intermarriage: Quasi-experimental evidence from two European Union Eastern enlargements," *Demographic Research*, Vol. 36, No. 1, pp. 1299–1336.

Basu, Sukanya (2015) "Intermarriage and the labor market outcomes of Asian women," *Economic Inquiry*, Vol. 53, No. 4, pp. 1718–1734.

Baudin, Thomas, David De La Croix, and Paula Gobbi (2015) "Fertility and childlessness in the United States," *American Economic Review*, Vol. 105, No. 6, pp. 1852–1882.

——— (2020) "Endogenous Childlessness and Stages of Development," *Journal of the European Economic Association*, Vol. 18, No. 1, pp. 83–133.

Becker, Gary S. (1973) "A Theory of Marriage: Part I," *Journal of Political Economy*, Vol. 81, pp. 813–846.

——— (1974) "A Theory of Marriage: Part II," *Journal of Political Economy*, Vol. 82, pp. 11–26.

——— (1981) *A Treatise on the Family*: Harvard University Press.

Becker, Gary S. and Robert J. Barro (1988) "A Reformulation of the Economic Theory of Fertility," *The Quarterly Journal of Economics*, Vol. 103, No. 1, pp. 1–25.

Becker, Gary S, Kevin M Murphy, and Robert Tamura (1990) "Human Capital , Fertility , and Economic Growth," *Journal of Political Economy*, Vol. 98, No. 5 (Part 2), pp. 12–37.

Becker, Sascha O., Francesco Cinnirella, and Ludger Woessmann (2010) "The trade-off between fertility and education: Evidence from before the demographic transition," *Journal of Economic Growth*, Vol. 15, No. 3, pp. 177–204.

Becker, Sascha O., Francesco Cinnirella, and Ludger Woessmann (2013) "Does Women's Education Affect Fertility? Evidence from Pre-Demographic Transition Prussia," *European Review of Economic History*, Vol. 17, No. 1, p. 24.

Becker, Sascha O. and Ludger Woessmann (2008) "Luther and the Girls: Religious Denomination and the Female Education Gap in 19th Century Prussia," *Scandinavian Journal of Economics*, Vol. 110, No. 4, p. 777.

——— (2009) "Was Weber Wrong? A Human Capital Theory of Protestant Economic History," *Quarterly Journal of Economics*, Vol. 124, No. 2, pp. 531–596.

——— (2010) "The effect of Protestantism on education before the industrialization: Evidence from 1816 Prussia," *Economics Letters*, Vol. 107, No. 2, p. 224.

Benedictow, Ole Jorgen (2004) *The Black Death, 1346-1353: The Complete History*, Rochester, N.Y.: Boydell Press.

Bertrand, Marianne, Claudia Goldin, and Lawrence F. Katz (2010) "Dynamics of the gender gap for young professionals in the financial and corporate sectors," *American Economic Journal: Applied Economics*, Vol. 2, No. 3, pp. 228–255.

Bhattacharya, Joydeep and Shankha Chakraborty (2017) "Contraception and the Demographic Transition," *Economic Journal*, Vol. 127, No. 606.

Biraben, Jean-Noel (1975) *Les hommes et la peste en France et dans les pays Européens et Mèditerraèes*, Vol. 1, Paris: Mouton.

——— (1976) *Les hommes et la peste en France et dans les pays Européens et Mèditerraèes*, Vol. 2, Paris: Mouton.

Boerner, Lars and Battista Severgnini (2014) "Epidemic Trade," *LSE Economic History Working Papers*, Vol. 212/2014.

Bos, Kirsten I., Alexander Herbig, Jason Sahl, Nicholas Waglechner, Mathieu Fourment, Stephen A. Forrest, Jennifer Klunk, Verena J. Schuenemann, and Debi Poinar (2016) "Eighteenth century Yersinia pestis genomes reveal the long-term persistence of an historical plague focus," *eLife – Epidemiology and Global Health Microbiology and Infectious Disease*, Vol. 5, No. e12994.

Bosker, Maarten, Eltjo Buringh, and Jan Luiten van Zanden (2013) "From Baghdad to London: Unraveling Urban Development in Europe, the Middle East, and North Africa, 800-1800," *Review of Economics and Statistics*, Vol. 95, No. 4, pp. 1418–1437.

Browning, Martin, Pierre André Chiappori, and Arthur Lewbel (2013) "Estimating consumption economies of scale, adult equivalence scales, and household bargaining power," *Review of Economic Studies*, Vol. 80, No. 4, pp. 1267–1303.

Bruns, Friedrich and Hugo Weczerka (1962) *Hansische Handelsstrassen. 1. Atlas*: Böhlau.

——— (1967) *Hansische Handelsstrassen: Textband.*

Budig, Michelle J. and Paula England (2001) "The Wage Penalty for Motherhood," *American Sociological Review*, Vol. 66, No. 2, pp. 204–225.

Bumpass, Larry and Charles F. Westoff (1970) "Unwanted Births and U . S . Population Growth," *Family Planning Perspectives*, Vol. 2, No. 4, pp. 9–11.

Büntgen, Ulf, Christian Ginzler, Jan Esper, Willy Tegel, and Anthony J McMichael (2012) "Digitizing Historical Plague," *Clinical Infectious Diseases*, Vol. 55, No. 11, pp. 1586–1588.

Campbell, Bruce M S (2016) *The Great Transition: Climate, Disease and Society in the Late-Medieval World*, Cambridge: Cambridge University Press.

Cantoni, Davide (2012) "Adopting a New Religion: The Case of Protestantism in 16th Century Germany," *Economic Journal*, Vol. 122, No. 560, pp. 502–531.

Cantor, N. F. (2002) *In the Wake of the Plague: The Black Death and the World It Made*, New York: Simon and Schuster.

Caucutt, Elizabeth, Nezih Guner, and Christopher Rauh (2018) "Is Marriage for White People? Incarceration, Unemployment, and the Racial Marriage Divide," *CEPR Discussion Papers.*

Caucutt, E.M., N. Guner, and J. Knowles (2002) "Why do women wait? Matching, wage inequality and incentives for fertility delay," *Review of Economic Dynamics*, Vol. 855, pp. 815–855.

Cervellati, Matteo and Uwe Sunde (2011) "Life Expectancy and Economic Growth: The Role of the Demographic Transition," *Journal of Economic Growth*, Vol. 16, pp. 99–133.

——— (2013) "Life Expectancy, Schooling, and Lifetime Labor Supply: Theory and Evidence Revisited," *Econometrica*, Vol. 81, No. 5, pp. 2055–2086.

——— (2015) "The Economic and Demographic Transition, Mortality, and Comparative Development," *American Economic Journal: Macroeconomics*, Vol. 7, No. 3, pp. 1–39.

——— (2016) "On the Emergence of Religious Norms - Theory and Evidence from the Protestant Reformation," *mimeo.*

Chesnais, Jean-Claude (1992) *The Demographic Transition: Stages, Patterns and Economic Implications. A Longitudinal Study of Sixty-Seven Countries Covering the Period 1720-1984*, Oxford: Clarendon Press.

Chevalier, Arnaud and Olivier Marie (2017) "Economic uncertainty, parental selection, and children's educational outcomes," *Journal of Political Economy*, Vol. 125, No. 2, pp. 393–430.

Chiappori, Pierre-Andre (1988) "Rational Household Labor Supply," *Econometrica*, Vol. 56, No. 1, pp. 63–90.

——— (1992) "Collective Labor Supply and Welfare," *Journal of Political Economy*, Vol. 100, No. 3, pp. 437–467.

Chiappori, Pierre-Andre, Monica Costa Dias, and Costas Meghir (2018) "The Marriage Market, Labor Supply and Education Choice," *Journal of Political Economy*, Vol. 126, No. 1, pp. 26–72.

Chiappori, Pierre-Andre, Bernard Fortin, and Guy Lacroix (2002) "Marriage Market, Divorce Legislation, and Household Labor Supply," *Journal of Political Economy*, Vol. 110, No. 1, pp. 37–72.

Chiappori, Pierre-Andre, Bernard Salanie, and Yoram Weiss (2017) "Partner choice, investment in children, and the marital college premium," *American Economic Review*, Vol. 107, No. 8, pp. 1–66.

Choo, Eugene and Aloysius Siow (2006) "Who marries whom and why," *Journal of Political Economy*, Vol. 114, No. 1, pp. 175–201.

Clark, Gregory (2008) *A Farewell to Alms: A Brief Economic History of the World*, Princeton, N.J.: Princeton University Press.

Coale, Ansley J. and Susan Coats-Watkins (1986) *The Decline of Fertility in Europe. The Revised Proceedings of a Confernce on the Princeton European Fertility Project*, Princeton, N.J.: Princeton University Press.

Cohn, Samuel K Jr. (2008) "Epidemiology of the Black Death and Successive Waves of Plague," *Medical History (Supplement)*, Vol. 27, pp. 74–100.

Cox, D. R. (1972) "Regression Models and Life-Tables," *Jornal of the Royal Statistical Society. Series B (Methodological)*, pp. 187–220.

Crafts, Nicholas and Terence C Mills (2017) "Six centuries of British economic growth: a time-series perspective," *European Review of Economic History*, Vol. 21, No. 2, pp. 141–158.

Curtis, Daniel R. and Joris Roosen (2017) "The Sex-Selective Impact of the Black Death and Recurring Plagues in the Southern Netherlands, 1349–1450," *American Journal of Physical Anthropology*, Vol. 164, No. 2, pp. 246–259.

Daudin, Guillaume, Raphaël Franck, and Hillel Rapoport (2019) "Can Internal Migration Foster the Convergence in Regional Fertility Rates? Evidence from 19th Century France," *Economic Journal*, Vol. 129, No. 620, pp. 1618–1692.

Davis, D. E. (1986) "The Scarcity of Rats and the Black Death: An Ecological History," *Journal of Interdisciplinary History*, Vol. 16, No. 3, pp. 455–470.

De La Croix, David and Faustine Perrin (2018) "How far can economic incentives explain the French fertility and education transition?," *European Economic Review*, Vol. 108, pp. 221–245.

De Moor, Tine and Jan Luiten Van Zanden (2010) "Girl power: The European marriage pattern and labour markets in the North Sea region in the late medieval and early modern period," *Economic History Review*, Vol. 63, No. 1, pp. 1–33.

De Witte, Sharon N (2010) "Age patterns of mortality during the Black Death in London, A.D.\ 1349-1350," *Journal of Archeological Science*, Vol. 37, No. 2, pp. 3394–3400.

Dijkstra, Edsger W (1959) "A note on two problems in connexion with graphs," *Numerische Mathematik*, Vol. 1, No. 1, pp. 269–271.

Dittmar, Jeremiah E. and Ralf R. Meisenzahl (2020) "Public Goods Institutions, Human Capital, and Growth: Evidence from German History," *Review of Economic Studies*, Vol. 87, No. 2, pp. 959–996.

Doepke, Matthias (2004) "Accounting for fertility decline during the transition to growth," *Journal of Economic Growth*, Vol. 9, No. 3, pp. 347–383.

Dribe, Martin and Paul Nystedt (2015) "Is there an intermarriage premium for male immigrants? exogamy and earnings in Sweden 1990-2009," *International Migration Review*, Vol. 49, No. 1, pp. 3–35.

Echevarria, Cristina and Antonio Merlo (1999) "Gender Differences in Education in a Dynamic Household Bargaining Model," *International Economic Review*, Vol. 40, No. 2, pp. 265–286.

Fitzenberger, Bernd, Aderonke Osikominu, and Robert Voelter (2006) "Imputation Rules to Improve the Education Variable in the IAB Employment Subsample," *Schmollers Jahrbuch: Journal of Applied Social Science Studies / Zeitschrift für Wirtschafts- und Sozialwissenschaften.*

Furtado, Delia and Nikolaos Theodoropoulos (2009) "I'll marry you if you get me a job: Marital assimilation and immigrant employment rates," *International Journal of Manpower*, Vol. 30, No. 1-2, pp. 116–126.

Galloway, Patrick (1994) "Fertility decline in Prussia 1875 to 1910: a pooled cross-section time series analysis," *Population Studies*, Vol. 48, No. 1, p. 135.

——— (2007) "Galloway Prussia Database 1861 to 1914," *www.patrickgalloway.com.*

Galor, Oded (2011) *Unified Growth Theory*, Princeton, N.J.: Princeton University Press.

Galor, Oded and Marc Klemp (2019) "Human genealogy reveals a selective advantage to moderate fecundity," *Nature Ecology and Evolution*, Vol. 3, No. 5, pp. 853–857.

Galor, Oded and Omer Moav (2002) "Natural Selection and the Origin of Economic Growth," *The Quarterly Journal of Economics*, Vol. 117, No. 4, pp. 1133–1191.

Galor, Oded and Ömer Özak (2016) "The Agricultural Origins of Time Preference," *American Economic Review*, Vol. 106, No. 10, p. 3064.

Galor, Oded and David N. Weil (2000) "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond," *American Economic Review*, Vol. 90, No. 4, pp. 807–828.

García-Morán, Eva and Zoë Kuehn (2017) "With strings attached: Grandparent-provided child care and female labor market outcomes," *Review of Economic Dynamics*, Vol. 23, pp. 80–98.

Gayle, George-Levi and Andrew Shephard (2019) "Optimal Taxation, Marriage, Home Production, and Family Labor Supply," *Econometrica*, Vol. 87, No. 1, pp. 291–326.

Goldin, Claudia (2006) "The quiet revolution that transformed women's employment, education, and family," *American Economic Review*, Vol. 96, No. 2, pp. 1–21.

González-Val, Rafael and Miriam Marcén (2017) “Divorce and the business cycle: a cross-country analysis,” *Review of Economics of the Household*, Vol. 15, No. 3, pp. 879–904.

——— (2018) “Unemployment, marriage and divorce,” *Applied Economics*, Vol. 50, No. 13, pp. 1495–1508.

Goussé, Marion, Nicolas Jacquemet, and Jean-Marc Robin (2017) “Marriage, Labor Supply, and Home Production,” *Econometrica*, Vol. 85, No. 6, pp. 1873–1919.

Greenwood, J., N. Guner, and J.A. Knowles (2003) “More on Marriage, Fertility, and the Distribution of Income,” *International Economic Review*, Vol. 44, No. 3, pp. 827–862.

Greenwood, Jeremy, Nezih Guner, Georgi Kocharkov, and Cezar Santos (2016) “Technology and the Changing Family: A Unified Model of Marriage, Divorce, Educational Attainment, and Married Female Labor-Force Participation,” *American Economic Journal: Macroeconomics*, Vol. 8, No. 1, pp. 1–41.

Greenwood, Jeremy, Nezih Guner, and Guillaume Vandenbroucke (2017) “Family Economics Writ Large,” *Journal of Economic Literature*, Vol. 55, No. 4, pp. 1346–1434.

Grossbard-Shechtman, Amyra (1984) “A Theory of Allocation of Time in Markets for Labour and Marriage,” *The Economic Journal*, Vol. 94, No. 376, pp. 863–882.

Hansen, Hans Tore (2005) “Unemployment and marital dissolution: A panel data study of Norway,” *European Sociological Review*, Vol. 21, No. 2, pp. 135–148.

Henry, Louis (1961) “Some data on natural fertility,” *Biodemography and Social Biology*, Vol. 8, No. 2, pp. 81–91.

Herr, Jane Leber (2016) “Measuring the effect of the timing of first birth on wages,” *Journal of Population Economics*, Vol. 29, No. 1, pp. 39–72.

Hitzer, Hans (1971) *Die Strasse: vom Trampelpfad zur Autobahn. Lebensadern von der Urzeit bis heute*: Callwey.

Iyigun, Murat and Randall P. Walsh (2007) "Endogenous gender power, household labor supply and the demographic transition," *Journal of Development Economics*, Vol. 82, No. 1, pp. 138–155.

Jebwab, Remi, Noel D. Johnson, and Mark Koyama (2019) "Pandemics, Places, and Populations: Evidence from the Black Death," *George Mason University, Department of Economics Working Paper*, Vol. 19-04.

Jensen, Peter and Nina Smith (1990) "Unemployment and marital dissolution," *Journal of Population Economics*, Vol. 3, No. 3, pp. 215–229.

Jones, Larry E., Alice Schoonbroodt, and Michèle Tertilt (2010) *Fertility Theories: Can They Explain the Negative Fertility-Income Relationship?*, Chicago: University of Chicago Press, pp.43–100.

Kantarevic, Jasmin (2005) "Interethnic Marriages and Economic Assimilation of Immigrants," *IZA Discussion Papers*, Vol. 1142, No. 1142.

Kausrud, Kyrre Linné, Hildegunn Viljugrein, Arnoldo Frigessi, Mike Begon, Stephen Davis, Herwig Leirs, Vladimir Dubyanskiy, and Nils Chr Stenseth (2007) "Climatically driven synchrony of gerbil populations allows large-scale plague outbreaks.," *Proceedings. Biological sciences / The Royal Society*, Vol. 274, No. 1621, pp. 1963–1969.

Keeling, M J and C A Gilligan (2000) "Metapopulation dynamics of bubonic plague.," *Nature*, Vol. 407, No. 6806, pp. 903–906.

Keyser, Erich (1941) *Bevölkerungsgeschichte Deutschlands*, Leipzig: Hirzel.

——— (1974) *Deutsches Städtebuch, 5 Volumes (1939-1974)*, Stuttgart: Kohlhammer.

Knodel, A. J. (1974) *The Decline of Fertility in Germany, 1871-1939*, Princeton, N.J.: Princeton University Press.

Lafortune, Jeanne and Corinne Low (2017) "Tying the double-knot: The role of assets in marriage commitment," *American Economic Review: Papers & Proceedings*, Vol. 107, No. 5, pp. 163–167.

Lagerlöf, Nils Petter (2003) "From malthus to modern growth: Can epidemics explain the three regimes?."

Lee, Ronald (2003) "The demographic transition: Three centuries of fundamental change," *Journal of Economic Perspectives*, Vol. 17, No. 4, pp. 167–190.

Leridon, Henri (2004) "Can assisted reproduction technology compensate for the natural decline in fertility with age? A model assessment," *Human Reproduction*, Vol. 19, No. 7, pp. 1548–1553.

Low, Corinne (2017) "A "Reproductive Capital"? Model of Marriage Market Matching," *mimeo*, pp. 1–82.

Lubotsky, Darren and Martin Wittenberg (2006) "Interpretation of Regressions with Multiple Proxies," *Review of Economics and Statistics*, Vol. 88, No. 3, pp. 549–562.

Lundborg, Petter, Erik Plug, and Astrid Würtz Rasmussen (2017) "Can Women Have Children and a Career? IV Evidence from IVF Treatments," *American Economic Review*, Vol. 107, No. 6, pp. 1611–1637.

Malek, Maliya Alia, Idir Bitam, Anthony Levasseur, Jerome Terras, Jean Gaudart, Said Azza, Christophe Flaudrops, Catherine Robert, Didier Raoult, and Michel Drancourta (2017) "Yersinia pestis halotolerance illuminates plague reservoirs," *Nature Scientific Reports*, Vol. 7, No. 40022.

McFadden, Daniel (1974) "Conditional Logit Analysis of Qualitative Choice Behavior," in Paul Zarembka ed. *Frontiers in Econometrics*, pp. 105–142: New York: Academic Press.

Meng, Xin and Robert G. Gregory (2005) "Intermarriage and the economic assimilation of immigrants," *Journal of Labor Economics*, Vol. 23, No. 1, pp. 135–175.

Meng, Xin and Dominique Meurs (2009) "Intermarriage, language, and economic assimilation process: A case study of France," *International Journal of Manpower*, Vol. 30, No. 1-2, pp. 127–144.

Miller, Amalia R. (2011) "The effects of motherhood timing on career path," *Journal of Population Economics*, Vol. 24, No. 3, pp. 1071–1100.

Mosher, William D, Jo Jones, and Joyce C Abma (2012) "Intended and unintended births in the United States: 1982-2010.," *National health statistics reports*, No. 55, pp. 1–28.

Murphy, Tommy E (2015) "Old habits die hard (sometimes) – Can departement heterogeneity tell us something about the French fertility decline?," *Journal of Economic Growth*, Vol. 20, No. 3, pp. 177–222.

Myong, Sunha, JungJae Park, and Junjian Yi (2018) "Social Norms and Fertility," IZA Discussion Paper.

Olea, Ricardo A. and George Christakos (2005) "Duration of Urban Mortality for the 14th-Century Black Death Epidemic," *Human Biology*, Vol. 77, No. 3, pp. 291–303.

Ortmayr, Norbert (1995) "Late Marriage: Causes and Consequences of the Austrian Alpine Marriage Pattern," in Rudolph, R ed. *The European Peasant Family and Society: Historical Studies*, pp. 49–63, Liverpool: Liverpool University Press.

Pamuk, Sevket (2007) "The Black Death and the origins of the 'Great Divergence' across Europe, 1300–1600," *European Review of Economic History*, Vol. 11, No. 3, pp. 289–317.

Perry, Robert D. and Jacqueline D. Fetherston (1997) "Yersinia pestis - Etiologic agent of plague."

Persson, Petra (2020) "Social Insurance and the Marriage Market," *Journal of Political Economy*, Vol. 128, No. 1, pp. 252–300.

Pollak, Robert A. (2005) "Bargaining Power in Marriage: Earnings, Wage Rates and Household Production.," *NBER working paper series*, No. 11239, pp. 1–29.

Powell, M. J D (2002) "UOBYQA: Unconstrained optimization by quadratic approximation," *Mathematical Programming, Series B*, Vol. 92, No. 3, pp. 555–582.

Regalia, Ferdinando, Jose-Victor Rios-Rull, and Jacob Short (2011) "What Accounts for the Increase in Single Households ?," *mimeo*, pp. 0–44.

Reijniers, Jonas, Stephen Davis, Mike Begon, Johan A P Heesterbeek, Vladimir S. Ageyev, and Herwig Leirs (2012) "A curve of thresholds governs plague epizootics in Central Asia," *Ecology Letters*, Vol. 15, No. 6, pp. 554–560.

Rios-Rull, Jose-Victor (1993) "Working in the Market , Working at Home , and the Acquisition of Skills : A General- Equilibrium Approach," *American Economic Review*, Vol. 83, No. 4, pp. 893–907.

Ritter, G. (1966) "Zur Entwicklung des geburtshilflichen Phantoms im 19. und 20. Jahrhundert," *Medizinhistorisches Journal*, Vol. 1, No. 4, pp. 224–234.

Roosen, Joris and Daniel R Curtis (2018) "Dangers of Noncritical Use of Historical Plague Data," *Emerging Infectious Diseases*, Vol. 24, No. 1, pp. 103–110.

Samia, Noelle I, Kyrre Linné Kausrud, Johan A P Heesterbeek, Vladimir S. Ageyev, Mike Begon, Kung-Sik Chan, and Nils Chr Stenseth (2011) "Dynamics of the plague-wildlifehuman system in Central Asia are controlled by two epidemiological thresholds," *Proceedings of the National Academy of Sciences*, Vol. 108, No. 35, pp. 14527–14532.

Schaller, Jessamyn (2013) "For richer, if not for poorer? Marriage and divorce over the business cycle," *Journal of Population Economics*, Vol. 26, No. 3, pp. 1007–1033.

Schmid, Boris V, Ulf Büntgen, W Ryan Easterday, Christian Ginzler, Lars Walløe, Barbara Bramanti, and Nils Chr Stenseth (2015) "Climate-driven introduction of the Black Death and successive plague reintroductions into Europe.," *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 112, No. 10, pp. 3020–5.

Seifert, Lisa, Ingrid Wiechmann, Michaela Harbeck, Astrid Thomas, Gisela Grupe, Holger C. Scholz Michaela Projahn, and Julia M Riehm (2016) "Genotyping Yersinia pestis in Historical Plague: Evidence for Long-Term Persistence of Y. pestis in Europe from the 14th to the 17th Century," *PLoS ONE*, Vol. 11, No. 1.

Shankha, Chakraborty., Chris Papageorgiou, and Fidel Perez-Sebastian (2010) "Diseases, Infection Dynamics, and Development," *Journal of Monetary Economics*, Vol. 57, No. 7, pp. 859–872.

Skog, Lars and Hans Hauska (2013) “Spatial Modeling of the Black Death in Sweden,” *Transactions in GIS*, Vol. 17, No. 4, pp. 589–611.

Slack, P. (2012) *Plague: A Very Short Introduction*, Oxford: Oxford University Press.

Spolaore, Enrico and Romain Wacziarg (2014) “Fertility and Modernity,” mimeo.

Spyrou, M.A. et al. (2016) “Historical Y. pestis Genomes Reveal the European Black Death as the Source of Ancient and Modern Plague Pandemics,” *Cell Host Microbe*, Vol. 19, No. 6.

Stenseth, Nils Chr et al. (2006) “Plague dynamics are driven by climate variation.,” *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 103, No. 35, pp. 13110–13115.

Strittmatter, Anthony and Uwe Sunde (2013) “Health and economic development – evidence from the introduction of public health care,” *Journal of Population Economics*, Vol. 26, pp. 1549–1584.

Tietze, Christopher (1957) “Reproductive span and rate of reproduction among hutterite women,” *Fertility and Sterility*, Vol. 8, No. 1, pp. 89–97.

Voigtländer, Nico and Hans Joachim Voth (2013a) “How the West “Invented” Fertility Restriction,” *American Economic Review*, Vol. 103, No. 6, pp. 2227–2264.

——— (2013b) “The three horsemen of riches: Plague, war, and urbanization in early modern Europe,” *Review of Economic Studies*, Vol. 80, No. 2, pp. 774–811.

Wahl, Fabian (2017) “Does European Development Have Roman Roots? Evidence from the German Limes,” *Journal of Economic Growth*, Vol. 22, No. 3, pp. 313–349.

Wood, Robert G., Mary E. Corcoran, and Paul N. Courant (1993) “Pay Differences among the Highly Paid: The Male-Female Earnings Gap in Lawyers’ Salaries,” *Journal of Labor Economics*, Vol. 11, No. 3, pp. 417–441.

Yue, Ricci P.H., Harry F. Lee, and Connor Y. H. Wu (2016) “Navigable rivers facilitated the spread and recurrence of plague in pre-industrial Europe,” *Nature Scientific Reports*, Vol. 6, No. 34867.