DISCUSSION PAPER SERIES

DP16017

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ECONOMIC HISTORY

INTERNATIONAL TRADE AND REGIONAL ECONOMICS

MACROECONOMICS AND GROWTH

CEPR

ISSN 0265-8003

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Discussion Paper DP16017
Published 08 April 2021
Submitted 07 April 2021

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www.cepr.org

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JEL Classification: N/A

Keywords: N/A

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Acknowledgements
I thank Moritz Drechsel-Grau and Borui Niklas Zhu for excellent research assistance, Maya Judd for editorial comments, and Sunil Nepal at grepsr for assistance with the WWI casualty database. I also thank the House of History of Baden-Württemberg and the Statistical Agency of Baden-Württemberg for their help with the municipality data. Financial support by the German Research Foundation (DFG) through CRC TR 224 is gratefully acknowledged.

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1 Introduction

Predicting which cities will grow large is difficult but, as Auerbach (1913) noted, city size distributions may still satisfy empirical regularities. Auerbach shows that size distributions of cities in Germany and the US before World War I satisfy a power law.[1] Studies for later years and other countries yield similar city size distributions (e.g. Lotka, 1925; Zipf, 1949; Rosen and Resnick, 1980; Carroll, 1982; Gabaix and Ioannides, 2004; Rozenfeld et al., 2011).[2]

One theory of city size is that it is determined by locational fundamentals. Examples of such fundamentals are natural resources like agricultural land.[3] This view implies that the city size distribution reflects the spatial distribution of locational fundamentals. Another theory is that city size—and the city size distribution—is the cumulative result of past growth shocks that persist over time (e.g. Simon, 1955). See Gabaix (1999) for a model of random city growth that generates city size distributions satisfying a power law and Duranton (2006) for a model of random city growth based on purposeful innovation.[4] A key building block of this theory of city size and city size distributions is Gibrat's law for cities.

For Gibrat's law for cities to hold, city growth should be unrelated to past city size. This is found to be the case in Glaeser, Scheinkman, and Shleifer (1995), Eaton and Eckstein (1997), Ioannides and Overman (2003), and Eeckhout (2004). On the other hand, Black and Henderson (2003) find a strong negative relationship between city growth and past city size when they allow for unobserved heterogeneity in steady-state city size by using a dynamic panel model with fixed effects. This raises a potentially important issue. Suppose that the size of cities converges to a steady state determined by locational fundamentals; city growth may nevertheless appear only weakly related or unrelated to past city size if the empirical framework does not account for heterogeneity in steady-state city size (e.g. Caselli, Esquivel, and Lefort, 1996). This could lead to the unwarranted conclusion that differences in city

[1] In addition, Auerbach examines city size distributions in France and Great Britain. As Rybski (2013) explains in his short biography of Auerbach, Auerbach's contribution was recognized in Zipf's (1949) work on power laws in different scientific disciplines. For an English translation of Auerbach see Ciccone (2021).

[2] Lotka (1925) examines Auerbach's hypothesis for US cities in 1920 and introduces the plot of log(city population size) against log(city population rank) still used today (e.g. Gabaix and Ioannides, 2004).

[3] See Fujita (1989), Anas, Arnott, and Small (1998), and Fujita, Krugman, and Venables (1999) for reviews of different theories of urban spatial structure. Hsu (2012) shows that one of the main theories of urban spatial structure, central place theory, can generate a city size distribution that satisfies a power law.

[4] See Gabaix and Ioannides (2004) for a survey and Duranton (2007), Córdoba (2008), Rossi-Hansberg and Wright (2007), and Rozenfeld et al. (2011) for more recent related work.

size are generated by Gibrat's law for cities when they are actually driven by locational fundamentals. However, panel data sets for cities have a relatively small time dimension and dynamic panel estimators can be subject to substantial bias in such circumstances—especially if shocks are persistent, which would be the case if Gibrat's law for cities holds (e.g. Alonso-Borrego and Arellano, 1999; Arellano and Honoré, 2001; Phillips and Sul, 2007).[5]

I contribute to the literature on Gibrat's law for cities by examining the persistence of observed city-specific population shocks: German military casualties in World War I by municipality of birth. If Gibrat's law holds and the population growth rate of municipalities is independent of their population size, WWI military casualties should have a permanent effect on population size. On the other hand, if the size of municipalities is determined by locational fundamentals, the effect of military casualties on population should be transitory.

I find a strong negative effect of WWI military casualties on the male population of municipalities just after the war. This effect persists to 1933, 15 years after the war. Outside of municipalities with the most agricultural land per capita, the reduction in male population due to WWI casualties persists for an even longer period. The effect of WWI casualties on female population and the number of households is similar to the effect on male population by 1950, when women in the generation that fought WWI started reaching their life expectancy.

The data on German WWI military casualties I use comes from official listings. I examine municipalities in the historical state of Württemberg since pre-WWI data exists for a wide range of economic and demographic municipality characteristics in statistical compendia published in 1898 and 1910. These compendia include data on income, wages, taxes on land, taxes on buildings, business taxes, the insurance value of buildings, the number and size of non-farm businesses, the size distribution of farms, labor-force participation, population born in the municipality, age distribution, and infant mortality.

The number of military casualties in WWI was large. German military casualties are estimated around 10 percent of the pre-war population and estimates for Württemberg are similar (Schwarzmaier and Fenske, 1992). In contrast to the states on Germany's western border, Württemberg did not see any ground combat and only few aerial bombings with little

[5] Black and Henderson (2003) use data for 282 US metro areas at 10 points in time (the US decennial censuses from 1900 to 1990). In principle, one could construct somewhat longer panels, but longer panels make it more difficult to define metro areas consistently over time (Gabaix and Ioannides, 2004).

destruction of infrastructure, buildings, or factories and a small number of local casualties.[6] Württemberg was also unaffected by military occupation or border changes following WWI.

The starting point of my empirical analysis is the effect of WWI military casualties born in a given municipality on that municipality's male population in 1919, one year after the end of WWI (1914-1918). I find a strong negative effect. The left panel of Figure 1 illustrates this effect using binned scatter plots (e.g. Chetty, Friedman, and Rockoff, 2014). It shows the effect of military casualties relative to 1905 population on male population growth between 1910 and 1919, controlling for 1905 population to account for mean reversion. The strong negative effect of casualties on male population growth is apparent. This effect does not appear to be be driven by omitted variables. The right panel in Figure 1 adds 39 pre-1910 economic and demographic municipality controls. The two panels are on the same scale. The controls account for a substantial amount of the variation in male population growth across municipalities (the R-squared increases by 19 percentage points). However, the negative effect of military casualties on 1910–1919 male population growth is nearly unchanged.

Figure 2 examines the relationship between WWI military casualties and pre-war male population growth. It shows the effect of WWI casualties as a proportion of 1895 population on male population growth between 1900 and 1910. The empirical approach is analogous to Figure 1. The left panel controls for 1895 population only, while the right panel adds a range of pre-1900 municipality controls. Both panels show no correlation between 1900–1910 male population growth and WWI casualties. Hence, WWI military casualties do not appear to reflect pre-war economic or demographic trends affecting male population growth.

My main interest is examining whether the effect of WWI military casualties on the male population of municipalities persists to 1933. I focus on 1933 as the 15-year period between the end of WWI and 1933 is of similar length to the 10-year periods analyzed in the existing literature on Gibrat's law for cities (e.g. Black and Henderson, 2003; Ioannides

[6]For an analysis of the effect of aerial bombings on the growth of Japanese cities during and after World War II using an empirical approach that is similar to the approach here, see Davis and Weinstein (2002). They exploit that the destruction of buildings had a statistically significant, negative effect on 1940-1947 population growth (bombing deaths also had a negative effect on 1940-1947 population growth, but the effect is not statistically significant). They find that the typical Japanese city recovered its former relative size within 15 years of the end of WWII. Ochsner (2017) examines the effect of violence and the dismantling of plants and infrastructure around the end of WWII on the spatial population distribution in Austria and observes strong persistence.

and Overman, 2003).[7] I find that the effect of WWI military casualties on male population is highly persistent. This is illustrated in Figure 3. The left panel reproduces the effect of WWI casualties on male population growth between 1910 and 1919 controlling for pre-1910 municipality characteristics in Figure 1. The right panel in Figure 3 shows the effect of WWI military casualties on male population growth between 1910 and 1933 using the same specification as the left panel. The two panels are on the same scale. It is apparent that the effect of WWI military casualties on male population in 1933 is very similar to the effect on male population in 1919. In fact, the least-squares regression lines in the left and the right panel have nearly the same slope. Hence, the effect of WWI military casualties on male population in 1919 persists strongly to 1933. The main difference between the two regression lines is in their intercepts. This reflects positive general population growth after WWI.

The persistent effect of WWI military casualties on the male population of municipalities in 1933 suggests that no strong post-war incentives existed for men to move to municipalities that had seen more casualties. Outside of municipalities with the most pre-war agricultural land per capita, I find that the effect of WWI military casualties on male population also persists to 1939, 1950, 1960, and—by then quite noisily—to 1970. My analysis stops in 1970 because of a territorial reform that reduced the number of municipalities by more than half.

While WWI military casualties had a significant effect on the male population of municipalities in 1933, the effect on the female population and the number of households is statistically insignificant. There do not appear to have been strong post-war incentives for women and families to move away from municipalities that had seen more casualties in WWI. However, the differential effect of WWI military casualties on the male population and the female population vanishes once women in the generation that fought WWI start reaching their life expectancy. By 1950, the effect of WWI casualties is negative and statistically significant for both the female and the male population of municipalities outside of the most agricultural municipalities. Hence, WWI military casualties had a persistent negative impact on the male population of municipalities and eventually also reduced the female population of municipalities by about the same magnitude.

The next section introduces the data. Section 3 presents the empirical framework and

[7] The time period is also of similar length to the period following the WWII bombing of Japanese cities examined by Davis and Weinstein (2002).

Section 4 discusses the empirical results. Section 5 concludes.

2 Data

The data covers the historical German state of Württemberg from 1875 to 1970. The state was named Kingdom of Württemberg until the end of World War I and then the Free People's State of Württemberg until the end of World War II. Württemberg bordered other German states to the north, east, and west and Lake Constance to the south. After World War II, Württemberg became part of the state of Baden-Württemberg.[8] The size of Württemberg was just below 20,000 square kilometers and its population in 1905 was 2.1 million. Before 1933, the necessary data is available for around 1630 municipalities (of a total of 1800).[9] Württemberg industrialized later than the leading German states, but its income per capita is estimated to have been close to the median of German regions by 1913 (Hentschel, 1978).

The sources of the data used are: (i) a compendium of official statistics for Württemberg published in 1910 containing an extensive range of municipality characteristics mostly referring to the period of 1900–1909 (Württembergisches Statistisches Landesamt, 1910); (ii) the first compendium of offical municipal statistics for the state, published in 1898 with a somewhat less detailed range of characteristics than the 1910 compendium, mostly referring to the period of 1893–1898 (Württembergisches Statistisches Landesamt, 1898); (iii) 1875-1890 population data from the censuses of Württemberg (Statistisches Landesamt Baden-Württemberg, 2008); (iv) a shapefile provided by the House of History of Baden-Württemberg with the municipal borders for Württemberg in the 1910 municipality statistics; (v) municipal statistics for Württemberg on male and female population, number of households, and land area in 1933 (Württembergisches Statistisches Landesamt, 1935) (vi) municipal statistics for Baden-Württemberg on male and female population, number of households, and land area in 1950, as well as male and female population in 1960 and 1970 (Statistisches Landesamt Baden-Württemberg, 1952, 1964, 1970).[10]

[8]For a map of Württemberg within Germany see Figure 1 in the Supplementary Appendix.

[9]For comparison, in the year 2000, the US had a population of around 280 million and 20,000 municipal governments (U.S. Census Bureau, 2007). The area of Württemberg in 1905 was about the current size of the US state of New Jersey. In the year 2000, New Jersey had a population of just over 8 million and fewer than 600 municipal governments.

[10]The municipal statistics for Württemberg in (i), (ii), and (v), and part of (vi), had to be hand-digitized.

My analysis focuses on the effect of WWI military casualties on population size in 1933. This is because the 15-year period between the end of WWI and 1933 is of similar length to the 10-year periods analyzed in the existing literature on Gibrat's law for cities. However, I also analyze the effect of WWI casualties on population size in 1939, 1950, 1960, and 1970. Between 1933 and 1939, the number of municipalities falls from around 1630 to around 1560 due to a 1933-1939 territorial reform.[11] After 1939, the number of municipalities changed little until a territorial reform in the early 1970s reduced it by more than half.

The data on WWI military casualties originally comes from official listings of the German armed forces during the war, which comprise some 2500 separate publications. Casualties are defined as members of the armed forces who died, were injured, or went missing in service. All casualties are men as women were not admitted to the armed forces. The first and last names of these casualties and their municipality and county of birth have been digitized and made available in an online database by the Verein für Computergenealogie (CompGen).[12]

I employ this database to obtain two different casualty counts for the municipalities in the official municipal statistics for Württemberg published in 1910 (Württembergisches Statistisches Landesamt, 1910). The first casualty count is the total number of entries that appear in the database when I search for a municipality and county. A drawback of this count for my analysis is that the database contains separate entries for each time a person was injured or went missing in service, in addition to an entry if the person died. The result is that the same person can appear more than once. I therefore generate a second casualty count as the total number of unique first and last names that appear in the database under the same municipality. This avoids overcounting the number of people who died, were injured, or went missing in service in cases where the same person appears more than once. The drawback is that I am undercounting the number of people who died, were injured, or went missing in service in cases where the database refers to two different persons with the same first and last name born in the same municipality. However, the majority of cases where the same name appears more than once under the same municipality refer to the same person. This can be checked using the day and month of birth of the person that is

[11] Municipalities affected by this reform are listed in Table 3 in the Supplementary Appendix.

[12] See www.compgen.de and des.genealogy.net/eingabe-verlustlisten/search. Other information is very sparse and the type of casualty is only rarely available.

sometimes mentioned in the (nondigitized) scan of the official publication linked to casualties in the database.[13] An examination of the data for 28 municipalities of different sizes with a total population of around 40,000 yielded 369 cases where the same name appeared more than once under the same municipality and the day and month of birth of the entries was available in the linked scan. In 304 of these 369 cases, the day and month of birth coincided.[14] Hence, 82 percent of the cases where the same name appears more than once under the same municipality correspond to the same person. As a result, the casualty count based on unique names should be closer to the number of persons who died, were injured, or went missing in military service during WWI than the casualty count including repeated names. I therefore use the casualty count based on unique names in my main analysis. Results for the casualty count including repeated names are similar and detailed in the Supplementary Appendix.

The number of military casualties in World War I was large. German casualties are estimated at around 10 percent of the 1910 population and fatalities at around 3 percent; the available estimates for Württemberg are similar (Schwarzmaier and Fenske, 1992).[15] Württemberg did not see any ground combat and, due to its distance from Germany's western border and aviation technology at the time, experienced few aerial bombings with very limited destruction of infrastructure, buildings, or factories and a relatively small number of local casualties. The deadliest aerial bombing in Württemberg occurred in

[13]The year of birth is mentioned only rarely.

[14]Municipalities were chosen from different percentiles of the distribution of population size across municipalities. I chose 10 municipalities with 1905 population just below the 25th percentile of the distribution with a total population of the 10 municipalities just above 5,000, 8 municipalities with 1905 population just below the 50th percentile with a total population just above 5,000, 5 municipalities with 1905 population just below the 75th percentile with a total population just above 5,000, and 3 municipalities with 1905 population just below the 90th percentile with a total population just above 5,000. I also chose 2 municipalities with 1905 population just below the 99th percentile with a population of around 10,000 each. For municipalities with population below the 25th percentile, 90 percent of the entries with the same name correspond to the same person. For municipalities with population below the 50th percentile, 88 percent of the entries with the same name correspond to the same person. For municipalities with population below the 75th percentile, 78 percent of the entries with the same name correspond to the same person. For municipalities with population just below the 90th percentile, 75 percent of the entries with the same name correspond to the same person. And for municipalities with population below the 99th percentile, 82 percent of the entries with same name correspond to the same person.

[15]Fatalities from Württemberg are estimated at 83,000, which is around 3.6 percent of the 1905 population of Württemberg (I am using 1905 population as it is the latest population figure in the 1910 compendium of statistics for Württemberg, where most of the pre-WWI data stems from). For comparison, total German fatalities relative to 1905 population were around 3.4 percent. According to the www.compgen.de database, WWI military casualties of municipalities in Württemberg relative to 1905 population average to 14 percent when counting all entries (including repeated names) and 10 percent when counting unique names only.

September 1918, when an attack targeting a Daimler engine factory near Stuttgart instead destroyed a residential building in the city, killing 10 inhabitants. In total, aerial bombings in Württemberg killed around 30 people and destroyed several buildings; there does not appear to have been significant damage to infrastructure or factories (Mönch, 2014).[16]

3 Empirical Framework

I first present a standard dynamic model in which city growth may be independent of past city size or reflect convergence to city-specific steady states. The model is useful for a discussion of how the degree of persistence of population shocks can be estimated. I then describe my main estimating equations.

3.1 A Dynamic Model of City Size

Denote the log population of city c at time t relative to the total population of all cities by $p_{c,t}$. A simple and standard model where relative city size may be determined by city-specific locational fundamentals and shocks to relative city size may either be transitory or permanent is

$$p_{c,t} - \alpha_c = \theta(p_{c,t-1} - \alpha_c) + \epsilon_{c,t} \tag{1}$$

where $\epsilon_{c,t}$ denote mean zero, i.i.d. population shocks between $t-1$ and t, and θ is a parameter that captures the persistence of these population shocks. The model has two main cases of interest, which depend on θ. When $0 < \theta < 1$, the relative size of each city converges towards a city-specific stochastic steady state with expected city size α_c; the parameters α_c can be interpreted as capturing the effect of city-specific locational fundamentals on city size. Hence, when $0 < \theta < 1$, the effect of population shocks $\epsilon_{c,t}$ on relative city size is transitory. The second case of interest is when $\theta = 1$. In this case, the model simplifies to $p_{c,t} - p_{c,t-1} = \epsilon_{c,t}$ and population shocks $\epsilon_{c,t}$ have permanent effects on relative city size.[17]

[16] The total number of World War I fatalities from aerial bombings in Germany is estimated at around 800. Most fatalities were in states close to Germany's western border.

[17] Davis and Weinstein's (2002) analysis of the effect of aerial bombings on the growth of Japanese cities during and after World War II uses a very similar model.

3.2 Estimating the Persistence Parameter

If the estimation of the persistence parameter θ ignores the possibility of city-specific steady states by imposing $\alpha_c = \alpha$, the result may indicate that the persistence parameter is (close to) unity even if the parameter is actually substantially below unity.[18] Estimation should therefore account for city-specific steady states by allowing for city-specific fixed effects. This could be done using dynamic panel estimators. However, these estimators can be subject to substantial bias when the panel data set has a relatively small time dimension, especially if shocks are persistent, see Arellano and Bond (1991), Arellano and Bover (1995), Alonso-Borrego and Arellano (1999), Arellano and Honoré (2001), and Phillips and Sul (2007). This is an important issue in the present context as panels for cities have a relatively small time dimension and population shocks are persistent if Gibrat's law for cities holds.

Estimation of the persistence parameter θ in (1) would be relatively straightforward if city-specific population shocks were at least partly observable at some point in time. To see this, it is useful to subtract $p_{c,t-2} - \alpha_c$ from both sides of the equation. This yields

$$\underbrace{p_{c,t} - p_{c,t-2}}_{\substack{\text{pop. growth over} \\ \text{entire period}}} = \theta \underbrace{\left(p_{c,t-1} - p_{c,t-2}\right)}_{\substack{\text{pop. growth over} \\ \text{first sub-period}}} + (1-\theta) \underbrace{\left(\alpha_c - p_{c,t-2}\right)}_{\substack{\text{distance from} \\ \text{steady state pop.} \\ \text{at beginning of} \\ \text{first sub-period}}} + \underbrace{\epsilon_{c,t}}_{\substack{\text{pop. shock} \\ \text{in second} \\ \text{sub-period}}} \tag{2}$$

The left-hand side of this equation $(p_{c,t} - p_{c,t-2})$ is the growth rate of relative city size between $t-2$ and t, the entire time period considered. The right-hand side points to three factors that may determine this growth rate. The first factor is the extent to which population growth during the first sub-period from $t-2$ to $t-1$ $(p_{c,t-1} - p_{c,t-2})$ persists to t. The second factor is the distance between actual and steady-state city size at $t-2$ $(\alpha_c - p_{c,t-2})$ and how quickly city size converges to the steady state. The third factor consists of population shocks during the second sub-period from $t-1$ to t $(\epsilon_{c,t})$.

The main difficulty in estimating the persistence parameter θ using (2) is that the city-specific distance between actual and steady-state city size at $t-2$ $(\alpha_c - p_{c,t-2})$ on the right-hand side is not observable and that this distance is generally correlated with population

[18]The bias increases with the variance of α_c relative to the variance of $\epsilon_{c,t}$. See Caselli, Esquivel, and Lefort (1996) for a discussion in the context of cross-country growth regressions.

growth between $t-2$ and $t-1$ ($p_{c,t-1} - p_{c,t-2}$). This issue could be addressed if population shocks $\epsilon_{c,t-1}$ between $t-2$ and $t-1$ were at least partly observable. To see this suppose we observe some component $z_{c,t-1}$ of population shocks $\epsilon_{c,t-1}$. Clearly, the model in (1) implies that shocks $z_{c,t-1}$ affect the population growth rate during the first sub-period $p_{c,t-1} - p_{c,t-2}$. Hence, $z_{c,t-1}$ could be used as an instrument for the population growth rate during the first sub-period on the right-hand side of (2). This would yield a consistent estimate of the persistence parameter θ under two conditions: (i) the observable shocks $z_{c,t-1}$ during the first sub-period are independent of the population shocks $\epsilon_{c,t}$ during the second sub-period and (ii) the observable shocks $z_{c,t-1}$ during the first sub-period are independent of the distance between actual and steady-state city size at $t-2$, the beginning of the first sub-period.

This approach could actually be used to estimate the persistence of population shocks even if the parameters α_c capturing locational fundamentals vary over time. This is possible as long as changes in $\alpha_{c,t}$ are independent of lagged population shocks $\epsilon_{c,t-1}$. If this condition is not satisfied, shocks can have permanent effects on city size even if $0 < \theta < 1$. As a result, the line between transitory and permanent population shocks becomes blurred and θ can no longer be interpreted as capturing the persistence of population shocks.

3.3 Main Estimating Equations

The first-stage estimating equation is for male population growth between 1910 and 1919, which is the closest approximation available to the beginning (1914) and end (1918) of WWI

$$male\,population\,growth_{c,1910}^{1919} = \gamma_{1919}\left(\frac{WWI\;casualties_c}{population_c\;or\;households_c}\right) + \delta X_c + \eta_{c,1910}^{1919} \tag{3}$$

where *casualties*/(*population or households*) denotes WWI military casualties relative to either 1905 population or number of households and X a range of pre-1910 municipality characteristics. Unobservable shocks to 1910–1919 male population growth are captured by $\eta_{c,1910}^{1919}$. The parameter γ_{1919} is the effect of WWI casualties on male population in 1919. Equation (3) will be estimated using least squares. As a result, estimates of the effect of WWI military casualties on male population may be attenuated due to classical measurement error in the casualty count.

The reduced-form estimating equation for population growth between 1910 and 1933 has the exact same right-hand-side variables as (3)

$$population\ growth^{1933}_{c,1910} = \gamma_{1933} \left(\frac{WWI\ casualties_c}{population_c\ or\ households_c} \right) + \kappa X_c + \eta^{1933}_{c,1910}. \qquad (4)$$

The parameter γ_{1933} captures the effect of WWI military casualties on male population in 1933. If estimates of γ_{1933} in (4) are similar to estimates of γ_{1919} in (3), the data indicates that the effect of WWI casualties on male population in 1933 is similar to the effect in 1919. Hence, the effect of WWI casualties on male population would be persistent over time.[19] I also estimate versions of (4) for population growth up to 1939, 1950, 1960, and 1970.

The instrumental-variables estimating equation for the degree of persistence of 1910-1919 population shocks to 1933 is

$$population\ growth^{1933}_{c,1910} = \phi \left(male\ population\ growth^{1919}_{c,1910} \right) + \mu X_c + \eta^{1933}_{c,1919} \qquad (5)$$

where $\eta^{1933}_{c,1919}$ captures post-1919 population shocks. The 1910–1919 population growth rate on the right-hand side of the equation will be instrumented using WWI military casualties relative to either 1905 population or number of households. Estimates of ϕ capture the extent to which 1910–1919 population shocks persist to 1933 under the identifying assumption that, conditional on municipality characteristics X, normalized WWI casualties are independent of post-1919 population shocks and the pre-war distance between actual and steady-state city size. While classical measurement error in the WWI military casualty count may lead to attenuated least-squares estimates of γ in (3) and (4), instrumental-variables estimates of ϕ in (5) are unaffected as long as the measurement error in the casualty count is unrelated to any measurement error in the 1910-1919 male population growth rate.

[19] Just like least-squares estimates of γ_{1919}, least-squares estimates of γ_{1933} may be attenuated due to classical measurement error in the WWI military casualty count. As the right-hand-side variables of the estimating equations in (3) and (4) are identical, this bias would be the same for both parameters.

4 Empirical Results

I start by examining the effect of WWI military casualties on the male population of municipalities in 1919. This is the closest the data allows me to get to the end of the war (1918). I then analyze the effect of WWI casualties on male population, female population, and the number of households in 1933, 15 years after the war. I conclude by examining the effect of WWI military casualties on population in 1939, 1950, 1960, and 1970.

4.1 World War I Casualties and Male Population in 1919

Table 1 summarizes the effect of WWI military casualties on male population growth between 1910 and 1919. Row A reports least-squares estimates for WWI military casualties measured relative to population in 1905. Row B reports least-squares estimates for WWI military casualties relative to the number of households in 1905. Robust standard errors are in parentheses and Conley standard errors in brackets. Different columns control for different sets of municipality characteristics.[20] Table 2 contains the data sources for the municipality characteristics in Table 1, as well as descriptive statistics.

The effect of WWI military casualties relative to 1905 population on 1910–1919 male population growth in Table 1 is estimated between −0.29 and −0.37. When all municipality controls are included in column (9), the effect of WWI casualties on 1910–1919 male population growth is 0.33 with a robust standard error of 0.07 and a Conley standard error of 0.065.[21] Hence, the effect of WWI military casualties on the male population of municipalities in 1919 is highly statistically significant. The estimate implies that a one-standard-deviation increase in WWI casualties relative to population lowered male population in 1919 by around one percentage point. Because of classical measurement error in the WWI military casualty count, this estimate is likely to understate the strength of the true effect.

Table 1 controls for up to 40 demographic and economic municipality characteristics. For example, column (3) includes controls for log population, log number of households, log male to female population, log population density, and labor-force participation in 1905, and also controls for pre-1910 male and female population growth going back to 1880. In column

[20] Estimates for the controls are shown in Tables 1 and 2 in the Supplementary Appendix.

[21] The two types of standard errors tend to be similar once all municipality controls are included.

(4), I add pre-1910 wage growth and the log wage level in 1895. Column (5) also includes 1905 controls for log income per capita from official income tax records and the log of the agricultural population—the population whose work and livelihood comes from agriculture—relative to total population. In column (6) I add controls capturing the (male and female) population less than 14 years old in various years between 1875 and 1895. Finally, column (9) includes pre-1910 municipality controls capturing further economic characteristics like the number of non-farm businesses and their size, business tax revenues, land tax revenues, building tax revenues, building insurance values, and the size distribution of farms. Moreover, column (9) also controls for demographic characteristics like child mortality and the locally born male and female population around 1900, the distance to the next train station in 1905, and the growth in the land area of the municipality between 1905 and 1933.[22] It can be seen from the R-squared at the bottom of Table 1 that the added municipality characteristics explain around one-fifth of the variation in 1910-1919 male population growth across municipalities.

A natural starting point is to measure WWI military casualties relative to pre-war population. However, there are good reasons to consider the pre-war number of households instead of population. The population census before WWI could not draw on a register of residents and therefore counted the number of people present in the municipality on census day.[23] Hence, population figures include persons who are temporarily present and exclude those who are temporarily absent. This approach seems likely to produce greater mean-reverting measurement error in the population data than in the number of households. It is well known that mean-reverting measurement error in population data biases the effect of population size at a point in time on subsequent population growth downward and that the bias can be substantial even for modest measurement error. When WWI military casualties are measured relative to pre-war population, mean-reverting measurement error in

[22]The reason for the last control is that the land area of municipalities is not always the same in the 1910 statistical compendium and the statistics available for 1933 (between these years there is no information on the land area of municipalities). These discrepancies could reflect transcription errors or changes in the borders of municipalities without an official record. As such territorial modifications may have resulted in changes in population, I include the growth in the land area of the municipalities as an additional control, though it is not statistically significant.

[23]Starting in 1933, the population census counted the population who had their main residence in the municipality (see Statistisches Bundesamt, 1966).

the population data biases the effect of casualties on subsequent population growth upward.[24] This could lead to the unwarranted conclusion that WWI military casualties did not have a (persistent) negative effect on the population size of municipalities.

For this reason, Table 1 also presents estimates where WWI military casualties are measured relative to the number of households in 1905. The control sets are unchanged and, starting in column (3), always include log population and number of households in 1905. Hence, any effect of the average size of households on population growth is accounted for. The effect of military WWI casualties on 1910–1919 male population growth is now −0.074 with a standard error of 0.014 when all municipality controls are included in column (9). Estimates are smaller than when WWI casualties are measured relative to population, as the number of households of municipalities is smaller than their population, and somewhat more precise. The point estimate of −0.074 in column (9) implies that a one-standard-deviation increase in WWI military casualties relative to the number of households lowered male population in 1919 by around 1.2 percentage points.

Figure 4A summarizes the effect of WWI military casualties relative to population on male population growth between 1910 and 1919 in the full sample and outside of the most agricultural municipalities. I use the amount of agricultural land relative to total population in 1905 to measure how agricultural a municipality is. I am interested in the effect of WWI casualties on population growth outside of the most agricultural municipalities because agriculture was the principal economic activity in many municipalities before WWI and agricultural land is a fixed and location-specific production factor that can shape population dynamics. For example, in the most extreme Malthusian scenario, the population of agricultural municipalities is fully determined by the amount of agricultural land available. As a result, following negative shocks, the population of these municipalities would tend to return to pre-shock values. More generally, the availability of agricultural land may make the effect of negative population shocks less persistent than predicted by Gibrat's law for cities. This impact of agricultural land on the persistence of population shocks should become smaller outside of the most agricultural municipalities.

Figure 4A successively excludes the top-5 percent most agricultural municipalities, the

[24] As the measurement error will make casualties appear large (small) relative to population when population is underestimated (overestimated) and subsequent population growth appears high (low).

top-10 percent most agricultural municipalities, and so on from the empirical analysis. The figure shows point estimates and 90-percent confidence intervals when WWI military casualties are measured relative to the population in 1905.[25] Up to the point where the top-20 percent most agricultural municipalities are excluded from the analysis, the effect of WWI casualties on male population growth between 1910 and 1919 is approximately constant. The effect then starts to decrease somewhat in absolute value. The range of variation of the point estimates is between -0.26 and -0.35. As was to be expected, estimates become less precise as more municipalities are excluded from the analysis.

Figure 4B repeats the empirical analysis in Figure 4A, but measures WWI military casualties relative to the number of households in 1905. The range of variation of the point estimates is now between -0.064 and -0.079. Estimates are generally somewhat more precise than in Figure 4A. The pattern of results when a greater percentage of the most agricultural municipalities is excluded from the empirical analysis is similar to Figure 4A.

4.2 Male Population Growth before World War I

By examining the effect of WWI military casualties on pre-war male population growth, it is possible to check whether the effect of WWI casualties on post-1910 population growth captures economic or demographic trends that were already present earlier. The necessary data for pre-WWI population growth is available for the period from 1900 to 1910. The empirical analysis can actually be implemented with a set of pre-1900 municipality controls that is quite similar to the pre-1910 controls used for 1910–1919 male population growth in Table 1. This is possible because the statistical compendium for Württemberg published in 1898 contains pre-1900 values for many of the 1900-1909 municipality characteristics in the statistical compendium published in 1910.[26]

Table 3 summarizes the effect of WWI military casualties on male population growth between 1900 and 1910. WWI casualties are normalized by either population or the number

[25]The 90-percent confidence intervals are based on robust standard errors. Point estimates and robust as well as Conley standard errors corresponding to the figures are detailed in the Supplementary Appendix in Tables 4-17. Panels A contain the results for WWI military casualties normalized by 1905 households. Panels B contain the results for WWI military casualties normalized by 1905 population. Panels C contain the results for the casualty count including repeated names. And Panels D contain results when municipalities are excluded depending on the amount of agricultural land per household in 1905.

[26]Except for income and infant mortality. Also, there is only the sum of business, land, and building taxes.

of households in 1895. The table contains least-squares point estimates as well as robust and Conley standard errors. Table 4 contains the data sources for the municipality characteristics in Table 3, as well as descriptive statistics. The point estimates of the effect of WWI casualties on 1900–1910 male population growth are small and statistically insignificant. For example, the effect of WWI casualties relative to 1895 population on 1900–1910 male population growth is −0.005 when controlling for 1895 population in column (1) of Table 3. For 1910–1919 male population growth, the effect was −0.31 in the comparable specification in Table 1. The effect of WWI casualties relative to the 1895 number of households on 1900–1910 male population growth is −0.001 when controlling for the 1895 number of households in column (2) of Table 3. For 1910–1919 male population growth, the effect was −0.07 in the comparable specification. The effect of WWI casualties on 1900–1910 male population growth continues to be small and statistically insignificant in columns (3) and (4) of Table 3 where I add all pre-1900 municipality controls.[27]

4.3 World War I Casualties and Population in 1933

My main interest is examining whether the effect of WWI military casualties on the male population of municipalities in 1919 persisted to 1933. I focus on 1933 as the 15-year period between the end of WWI and 1933 is of similar length to the 10-year periods analyzed in the existing literature on Gibrat's law for cities (e.g. Black and Henderson, 2003; Ioannides and Overman, 2003). Figure 5A shows the effect of WWI military casualties relative to 1905 households on male population growth between 1910 and 1933, conditional on all the municipality characteristics included in Table 1. Point estimates vary between around −0.06 in the full sample and −0.1 when the top-20 percent most agricultural municipalities are excluded from the analysis.[28] For comparison, the effect on 1910–1919 male population growth in Figure 4B was around −0.07. Hence, the effect of WWI casualties on male population in 1933 is similar to the effect on male population in 1919 or even somewhat stronger. This indicates persistence of the effect of WWI military casualties on the male

[27] Some of the data is missing for four municipalities, which is why Table 3 is based on 1630 municipalities while Table 1 has 1634 municipalities. Dropping the most agricultural municipalities does not affect the conclusion, see Figures 2A and 2B in the Supplementary Appendix.

[28] Results for WWI casualties relative to 1905 population are in Table 6 in the Supplementary Appendix.

population of municipalities nearly one generation after the war.[29] It appears that no strong post-war incentives existed for men to move to municipalities that had seen more casualties.

An interesting feature of Figure 5A is that the negative effect of WWI military casualties on the male population of municipalities in 1933 becomes stronger up to the point where the top-20 percent most agricultural municipalities are excluded from the analysis. The corresponding effect of WWI casualties on the male population of municipalities in 1919 was approximately constant. A simple explanation is the role of agricultural land for the economies of the most agricultural municipalities. As mentioned above, agricultural land is a fixed and location-specific production factor that can shape population dynamics. For example, in the most extreme Malthusian scenario, the population of municipalities would return to pre-shock values following negative shocks. In the present context, this might happen because farms of families that suffered WWI casualties are taken over by younger children or more distant family who would have otherwise left the municipality in search of employment. More generally, negative population shocks may have less persistent effects than predicted by Gibrat's law for cities in the most agricultural municipalities.

Figure 5B summarizes the effect of WWI military casualties on the female population of municipalities in 1933 and the number of households. Results are for the full sample and outside of the most agricultural municipalities. All estimates are statistically insignificant. There do not appear to have been strong post-war incentives for women and families to move away from municipalities that had seen more military casualties. However—as will be seen below—by 1950, the effect of WWI casualties on the female population of municipalities and the number of households becomes similar to the effect on male population.

Figure 6 summarizes the results when I estimate the degree of persistence of population shocks using an instrumental-variables approach. The estimating equation is (5). The left-hand-side variable is male population growth between 1910 and 1933. The parameter of interest is the coefficient on 1910–1919 male population growth, ϕ, which captures the degree of persistence of 1910–1919 population shocks to 1933. The instrument for 1910–1919 male population growth is WWI military casualties relative to the number of households in 1905. The specification includes all municipality controls in Table 1. The identifying assumption

[29] Any attenuation bias due to classical measurement error in the WWI military casualty count would be the same for the 1910–1933 period and the 1910–1919 period.

is that, conditional on the included range of municipality controls, WWI casualties relative to 1905 households affect 1910–1933 population growth only through their effect on 1910–1919 population growth. Put differently, conditional on the included range of municipality controls, WWI military casualties relative to households should be unrelated to post-war population shocks and the pre-war distance between actual and steady-state population.

Point estimates of the degree of persistence of population shocks ϕ in Figure 6 vary between 0.8 and 1.5.[30] The degree of persistence increases up to the point where the top-30 percent most agricultural municipalities are excluded from the analysis. The standard error is around 0.3 in the largest sample and, as was to be expected, increases as a larger percentage of the most agricultural municipalities is excluded from the empirical analysis. The hypothesis that 1910–1919 male population shocks have a permanent effect on male population ($\phi = 1$) can never be rejected at the 5-percent significance level.

4.4 World War I Casualties and Population from 1939 to 1970

4.4.1 World War I Casualties and Population in 1939

Figure 7A summarizes the effect of WWI military casualties relative to 1905 households on male population growth between 1910 and 1939. The results shown are for the full sample and outside of the most agricultural municipalities.[31]

Just like the effect of WWI military casualties on the male population of municipalities in 1933, the effect on male population in 1939 is negative and becomes stronger outside of the most agricultural municipalities. Standard errors are around 50 percent larger in 1939 than in 1933. That estimates become noisier was to be expected, as municipalities are subject to new shocks over time. In the full sample, the effect of WWI casualties on the male population of municipalities in 1939 is -0.017, around one-third of the effect on the male population in 1933, and statistically insignificant. When the top-5 percent most agricultural

[30]Results for WWI casualties relative to population are similar, see Figure 2 and Table 6, Panel B in the Supplementary Appendix. Results for the casualty count including repeated names are also similar, see Table 6, Panel C in the Supplementary Appendix. Results when municipalities are dropped depending on agricultural land per 1905 household are again similar, see Table 6, Panel D in the Supplementary Appendix.

[31]The number of municipalities in the full sample is now 1558. This is 76 municipalities less than in the empirical analysis for 1910–1933. The reason is a territorial reform between 1933 and 1939 that incorporated small municipalities into nearby, larger municipalities or, very exceptionally, combined two municipalities into a new municipality. See Table 3 in the Supplementary Appendix for a list of the affected municipalities.

municipalities are excluded from the analysis, the effect of WWI casualties becomes stronger, around two-thirds of the effect on the male population in 1933, and is close to statistically significant at the 10-percent level. Once the top-10 percent most agricultural municipalities are excluded from the analysis, the effect of WWI military casualties on male population in 1939 is statistically significant and between around -0.07 and -0.11. For comparison, the corresponding effect of WWI casualties on male population in 1919 was between around -0.06 and -0.08 and the corresponding effect on male population in 1933 was between around -0.07 and -0.1. Hence, outside of the most agricultural municipalities, the effect of WWI casualties on male population is strongly persistent one generation after the war.

Figure 7B summarizes the effects of WWI military casualties on female population in 1939. As was the case for female population in 1933, the effect is statistically insignificant for the full sample and outside of the most agricultural municipalities.[32]

4.4.2 World War I Casualties and Population in 1950

Figure 8A summarizes the effect of WWI military casualties relative to 1905 households on male and female population growth between 1910 and 1950 for the full sample and outside of the most agricultural municipalities.

The effect of WWI military casualties on the male population of municipalities in 1950 is very similar to the effect in 1939. WWI casualties have a negative effect on male population that becomes stronger outside of the most agricultural municipalities. As expected, point estimates in 1950 are noisier than in previous years. In the full sample, the effect of WWI casualties on male population is statistically insignificant. When the top-10 percent most agricultural municipalities are excluded from the analysis, the effect of WWI casualties on the male population of municipalities in 1950 is -0.09 and statistically significant. This indicates very strong persistence 32 years after the end of WWI. For comparison, the corresponding effect of WWI casualties on the male population of municipalities was -0.074 in 1919, -0.084 in 1933, and -0.066 in 1939. The point estimate for 1950 implies that a one-standard-deviation increase in WWI military casualties relative to the number of households lowered 1950 male population by around 1.5 percentage points.

[32] There is no data on the number of households in 1939.

WWI military casualties continue to have a strong negative and statistically significant effect on the male population of municipalities in 1950 when I exclude more than the top-10 percent most agricultural municipalities from the analysis. Point estimates are between −0.13 and −0.17 and therefore indicate somewhat stronger effects on the male population of municipalities in 1950 than in 1939 and in 1933.

Figure 8A also shows that by 1950, the effect of WWI military casualties on the female population of municipalities is similar to the effect on the male population. Outside of the top-10, top-15, top-20, and top-25 percent most agricultural municipalities, the effect of WWI casualties on female population is −0.062, −0.096, −0.12, and −0.14, respectively. For comparison, the corresponding effects on male population are −0.094, −0.13, −0.15, and −0.17. The negative effect of WWI casualties on the female population of municipalities is statistically significant outside of the top-15 percent most agricultural municipalities. The most plausible explanation for why the effect of WWI casualties on the male and the female population of municipalities become similar by 1950 is that women in the generation that fought WWI started to reach their life expectancy. At age 30, women born in 1881 and in 1900 had a remaining life expectancy of 34 years and 36 years, respectively (Rahlf, 2015). Hence, women born in 1890, who were between the ages of 24 and 28 during WWI, could expect to live until around 1955. This explanation implies that by 1960, when women in the generation that fought WWI would have surpassed their life expectancy, the effect of WWI casualties on the female population of municipalities should become even more similar to the effect on the male population. This is indeed the case, as will be seen below.[33]

Figure 8B summarizes the effects of WWI military casualties on the total population of municipalities in 1950 and the number of households. The effects are similar to those on the male and female population in Figure 8A. Outside of the most agricultural municipalities, there is a sizable and significant negative effect of WWI military casualties on total population and the number of households. For example, the point estimates imply that outside of the top-15 percent most agricultural municipalities, a one-standard-deviation

[33]Another factor could play a role. As mentioned, starting in 1933, the census counted the population with their main residence in a municipality (see Statistisches Bundesamt, 1966). However, it was not until 1950 that the census specified that the main municipality of residence was the municipality from which a person commuted to work regularly. Hence, it is possible that before 1950, unmarried women who moved to another municipality for work might still have been counted in their municipality of origin.

increase in WWI military casualties relative to the number of households lowered the total population of municipalities in 1950 by around 1.5 percentage points.

4.4.3 World War I Casualties and Population in 1960

Figure 9A summarizes the effect of WWI military casualties relative to 1905 households on male and female population growth between 1910 and 1960 for the full sample and outside of the most agricultural municipalities. The effect of WWI casualties on the male population of municipalities in 1960 is similar to the effect in 1950 and in 1939. WWI casualties have a negative effect on male population in 1960 that becomes stronger outside of the most agricultural municipalities. In the full sample, the effect of WWI casualties on male population is statistically insignificant. When the top-10 percent most agricultural municipalities are excluded from the analysis, the effect of WWI casualties on male population in 1960 is −0.085, which is similar to the effect in 1950 (−0.094). However, as was to be expected, estimates continue to become noisier over time, and the estimate is not statistically significant. Once the top-15 percent most agricultural municipalities are excluded from the analysis, the effect of WWI casualties on the male population of municipalities in 1960 is −0.126 and statistically significant. For comparison, the corresponding effect of WWI casualties on male population is around −0.08 in 1919, −0.09 in 1933, and −0.13 in 1950. Hence, the effect of WWI military casualties on the male population of municipalities strongly persists over a time period spanning more than two generations. This continues to be the case when the share of the most agricultural municipalities excluded from the analysis is increased further. Estimates are between −0.16 and −0.19, which is similar to the range in 1950, and are statistically significant.

Figure 9A also shows that the effect of WWI military casualties on the female population of municipalities in 1960 is similar to the effect on the male population. Outside of the top-10, top-15, top-20, and top-25 percent most agricultural municipalities, the effect of WWI casualties on female population is −0.08, −0.11, −0.15, and −0.17, respectively. The corresponding effects on male population are −0.085, −0.126, −0.17, and −0.19. As already mentioned, the most plausible explanation for why the effects of WWI military casualties on the male and the female population of municipalities are similar in 1960 is that women in the generation that fought WWI surpassed their life expectancy by 1960.

Figure 9B shows that outside of the most agricultural municipalities, there is a sizable and statistically significant negative effect of WWI military casualties on the total population of municipalities in 1960. Outside of the top-15 percent most agricultural municipalities, a one-standard-deviation increase in WWI casualties relative to the number of households lowered the total population of municipalities in 1960 by around 2 percentage points.

4.4.4 World War I Casualties and Population in 1970

Figure 10A summarizes the effect of WWI military casualties relative to 1905 households on male and female population growth between 1910 and 1970 for the full sample and outside of the most agricultural municipalities.[34] The effect of WWI casualties on the male and the female population of municipalities in 1970 is similar to the effects in 1950 and in 1960. WWI casualties have a negative effect on male and female population that becomes stronger outside of the most agricultural municipalities. However, by 1970, point estimates have become quite noisy and are therefore often statistically insignificant at conventional levels.

In the full sample, the effect of WWI military casualties on the male population of municipalities in 1970 is weak and statistically insignificant, and this remains true when I exclude the top-10 percent most agricultural municipalities from the analysis. When the top-15 percent most agricultural municipalities are excluded, the effect of WWI casualties on male population is −0.078, which is similar to the effect in 1919 (−0.08), in 1933 (−0.09), and in 1939 (−0.09). Increasing the percentage of the most agricultural municipalities excluded from the analysis further, yields point estimates of the effect of WWI military casualties on the male population of municipalities in 1970 between around −0.12 and −0.16. This range of estimates is similar to the corresponding range in 1950 and in 1960.

The negative effect of WWI military casualties on the female population of municipalities in 1970 is actually somewhat stronger than the negative effect on the male population. Outside of the top-10, top-15, top-20, and top-25 percent most agricultural municipalities, the effect of WWI casualties on female population is −0.064, −0.11, −0.15, and −0.185, respectively. The corresponding effects on male population are −0.034, −0.078, −0.136,

[34] The total number of municipalities is now 1538 in the full sample because of the territorial reform that began in 1970. By the mid-1970s, the number of municipalities was reduced by more than half.

and −0.155. That point estimates indicate stronger effects on the female than the male population by 1970 is consistent with the explanation for why effects start becoming similar for males and females by 1950 and 1960: by 1970, women in the generation that fought WWI had surpassed their life expectancy by around 15 years and only few would have still been alive. The effect of WWI military casualties on the total population of municipalities in 1970 shown in Figure 10B is similar to the effect in 1950 and in 1960, although noisier.

5 Conclusion

My goal has been to examine Gibrat's law for cities using an empirical approach that allows for the alternative hypothesis that city size is determined by unobservable locational fundamentals. The approach I use analyzes the persistence of observed city-specific population shocks: German military casualties in World War I by municipality of birth. I find a strong negative effect of WWI military casualties on the male population of municipalities just after the war. This effect persists to 1933, 15 years after the war. The persistent effect of WWI military casualties on the male population of municipalities is consistent with Gibrat's law for cities. Under the alternative hypothesis that the size of municipalities is determined by locational fundamentals, one would have expected the effect of WWI casualties on male population to become weaker over time. Outside of the most agricultural municipalities, the reduction in male population due to WWI casualties persisted beyond 1933. The effect of WWI military casualties on the female population of municipalities and the number of households is similar to the effect on male population by 1950, when women in the generation that fought WWI started reaching their life expectancy.

The data for my empirical analysis comes from quite detailed municipality statistics of the historical German state of Württemberg. This state saw no ground combat in WWI and only few aerial bombings with little destruction of infrastructure, buildings, or factories and a small number of local casualties. The negative effect of WWI military casualties on the population size of municipalities I document is therefore unrelated to the violence against civilians or the destruction of infrastructure, buildings, and factories in wars. I also find that the effect of WWI military casualties on the post-war population of municipalities does not reflect economic or demographic trends affecting population growth already before the war.

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Table 1: The Effect of World War I (WWI) Casualties on Male Population Growth 1910–1919

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A: WWI casualties relative to 1905 population	-0.314	-0.294	-0.302	-0.287	-0.286	-0.371	-0.370	-0.343	-0.331
	(0.058)	(0.058)	(0.062)	(0.062)	(0.062)	(0.065)	(0.065)	(0.070)	(0.070)
	[0.118]	[0.113]	[0.082]	[0.081]	[0.082]	[0.058]	[0.061]	[0.059]	[0.065]
B: WWI casualties relative to 1905 number of households	-0.073	-0.073	-0.065	-0.063	-0.063	-0.082	-0.081	-0.076	-0.074
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.014)	(0.014)
	[0.022]	[0.022]	[0.016]	[0.016]	[0.016]	[0.012]	[0.012]	[0.012]	[0.014]
log population, 1905	yes	–	yes	yes	yes	yes	yes	yes	yes
log number of households, 1905	–	yes	yes	yes	yes	yes	yes	yes	yes
log male pop. to female pop., 1905	–	–	yes	yes	yes	yes	yes	yes	yes
log population density, 1905	–	–	yes	yes	yes	yes	yes	yes	yes
male population growth, 1905 to 1910	–	–	yes	yes	yes	yes	yes	yes	yes
male population growth, 1900 to 1905	–	–	yes	yes	yes	yes	yes	yes	yes
male population growth, 1880 to 1900	–	–	yes	yes	yes	yes	yes	yes	yes
female population growth, 1905 to 1910	–	–	yes	yes	yes	yes	yes	yes	yes
female population growth, 1900 to 1905	–	–	yes	yes	yes	yes	yes	yes	yes
female population growth, 1880 to 1900	–	–	yes	yes	yes	yes	yes	yes	yes
labor force to total population, 1905	–	–	yes	yes	yes	yes	yes	yes	yes
log income per capita, 1905	–	–	–	yes	yes	yes	yes	yes	yes
log agricultural relative to total population 1905	–	–	–	yes	yes	yes	yes	yes	yes
log wage, 1898	–	–	–	–	yes	yes	yes	yes	yes
wage growth, 1884 to 1909	–	–	–	–	yes	yes	yes	yes	yes
log male pop. younger 14 over total male pop., 1875	–	–	–	–	–	yes	yes	yes	yes
log male pop. younger 14 over total male pop., 1880	–	–	–	–	–	yes	yes	yes	yes
log male pop. younger 14 over total male pop., 1885	–	–	–	–	–	yes	yes	yes	yes
log female pop. younger 14 over total female pop., 1875	–	–	–	–	–	yes	yes	yes	yes
log female pop. younger 14 over total female pop., 1880	–	–	–	–	–	yes	yes	yes	yes
log female pop. younger 14 over total female pop., 1885	–	–	–	–	–	yes	yes	yes	yes
log pop. younger 14 over total pop., 1895	–	–	–	–	–	yes	yes	yes	yes
log nonagricultural businesses per capita, 1907/1905	–	–	–	–	–	–	yes	yes	yes
log nonagricultural business taxes per capita, 1908/1905	–	–	–	–	–	–	yes	yes	yes
log building tax per capita, 1905/07	–	–	–	–	–	–	yes	yes	yes
log building tax per building, 1907	–	–	–	–	–	–	yes	yes	yes
log land tax per square km, 1907	–	–	–	–	–	–	yes	yes	yes
log fire insurance building values per capita, 1908/1905	–	–	–	–	–	–	yes	yes	yes
log nonagricultural business employment per business, 1907	–	–	–	–	–	–	yes	yes	yes
log stillborn or died in first year over all births, 1896-1905	–	–	–	–	–	–	–	yes	yes
log pop. born in municipality per total pop., 1900	–	–	–	–	–	–	–	yes	yes
log pop. born in municipality per total pop., 1895	–	–	–	–	–	–	–	yes	yes
log male pop. born in municipality per total male pop., 1895	–	–	–	–	–	–	–	yes	yes
log fem. pop. born in municipality per total fem. pop., 1895	–	–	–	–	–	–	–	yes	yes
distance to next train station, 1905	–	–	–	–	–	–	–	yes	yes
share of farms below 2 hectars	–	–	–	–	–	–	–	–	yes
share of farms between 4 and 10 hectars	–	–	–	–	–	–	–	–	yes
share of farms between 10 and 20 hectars	–	–	–	–	–	–	–	–	yes
share of farms larger than 20 hectars	–	–	–	–	–	–	–	–	yes
growth in land area of municipality, 1905 to 1933	–	–	–	–	–	–	–	–	yes
R-square (A)	0.019	0.018	0.147	0.149	0.151	0.166	0.192	0.203	0.208
R-square (B)	0.021	0.022	0.149	0.151	0.153	0.170	0.195	0.205	0.211
Observations	1634	1634	1634	1634	1634	1634	1634	1634	1634

Notes: The left-hand-side variable is male population growth 1910–1919. Data sources and descriptive statistics are in Table 2. The numbers in parenthesis are robust standard errors and those in brackets are Conley standard errors with a Bartlett kernel and a 100 km distance cutoff. For point estimates and standard errors of the controls, see Tables 1 and 2 in the Supplementary Appendix.

Table 2: Data with Sources and Summary Statistics

	Variable	Source	Mean	Median	S.D.
1	male population growth, 1910 to 1919	SLBW	-0.02	-0.02	0.08
2	WWI casualties relative to 1905 population	WSL10,VG	0.10	0.10	0.03
3	WWI casualties relative to 1905 number of households	WSL10,VG	0.44	0.44	0.16
4	log population, 1905	WSL10	6.56	6.49	0.81
5	log number of households, 1905	WSL10	5.01	4.95	0.85
6	log male pop. to female pop., 1905	WSL10	-0.07	-0.07	0.12
7	log population density, 1905	WSL10	-0.18	-0.25	0.66
8	male population growth, 1905 to 1910	SLBW	0.02	0.02	0.07
9	male population growth, 1900 to 1905	SLBW	0.03	0.03	0.07
10	male population growth, 1880 to 1900	SLBW	-0.02	-0.04	0.15
11	female population growth, 1905 to 1910	SLBW	0.01	0.01	0.07
12	female population growth, 1900 to 1905	SLBW	0.01	0.01	0.07
13	female population growth, 1880 to 1900	SLBW	-0.02	-0.03	0.14
14	labor force to total population, 1905	WSL10	0.51	0.51	0.14
15	log income per capita, 1905	WSL10	-1.14	-1.13	0.31
16	log agricultural relative to total population, 1905	WSL10	-0.55	-0.37	0.53
17	log wage, 1898	WSL10	5.06	5.08	0.15
18	wage growth, 1884 to 1909	WSL10	0.45	0.44	0.16
19	log male pop. younger 14 over total male pop., 1875	SLBW	-1.80	-1.78	0.15
20	log male pop. younger 14 over total male pop., 1880	SLBW	-1.77	-1.75	0.16
21	log male pop. younger 14 over total male pop., 1885	SLBW	-1.65	-1.74	0.94
22	log female pop. younger 14 over total female pop., 1875	SLBW	-1.75	-1.74	0.15
23	log female pop. younger 14 over total female pop., 1880	SLBW	-1.73	-1.71	0.17
24	log female pop. younger 14 over total female pop., 1885	SLBW	-1.63	-1.70	0.99
25	log pop. younger 14 over total pop., 1895	WSL98	-1.09	-1.08	0.12
26	log nonagricultural businesses per capita, 1907/1905	WSL10	-3.12	-3.10	0.46
27	log nonagricultural business taxes per capita, 1908/1905	WSL10	-2.38	-2.65	1.17
28	log building tax per capita, 1905/07	WSL10	-0.54	-0.55	0.32
29	log building tax per building, 1907	WSL10	0.45	0.45	0.42
30	log land tax per square km, 1907	WSL10	-0.24	-0.23	0.47
31	log fire insurance building values per capita, 1908/1905	WSL10	0.27	0.26	0.32
32	log nonagricultural business employment per business, 1907	WSL10	0.60	0.46	0.46
33	log stillborn or died in first year over all births, 1896-1905	WSL10	-1.44	-1.42	0.27
34	log pop. born in municipality per total pop., 1900	WSL10	-0.32	-0.28	0.22
35	log pop. born in municipality per total pop., 1895	WSL98	-0.31	-0.27	0.18
36	log male pop. born in municipality per total male pop., 1895	WSL98	-0.28	-0.23	0.18
37	log fem. pop. born in municipality per total fem. pop., 1895	WSL98	-0.34	-0.31	0.18
38	distance to next train station, 1905	WSL10	4.24	3.80	4.04
39	share of farms below 2 hectars	WSL10	0.41	0.39	0.21
40	share of farms between 4 and 10 hectars	WSL10	0.24	0.24	0.13
41	share of farms between 10 and 20 hectars	WSL10	0.09	0.05	0.10
42	share of farms larger than 20 hectars	WSL10	0.04	0.01	0.06
43	growth in land area of municipality, 1905 to 1933	WSL10,WSL35	-0.00	0.00	0.10

Notes: There are 1634 municipalities with all the data available. WSL98, WSL10, and WSL35 stand for Württembergisches Statistisches Landesamt (1898), (1910), and (1935) [Statistical Agency of Württemberg]; SLBW stands for Statistisches Landesamt Baden-Württemberg (2008) [Statistical Agency of Baden-Württemberg]; VG stands for Verein für Computergenealogie [Association for Computer Genealogy].

Table 3: The Effect of World War I (WWI) Casualties on Male Population Growth 1900–1910

	(1)	(2)	(3)	(4)
WWI casualties relative to 1895 population	-0.005		-0.035	
	(0.072)		(0.085)	
	[0.155]		[0.084]	
WWI casualties relative to 1895 number of households		-0.001		-0.008
		(0.015)		(0.017)
		[0.036]		[0.019]
log population, 1905	yes	–	yes	yes
log number of households, 1905	–	yes	yes	yes
log male pop. to female pop., 1895	–	–	yes	yes
log population density, 1895	–	–	yes	yes
male population growth, 1895 to 1900	–	–	yes	yes
male population growth, 1890 to 1895	–	–	yes	yes
male population growth, 1875 to 1890	–	–	yes	yes
female population growth, 1895 to 1900	–	–	yes	yes
female population growth, 1890 to 1895	–	–	yes	yes
female population growth, 1875 to 1890	–	–	yes	yes
labor force to total population, 1895	–	–	yes	yes
log agricultural relative to total population, 1895	–	–	yes	yes
log wage, 1898	–	–	yes	yes
wage growth, 1884 to 1898	–	–	yes	yes
log male pop. younger 14 over total male pop., 1875	–	–	yes	yes
log male pop. younger 14 over total male pop., 1880	–	–	yes	yes
log male pop. younger 14 over total male pop., 1885	–	–	yes	yes
log female pop. younger 14 over total female pop., 1875	–	–	yes	yes
log female pop. younger 14 over total female pop., 1880	–	–	yes	yes
log female pop. younger 14 over total female pop., 1885	–	–	yes	yes
log pop. younger 14 over total pop., 1895	–	–	yes	yes
log land, building, and business tax per capita, 1895	–	–	yes	yes
log fire insurance building values per capita, 1895	–	–	yes	yes
log fire insurance building values per building, 1895	–	–	yes	yes
log pop. born in municipality per total pop., 1895	–	–	yes	yes
log male pop. born in municipality per total male pop., 1895	–	–	yes	yes
log fem. pop. born in municipality per total fem. pop., 1895	–	–	yes	yes
share of farms below 5 hectars	–	–	yes	yes
share of farms between 5 and 10 hectars	–	–	yes	yes
share of farms between 10 and 50 hectars	–	–	yes	yes
share of farms larger than 50 hectars	–	–	yes	yes
growth in land area of municipality, 1895 to 1905	–	–	yes	yes
R-squared	0.068	0.068	0.315	0.315
Observations	1630	1630	1630	1630

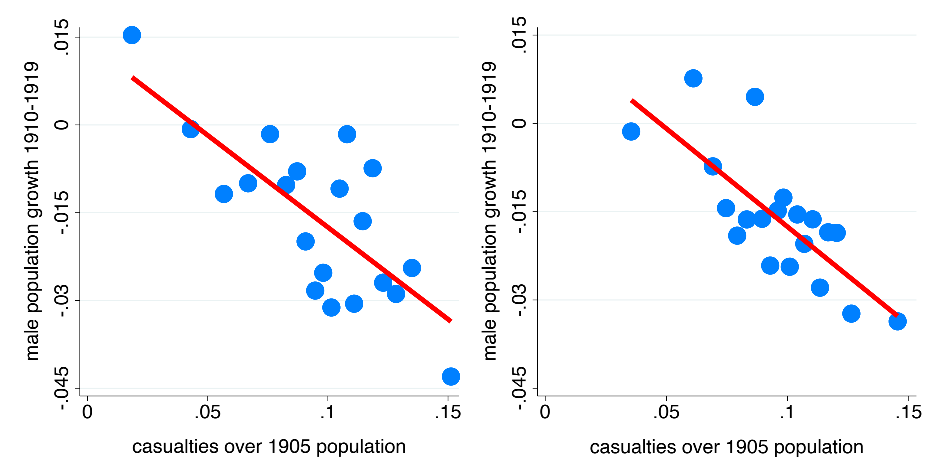
Notes: The left-hand-side variable is male population growth from 1900 to 1910. Data sources and descriptive statistics are in Table 4. The numbers in parenthesis are robust standard errors and those in brackets are Conley standard errors with a Bartlett kernel and a 100 km distance cutoff.

Table 4: Further Data with Sources and Summary Statistics

	Variable	Source	Mean	Median	S.D.
1	male population growth, 1900 to 1910	SLBW	0.05	0.05	0.11
2	WWI casualties relative to 1895 number of households	WSL98,VG	0.45	0.46	0.16
3	WWI casualties relative to 1895 population	WSL98,VG	0.10	0.10	0.03
4	log population, 1895	WSL98	6.53	6.49	0.77
5	log number of households, 1895	WSL98	4.91	4.87	0.80
6	log male pop. to female pop., 1895	WSL98	-0.09	-0.09	0.10
7	log population density, 1895	WSL98	-0.20	-0.25	0.63
8	male population growth, 1895 to 1900	SLBW	0.00	0.00	0.07
9	male population growth, 1890 to 1895	SLBW	-0.01	-0.01	0.09
10	male population growth, 1875 to 1890	SLBW	0.03	0.02	0.13
11	female population growth, 1895 to 1900	SLBW	-0.00	-0.00	0.06
12	female population growth, 1890 to 1895	SLBW	-0.01	-0.01	0.06
13	female population growth, 1875 to 1890	SLBW	0.02	0.02	0.11
14	labor force to total population, 1895	WSL98	0.44	0.43	0.06
15	log agricultural relative to total population, 1895	WSL98	-0.49	-0.33	0.47
16	log wage, 1898	WLS98	5.06	5.08	0.15
17	wage growth, 1884 to 1898	WSL98	0.09	0.06	0.14
18	log male pop. younger 14 over total male pop., 1875	SLBW	-1.80	-1.78	0.15
19	log male pop. younger 14 over total male pop., 1880	SLBW	-1.77	-1.75	0.16
20	log male pop. younger 14 over total male pop., 1885	SLBW	-1.65	-1.74	0.95
21	log female pop. younger 14 over total female pop., 1875	SLBW	-1.75	-1.74	0.15
22	log female pop. younger 14 over total female pop., 1880	SLBW	-1.73	-1.71	0.17
23	log female pop. younger 14 over total female pop., 1885	SLBW	-1.63	-1.70	0.99
24	log pop. younger 14 over total pop., 1895	WSL98	-1.09	-1.08	0.12
25	log land, building, and business tax per capita, 1895	WSL98	1.37	1.39	0.36
26	log fire insurance building values per capita, 1895	WSL98	6.91	6.91	0.31
27	log fire insurance building values per building, 1895	WSL98	8.58	8.55	0.38
28	log pop. born in municipality per total pop., 1895	WSL98	-0.31	-0.27	0.18
29	log male pop. born in municipality per total male pop., 1895	WSL98	-0.28	-0.23	0.18
30	log fem. pop. born in municipality per total fem. pop., 1895	WSL98	-0.34	-0.31	0.18
31	share of farms below 5 hectars	WSL98	0.29	0.29	0.11
32	share of farms between 5 and 10 hectars	WSL98	0.17	0.16	0.09
33	share of farms between 10 and 50 hectars	WSL98	0.13	0.07	0.14
34	share of farms larger than 50 hectars	WSL98	0.00	0.00	0.01
35	growth in land area of municipality, 1895 to 1905	WSL98,WSL10	0.00	0.00	0.09

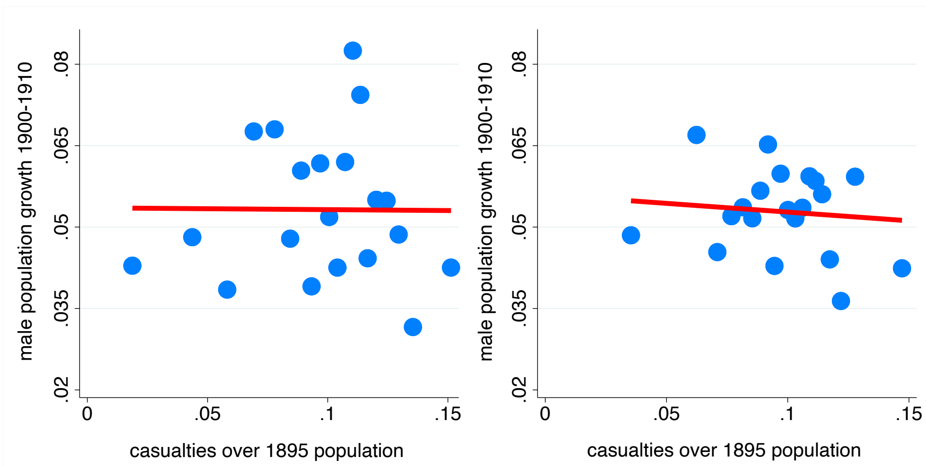
Notes: There are 1630 municipalities with all the data available. WSL98 and WSL10 stand for Württembergisches Statistisches Landesamt (1898) and (1910= [Statistical Agency of Württemberg]; SLBW stands for Statistisches Landesamt Baden-Württemberg (2008) [Statistical Agency of Baden-Württemberg]; VG stands for Verein für Computergenealogie [Association for Computer Genealogy].

Figure 1: Effect of WWI Casualties on 1910–1919 Male Population Growth



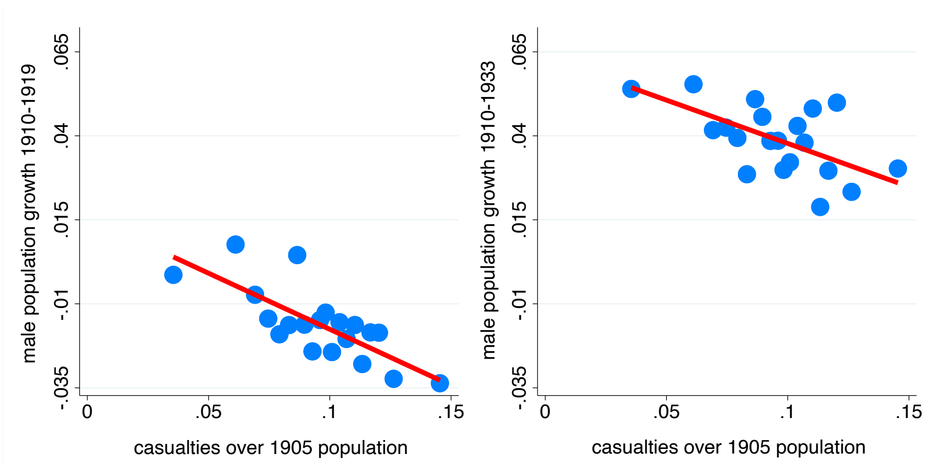
Notes: The left panel is a binscatter plot of the relationship between military World War I (WWI) casualties relative to 1905 population and male population growth 1910–1919 at the municipality level, controlling for log population in 1905. The right panel controls additionally for 39 pre-1910 municipality characteristics. These municipality characteristics include income from tax records; wages; labor-force participation; land tax revenues; building tax revenues; business tax revenues; insurance building values; number and size of non-farm businesses; size distribution of farms; population age distribution; and infant mortality. See Table 2 for a complete list. The two panels are on the same scale. The red lines are least-squares regression lines. For detailed regression results see Table 1.

Figure 2: Effect of WWI Casualties on 1900–1910 Male Population Growth



Notes: The left panel is a binscatter plot of the relationship between military World War I (WWI) casualties relative to 1895 population and male population growth 1900–1910 at the municipality level, controlling for log population in 1895. The right panel controls additionally for 33 pre-1900 municipality characteristics that are similar to the pre-1910 characteristics used as controls in Figure 1. See Table 4 for a complete list. The red lines are least-squares regression lines. For detailed regression results see Table 3.

Figure 3: Effect of WWI Casualties on 1910–1919 and 1910–1933 Male Population Growth



Notes: The left panel for male population growth 1910–1919 is identical to the right panel in Figure 1 except for a change in the scale of the vertical axis. The right panel repeats the analysis for male population growth 1910–1933. The two panels are on the same scale. The red lines are least-squares regression lines.

Figure 4A: Effect of WWI Casualties Relative to 1905 Population on Male Population Growth 1910–1919

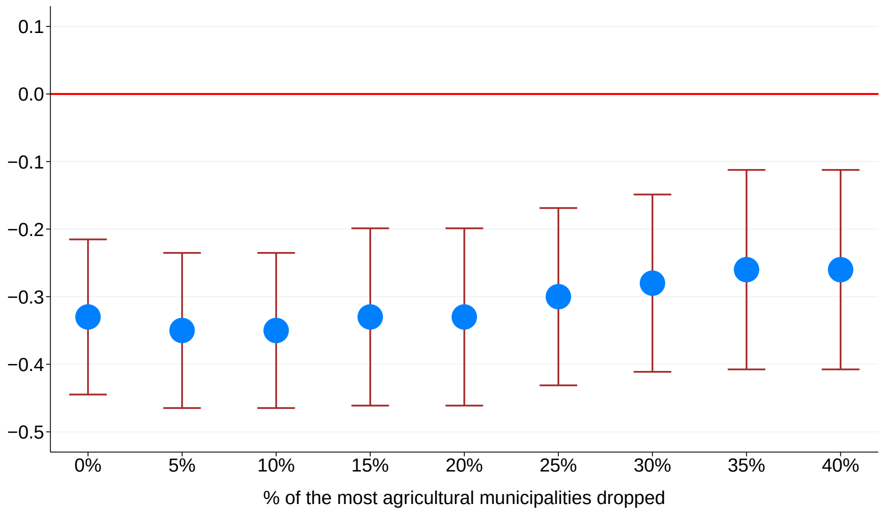
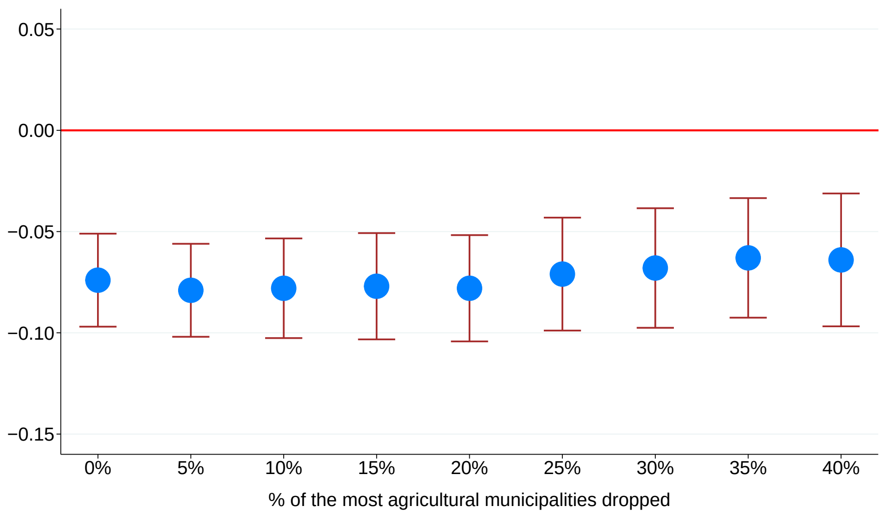


Figure 4B: Effect of WWI Casualties Relative to 1905 Households on Male Population Growth 1910–1919



Notes: World War I (WWI) casualties are measured either relative to population or the number of households in 1905. The figures show point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. The empirical analysis includes all the municipality controls in Table 1. There are 1634 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.

Figure 5A: Effect of WWI Casualties on Male Population Growth 1910–1933

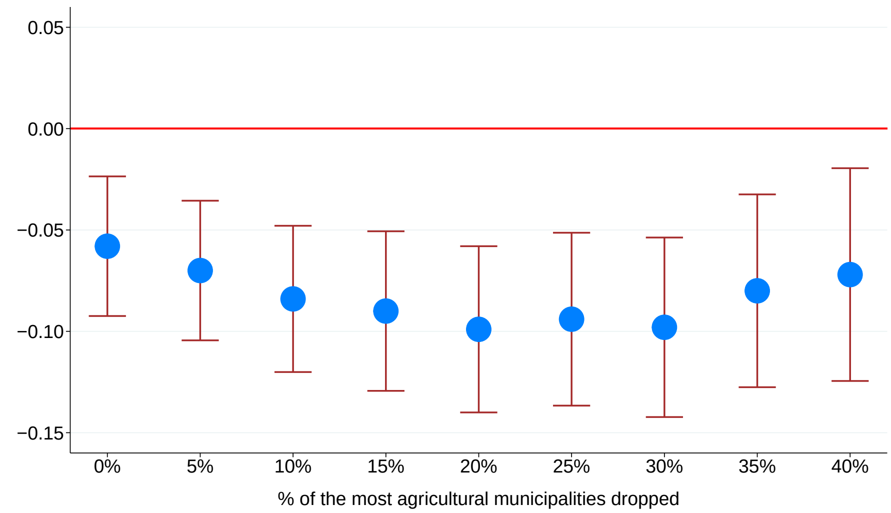
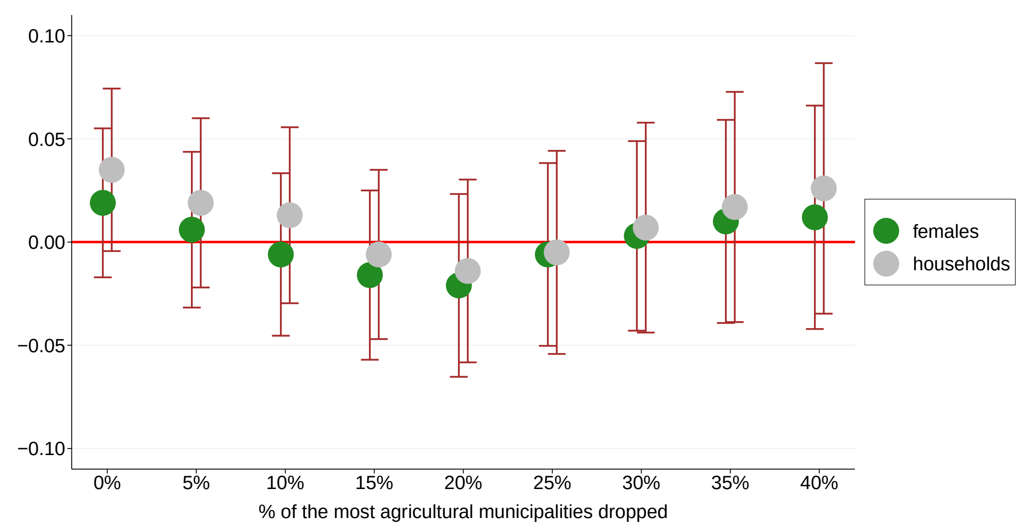
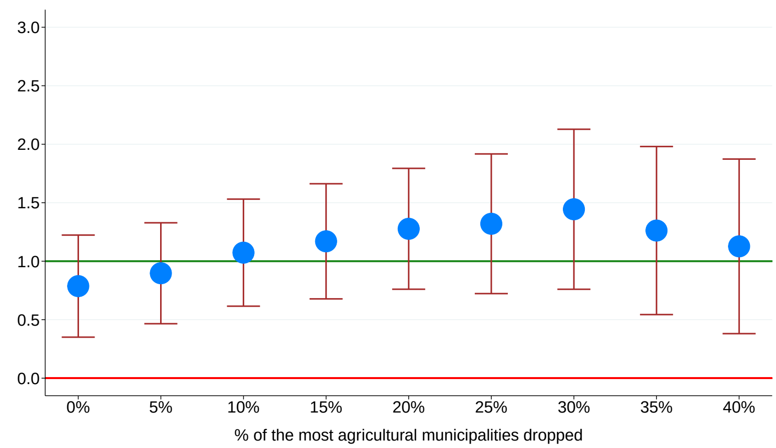


Figure 5B: Effect of WWI Casualties on Female Population Growth and Growth in the Number of Households 1910–1933



Notes: World War I (WWI) casualties are measured relative to the number of households in 1905. The figures show point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. The empirical analysis includes all the municipality controls in Table 1. There are 1634 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.

Figure 6: Persistence of the 1910–1919 Male Population Shock to 1933



Notes: The estimating equation is (5). The left-hand-side variable is male population growth between 1910 and 1933. The endogenous right-hand-side variable is male population growth between 1910 and 1919. The instrument is World War I (WWI) casualties relative to the 1905 number of households. The analysis includes all municipality controls in Table 1. The figure shows point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. There are 1634 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.

Figure 7A: Effect of WWI Casualties on Male Population Growth 1910–1939

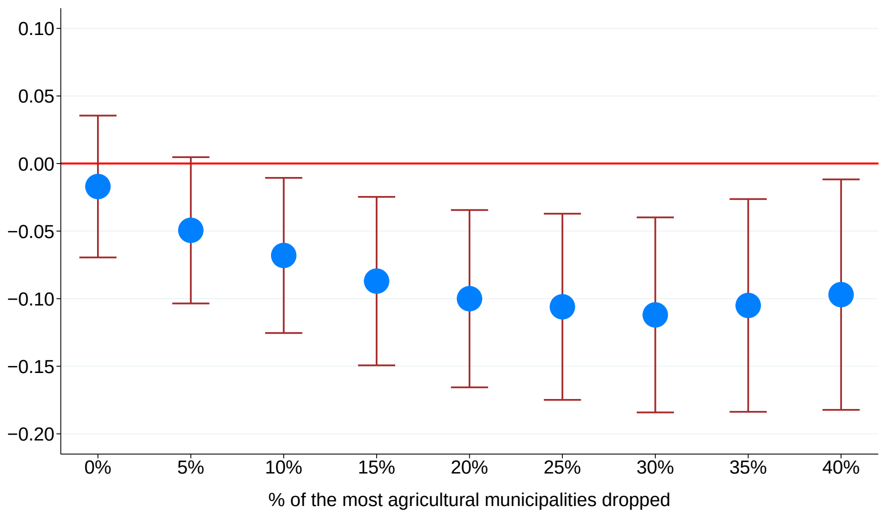
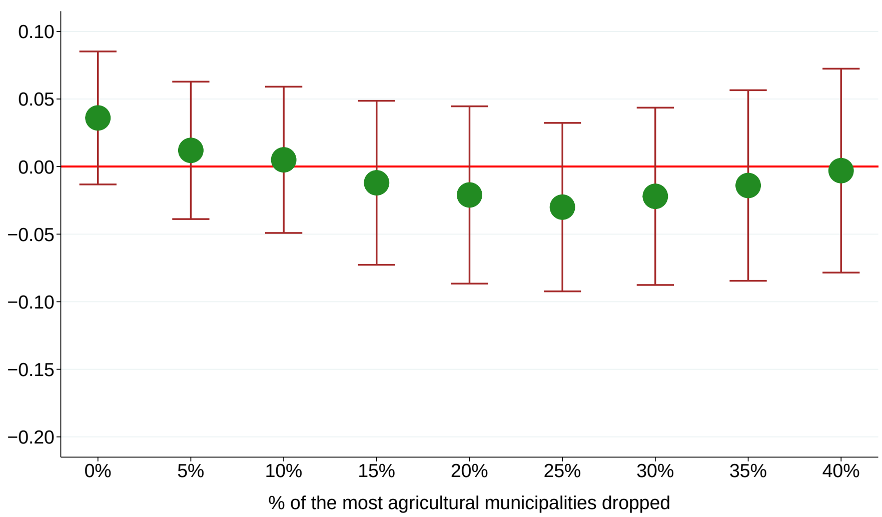


Figure 7B: Effect of WWI Casualties on Female Population Growth 1910–1939



Notes: World War I (WWI) casualties are measured relative to the number of households in 1905. The figures show point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. The empirical analysis includes all the municipality controls in Table 1. There are 1558 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.

Figure 8A: Effect of WWI Casualties on Male and Female Population Growth 1910–1950

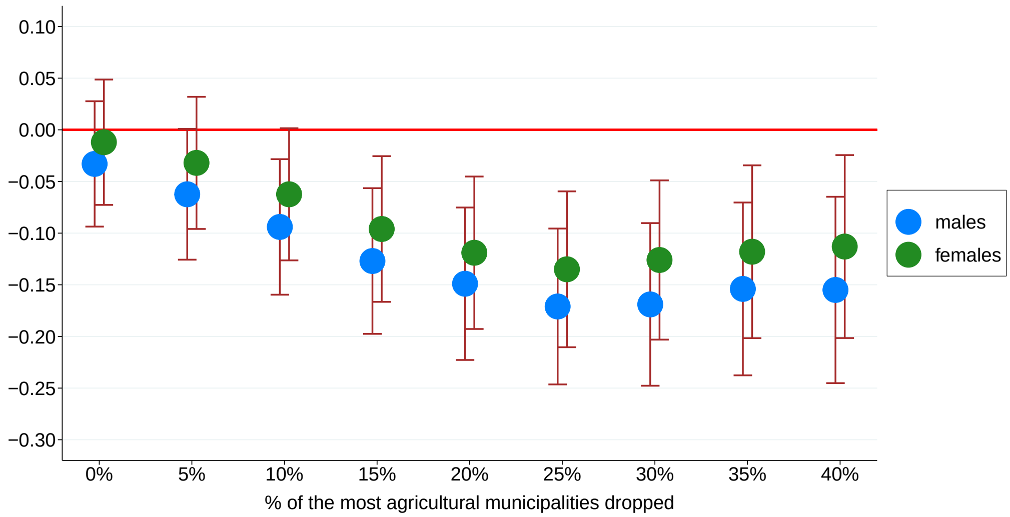
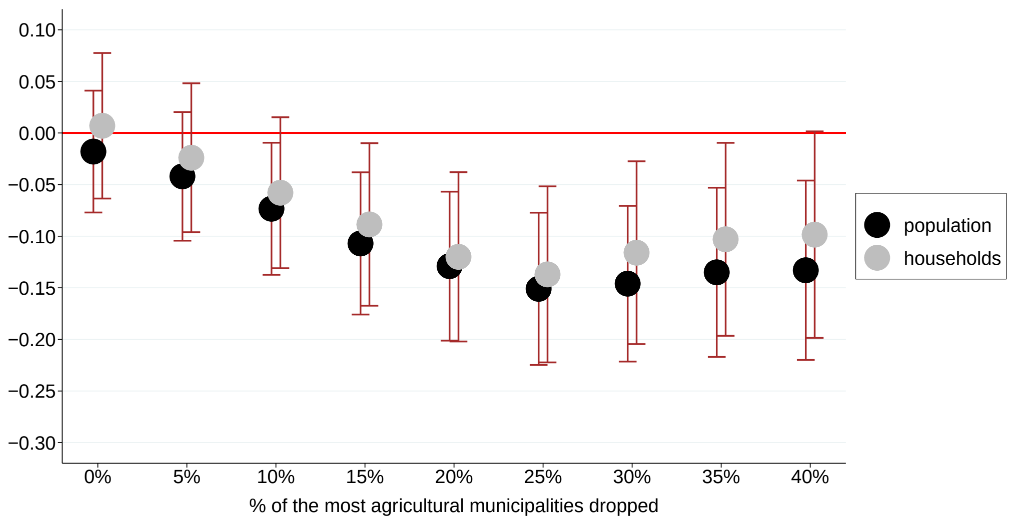


Figure 8B: Effect of WWI Casualties on Total Population Growth and Growth in the Number of Households 1910–1950



Notes: World War I (WWI) casualties are measured relative to the number of households in 1905. The figures show point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. The empirical analysis includes all the municipality controls in Table 1. There are 1558 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.

Figure 9A: Effect of WWI Casualties on Male and Female Population Growth 1910–1960

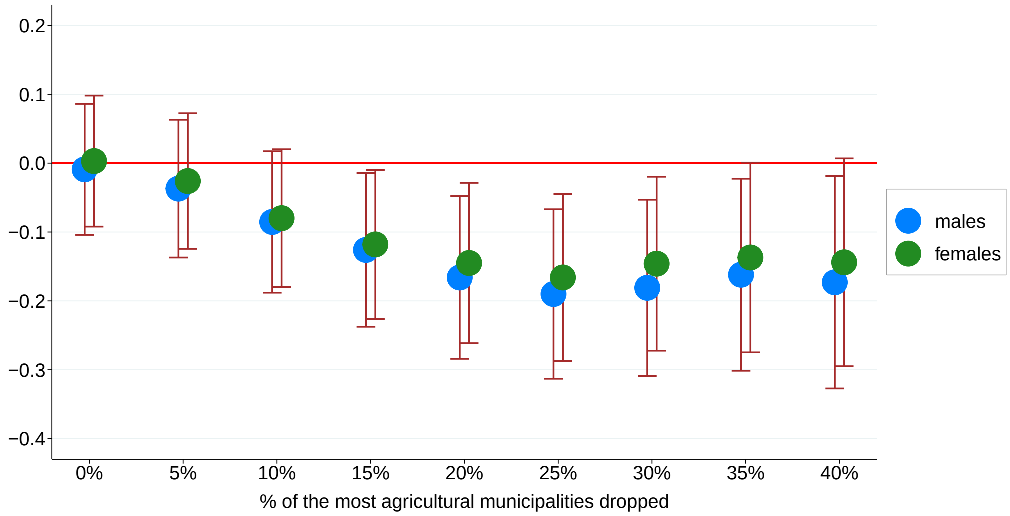
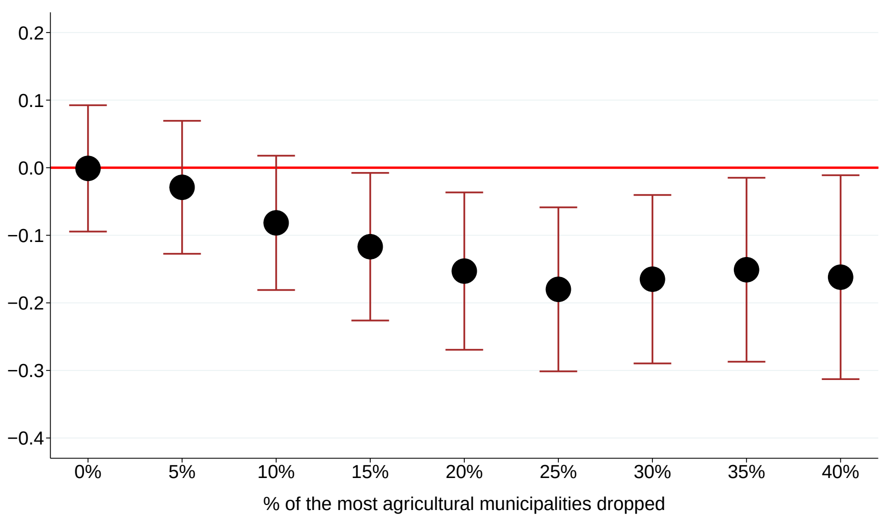


Figure 9B: Effect of WWI Casualties on Total Population Growth 1910–1960



Notes: World War I (WWI) casualties are measured relative to the number of households in 1905. The figures show point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. The empirical analysis includes all the municipality controls in Table 1. There are 1554 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.

Figure 10A: Effect of WWI Casualties on Male and Female Population Growth 1910–1970

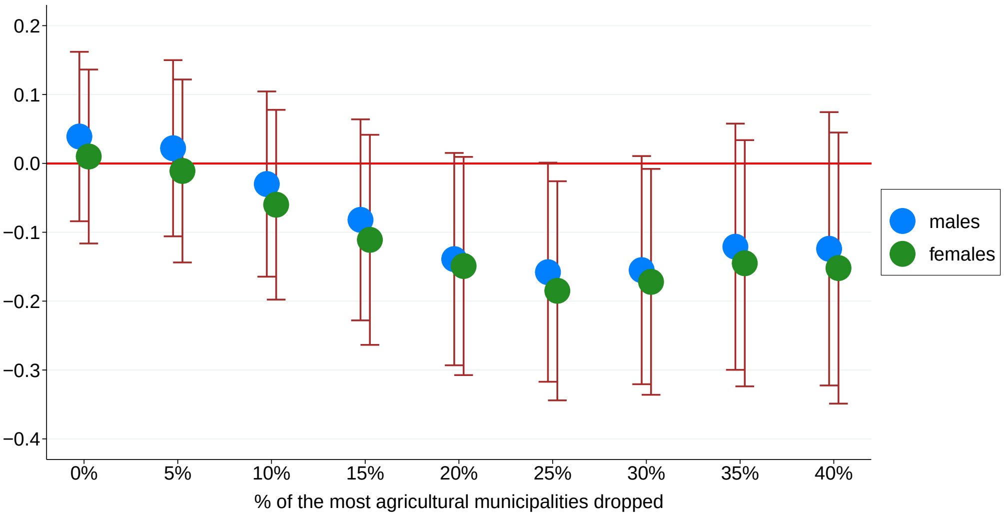
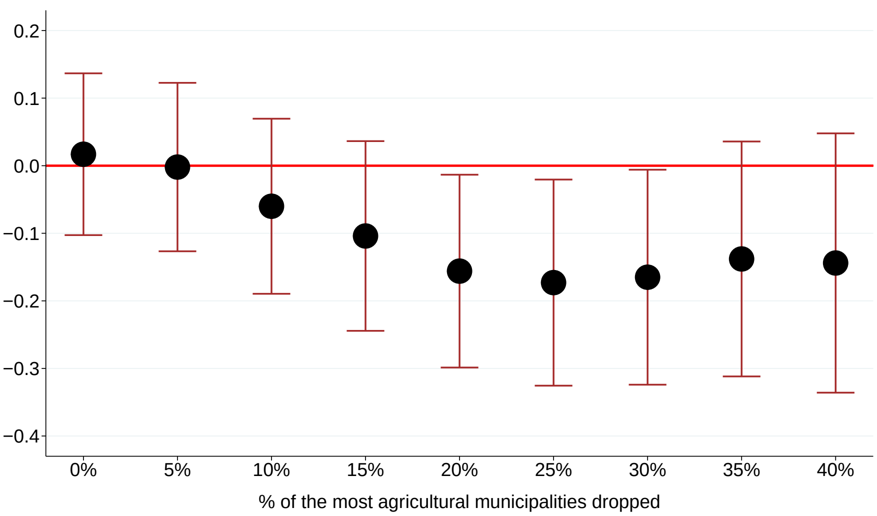


Figure 10B: Effect of WWI Casualties on Total Population Growth 1910–1970



Notes: World War I (WWI) casualties are measured relative to the number of households in 1905. The figures show point estimates and 90-percent confidence intervals when the x-percent most agricultural municipalities are excluded from the analysis. 90-percent confidence intervals are based on robust standard errors. The empirical analysis includes all the municipality controls in Table 1. There are 1538 municipalities in the full sample. Municipalities are considered to be more agricultural if they have more agricultural land per capita in 1905.