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Abstract

During World War I (1914–1918) the birth rates of countries such as France, Germany, the U.K., Belgium and Italy fell by almost 50%. In France, where the population was 40 millions in 1914, the deficit of births is estimated at 1.4 millions over 4 years while military losses are estimated at 1.4 millions too. Thus, the fertility decline doubled the demographic impact of the war. Why did fertility decline so much? The conventional wisdom is that fertility fell below its optimal level because of the absence of men gone to war. I challenge this view using the case of France. I construct a model of optimal fertility choice where a household in its childbearing years during the war faces three shocks: (i) an increased probability that its wife remains alone after the war; (ii) a partially-compensated loss of its husband's income; and (iii) a decline in labor productivity. I calibrate the model's parameters to the time series of fertility before the war and use military casualties and income data to calibrate the shocks representing the war. The model over-predicts the fertility decline by 10% even though it does not feature any physical separations of couples. It also over-predicts the increase in fertility after the war, and generates a temporary increase in the age at birth as observed in the French data.

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1 Introduction

The First World War lasted four years, from 1914 to 1918, and ravaged European countries to an extent that had never been seen until then. During the war, the birth rates of countries such as France, Germany, Belgium the United Kingdom or Italy declined by about 50% –see Figure 1. In France, an estimated 1.4 million children were not born because of this decline. This figure amounts to 3.5% of the total French population in 1914 (40 millions), and is comparable to the military losses which are estimated at 1.4 million men.[1] In short, the fertility decline doubled the already large demographic impact of the war.

Although the analysis that I present is about France during the First World War, neither France nor World War I are unique cases. As is clear from Figure 1 other belligerents of the war experienced the same fate as France. In Germany, for instance, the deficit of births was about 3.2 million, noticeably exceeding the 2 million military casualties. Furthermore, there is evidence, presented by Caldwell (2004), that fertility declined in many countries during various episodes of wars, civil wars, revolutions and dictatorships –see Table 1. The conclusions that I reach in this analysis can be extended, at least qualitatively, to these episodes.

What prompted fertility to decline by such magnitude during the First World War? The conventional wisdom is that the main cause of the fertility decline was the absence of men.[2] In this paper I challenge this view, and propose an alternative quantitative theory of the collapse of fertility. I develop a model of fertility choice where a household in its childbearing years during World War I faces three unanticipated shocks: (i) an increase in the probability that its wife remains alone after the war; (ii) a partially-compensated loss of its husband's income because of the mobilization; and (iii) a decline in productivity. I calibrate these shocks to be consistent with French data and find that the model predicts a strong decline in fertility: 10% more pronounced than in the data, even though it does not feature any physical separations of couples. The model also over-predicts the post-war fertility increase by 31% and generates, as observed in the data, a temporary rise in the age at birth after the war, due to the postponement of fertility by generations affected by the war.

The unit of analysis is a finitely-lived household which, at the beginning of age 1, is made of two adults: a husband and a wife. The household derives utility from consumption as well

[1] See Huber (1931, p. 413). Military losses include people killed and missing in action. They are a lower bound on the death toll of the war since they do not include civilian losses.

[2] See, for example Huber (1931), Vincent (1946) and Festy (1984).

as from the number of children and adults it comprises. It can give birth to children at age 1 and 2, but children are costly to raise. They require time, goods, and a share of household consumption for an exogenously given number periods after they are born. A husband supplies his time inelastically to the market in exchange for a wage, while a wife splits her time between the market, where she faces a lower wage than a husband, and raising children. From age 2 onward the number of adults follows one of two possible regimes. In peacetime it remains constant. During a war there is a positive probability that it decreases to one, i.e., that the wife remains alone in the household. The war is unanticipated, but once it breaks out there is a positive probability that it goes on for another period.

In this setup the war affects fertility as follows. First, it raises the marginal cost of a child. This is because the three shocks associated with the war lead to a reduction of consumption since, together, they imply a drop in contemporaneous and expected income, as well as an increase in income risk. The corresponding increase in the marginal utility of consumption raises the cost of diverting resources away from consumption and toward raising children. Second, the war reduces the marginal benefit of a child. This is because the expected marginal benefit of a child is lower when the expected number of adults in the household decreases. These two effects yield the decline in fertility during the war. In addition the war induces an age-1 household to postpone giving birth until later in life. This is because when the war prompts a household to reduce its fertility at age 1, its stock of children is abnormally low at the beginning of age 2, hence the marginal utility of a birth at age 2 is large. This effect is magnified if the war is over once the household reaches age 2. This mechanism yields the fertility catch-up observed after the war.

I adopt the following quantitative strategy. I calibrate the model's parameters to fit the time series of the French fertility rate from 1800 until the eve of World War I. Specifically, I minimize a distance between actual and computed fertility for generations of households who entered their fertile years before the war broke out. In this exercise I assume that peace prevails and that wages grow exogenously at a rate calibrated to be consistent with French data. I use the time series of fertility because it contains relevant information to discipline the parameters that determine the effect of the war. This is because to fit the downward trend of fertility in the data, preference parameters must be such that the income effect of rising wages on fertility is dominated by the substitution effect. Since the war is itself a combination of contemporaneous and expected income shocks, the discipline imposed by the time series on the size of the income effect is relevant for assessing the impact of the war. Using the calibrated parameters I then compute the optimal choices of generations exposed to an unanticipated war. To quantify the three shocks implied by the war I use three statistics. First, I use the military casualties relative to the number of men mobilized to calibrate the probability that a wife remains alone after the war. Second, I use income data to calibrate the proportion of uncompensated income loss by mobilized husbands. Third, I use data on output per worker to calibrate the reduction in wages that occurred during the war.

This paper contributes to a literature analyzing the consequences of the First World War on various aspect of the French population. Henry (1966) discusses the consequences of the war for the marriage market and, more recently, Abramitzky et al. (2011) also study the marriage market to evaluate the impact of the war on assortative matching. The closest studies are by Festy (1984) and Caldwell (2004). Festy (1984) offers a detailed description of the decline of fertility during the war. He concludes that it resulted from households being unable to achieve their desired fertility because men were physically away, rather than from a change in the desired level of fertility.[3] I challenge this view for three reasons. First the number of births in the early 1920s in France was above its pre-war level even though 1.4 million men did not come back from the War. This would not be possible if the absence of men was the sole reason for the collapse of fertility. Second, 30 to 50 percent of mobilized men were in the rear, in contact with the civilian population. Third, men at the front did not stay there for 4 years. Leave policies became more systematic and generous after the first year of the war. I develop these points in Section 2. Caldwell (2004) examines thirteen social crises, ranging from the English Civil War in the 17th century to the fall of communism. He documents noticeable falls in fertility in each cases, and concludes that they were mostly temporary adjustments to the uncertainty of the time. His results are consistent with the analysis that I carry out in this paper.

More generally, this paper is related to an already large literature focusing on the determinants of fertility across countries and over time. Seminal work was done by Barro and Becker (1988) and Barro and Becker (1989). Other authors have explored various aspects of fertility choices. Galor and Weil (2000) analyze the $\cap$-shaped pattern of fertility over the long-run. Greenwood et al. (2005) propose of theory of the baby boom in the United States. Jones et al. (2008) review alternative theories explaining the negative relationship between income and fertility across countries and over time. Albanesi and Olivetti

[3] "La chute de la natalité pendant les hostilités peut donc être vue, par différence, comme une conséquence 'mécanique' de l'impossibilité de s'unir pour procréer, plutôt que comme une volonté délibérée d'éviter d'avoir des enfants dans une période aussi troublée." (Festy, 1984, page 1003).

(2010) evaluate the effects of technological improvements in maternal health. Jones and Schoonbroodt (2011) theorize endogenous fertility cycles. Manuelli and Seshadri (2009) ask why do fertility rates vary so much across countries? And Bar and Leukhina (2010) investigate, simultaneously, the demographic transition and the industrial revolution. The paper is also related to the literature investing various consequences of wars and economic disasters. For instance, Barro (2006), Barro and Ursúa (2008) and Barro and Jin (2011) analyze economic disasters, including wars, and their impact on financial markets. The effect of a war on fertility is explored, in the case of World War II and the U.S. baby boom, by Doepke et al. (2007). Ohanian and McGrattan (2008) is an example where economic theory is used to investigate the effect of the fiscal shock that World War II represented for the U.S. economy. Finally, the paper relates to the literature focusing on the importance of labor market risk as a determinant of fertility, e.g. Da Rocha and Fuster (2006) and Sommer (2009).

In the next Section I present statistics relative to the number of births and deaths during the war as well as to the composition of the Army. I also discuss relevant facts pertaining to the marriage market and the situation of women during the war. I develop my model and discuss the determinants of optimal fertility in Section 3. I present the quantitative analysis and the results in Section 4. In Section 5 I show that the analysis done in the context of my model carries over to a setup where the quality-quantity tradeoff is key for the determination of fertility. I conclude in Section 6.

2 Facts

Some data are from the French census. The last census before the war was in 1911. The first census in the post-war era was in 1921. A census was scheduled in 1916 but was cancelled. This data, and the data from previous censuses, were systematically organized in the 1980s and made available from the Inter-University Consortium for Political and Social Research (ICPSR). It is also available from the French National Institute for Statistics and Economic Studies (Insee). Vital statistics are available during the war years for the 77 regions (départements) not occupied by the Germans. There was a total of 87 regions in France at the beginning of the war. Huber (1931) provides a wealth of data on the french population before, during and after the war. It also contains a useful set of income-related data.

2.1 Births and Deaths

The first month of World War I was August 1914, but the first severe reduction in the number of live births occurred nine months later: it dropped from 46,450 in April 1915 to 29,042 in May –a 37% decline.[4] During the course of the war the minimum was attained in November 1915 when 21,047 live births were registered. The pre-war level of births was reached again in December 1919. To put these numbers in perspective consider Figure 2, which shows the number of births per month in France and Germany from January 1906 until December 1921, as well as trend lines estimated using pre-war data. For France, the difference between the actual number of births and the trend, summed between May 1915 (9 months after the declaration of war) and August 1919 (9 months after the armistice), yields an estimated 1.4 million children not born. This figure amounts to 3.5% of the French population in 1914 (40 million) and is comparable to the military losses of the war: 1.4 million. The estimate for Germany is 3.2 million children not born. It amounts to 5% of the German population in 1911 (65 million) and exceeds the number of military deaths estimated at 2 million.[5] In short, the fertility reduction that occurred during World War I doubled the demographic impact of the war. Similar calculations, made by demographers, lead to comparable figures: Vincent (1946, p. 431) reports a deficit of 1.6 million French births and Festy (1984, p. 979) reports 1.4 million.[6]

The birth rate of Figure 1 and the number of births of Figure 2 measure contemporaneous changes in fertility. They are silent about the longer-term effect of the war: did the couples that reduced their fertility during the war only postponed births? To answer this question Figure 3 shows two standard measures of lifetime fertility, the Total Fertility rate and completed fertility. Completed fertility is of particular interest since it is a measure of realized lifetime fertility, namely the number of children born to a woman of a particular (synthetic) cohort throughout her fertile life. Figure 3 shows that the women who reached their twenties during the First World War gave birth, throughout their lives, to less children than the generations that preceded or followed them. Thus, even though there is evidence, discussed later, that these women postponed their fertility until after the war was over, they did not fully compensate the forgone births of the war. If they had, their completed fertility would have remained unaffected by the war since one less child today would be made up

[4] See Bunle (1954, Table XI, p. 309).

[5] See Huber (1931, pp. 7 and 449).

[6] Another statistic of interest can be computed with the trend lines of Figure 2. The realized number of births between May 1915 and August 1919 was 52% of the expected number in France, and 57% in Germany.

for by one more child later on.

At this stage, it is worth observing on Figure 2 that, early after the war, the number of births is not only above trend but that it is also higher than its pre-war level. This is true for both France and Germany and occurred despite the military casualties. If the physical absence of men was the sole reason for the decline in births at the outset of the war, then births could not be has high in the immediate aftermath of the war, when fewer men came back than initially left. Only if fertility behavior changed can Figure 2 be rationalized, and my analysis is precisely about understanding the effect of the war on optimal fertility behavior.[7]

The demographic consequences of the fertility decline in France was large and persistent. Consider Figure 4 which shows the age and sex structure of the population before the war, in 1910, and after the war, in 1930, 1950 and 1970. The differences between the pre- and post-war population structures are quite noticeable. The first effects of the war are visible in the 1930 panel. First, there is a deficit of men (relative to women) in the 30-50 age group. These are the men that fought during World War I and died. Second, there is a deficit of men and women in the teens. This is the generation that should have been born during the war but was not because of the fertility decline. The 1950 panel shows again the same phenomenon 20 years later. The men who died at war should have been in the 50-70 age group, and the generation not born during the war should have been in its thirties. Note also the deficit of births that occurred in the early 1940s, that is during World War II. What caused this? It could have been that, as during World War I, fertility declined. For the French, however, the impact of World War II was quite different than that of World War I, possibly because the fighting did not last as long. In fact, the birth rate in the 1940s shows a noticeable increase.[8] Thus, births were low in the 1940s because the generation that was in its childbearing period at that moment, e.g. of age 25 in 1940, was born in and around World War I. This generation was unusually small, so it gave birth to unusually little children despite a high birth rate. Thus, the deficit of births during World War I lead, mechanically, to another deficit 25 years because of a reduction in the size of the fertile population. The 1970 panel shows that, as late as in the seventies, the demographic impact of World War I is still quite noticeable. The generation that should have been born during

[7] Huber (1931, p. 521) reports a net migration of 330,000 workers between 1919 and 1920, so the deficit of french men was not compensated by an inflow of immigrants.

[8] One can argue that the baby boom was already under way in the early 1940s in France. Greenwood et al. (2005) propose of theory of the baby boom based on technical progress in the household that is consistent with this view.

the war should, by then, have reached its fifties.

Figure 5 shows the age and sex structure of the populations of Germany, Belgium, Italy as well as Europe as a whole and the United States in 1950. All European countries exhibit a deficit of births during the war which, as is the case for France, is still noticeable in the 1950 population. The United States, on the contrary, were not noticeably affected by the World War I. The United Kingdom appears to have experienced a reduced deficit of births during World War I compared with other European countries. Europe as a whole exhibits a noticeable deficit.

2.2 The Army

The mobilization was massive. A total of 8.5 million men served in the French army over the course of the war, while the size of the 20-50 male population is estimated at 8.7 million on January 1st 1914. Thus, almost all men served at some point during the war. In the model of Section 3 and the experiment of Section 4, I use this observation to justify the assumption that all men serve when the war breaks out. The vast majority of soldiers were mobilized, that is they were called to serve and had to report to military centers of incorporation. Huber (1931, p. 94) reports that a small, albeit not negligible, number of men (229,000 men) volunteered into the army between 1914 and 1919. Those men choose to serve even though, at the time they did, they were not compelled to do so by law. On August 1st 1914, the day of the mobilization, the army counted already 1 million men. The remaining 7.5 million were incorporated throughout the four years of the war.[9] Throughout the war the army regularly reviewed cases of men exempted from military duty for whatever reasons, and called large proportions of them to serve.

A commonly proposed explanation for the fertility decline is that soldiers were physically away and, therefore, unable to have children. The size of the decline in fertility was, in this view, a reflection of the size of the mobilization. Not all the men serving in the army were sent to the front, though. On July 1st, 1915, there were 5 million men in the army but 2.3 million of them served in the rear. These men were serving in factories, public administrations and in the fields to help with the production of food for the troops and the population.[10] Between August 1914 and November 1918, the fraction of men in the army actually serving in the rear remained between 30 and 50%. The men in the rear were in

[9] See Huber (1931, p. 89).

[10] See Huber (1931, p. 105).

touch with the civilian population and, therefore, were more likely to have the opportunities to procreate than the men at the front.

The combat troops did not spent all their time at the front either. Leaves were generalized in June 1915. Starting in October 1916 soldiers at the front were granted 7 days of leave every 4 months, not including the time needed to travel back to their families. These leaves could also be augmented at the discretion of one's superior officer. Later in the war leaves were increased to 10 days. These leaves augmented the physical opportunities to have children.

2.3 Women

Figure 6 shows evidence that the women reaching their childbearing years during World War I postponed their childbearing decisions. This observation is important to understand the behavior of fertility after the war. Fertility was above trend in the immediate aftermath of the war in part because the generations that could have given birth during the war did so after, together with the younger post-war generations. In the model of Section 3 households are allowed to choose how many children to have in 2 periods of their lives to allow this mechanism to operate and assess its importance for the post-war recovery of fertility. As mentioned in Section 2.1, however, this catch-up effect after the war, that is the above-trend fertility of older generations, was not enough to compensate for the lost births of the war. This is why the completed fertility of the generations reaching their twenties during the war was less than that of other generations –see Figure 3.

Henry (1966) shows that the marriage market was noticeably perturbed for the generations reaching their marriage and childbearing years during World War I. Women born in 1891-1895 (aged 21 in 1914) either got married before or after the war. After the war the marriage rate of this generation was abnormally high relative to other generations at the same age: a sign of "recuperation" of postponed marriages. A similar result holds true for the generation of women born in 1896-1900. The post-1918 marriages were characterized by a shift in the age structure of marriages: women married men of their age or younger more than they usually did, because the men they would have normally married were dead. Interestingly, Henry (1966) reports that the proportion of single women, at the age of 50, for the 1891-1895 generation is 12.5%, and that for the 1896-1900 generation it is 11.9%. These figures compare with similar figures for generations whose marriage decisions were not affected by the war such as the 1851-1855 generation: 11.2%, or the 1856-1860 generation: 11.3%. At this stage, two observations are worth making. First, although ex-post (that is at the age of 50) the women from the 1891-1895 and 1896-1900 generations achieved the same marriage rate as the women from other generations, from the perspective of 1914, when they had to decide whether to get married and have children, the probability of keeping (or replacing) a husband must have appeared quite different to them than to the previous generations at the same age. Second, the disruption in the marriage market does not imply that births should be affected. Although it is common, it is not necessary to be married to have children. Figure 7 shows that the proportion of out-of-wedlock births increased significantly during the war. Thus it seems reasonable, as a first approximation, to study fertility choices while abstracting from the marriage market.

Little information is available on female labor during the war. There was no exhaustive census available. Some were planned during the course of the war but ended up being cancelled. Robert (2005) reports that the best information available is from seven surveys conducted by work inspectors. These surveys did not cover all branches of the economy such as railways and state-owned firms. However, data are available for 40,000 to 50,000 establishments in food, chemicals, textile, book production, clothing, leather, wood, building, metalwork, transport and commerce. These establishments employed about 1.5 million workers before the war: about a quarter of the labor force in industry and commerce. Robert (2005, Table 9.1) reports the total number employed and the number of women employed in the establishments surveyed. Although this is not the participation rate *per se* it gives a picture of female labor during the war. The share of women worker was 30% in July 1914 and peaked in January 1915 at 38.2%. It then declined slowly throughout the war and during the following years. It was 32% in July 1920. Downs (1995) and Schweitzer (2002) emphasize that the increase in women's participation during the war is moderated by the fact that most, that is between 80 and 95%, of the women who worked during the war also worked in more feminized sectors before the war. Downs (1995, page 48) writes

> In the popular imagination, working women had stepped from domestic obscurity to the center of production, and into the most traditionally male of industries. In truth, the war brought thousands of women from the obscurity of ill-paid and ill-regulated works as domestic servant, weavers and dressmakers into the brief limelight of weapons production.

In the model of Section 3 a woman's labor is exogenous which, in light of the evidence just presented, is a reasonable abstraction.

3 The Model

3.1 The Environment

Time is discrete. The economy is populated by overlapping generations of individuals living for $I + J$ periods: I as a child and J as an adult. When an individual becomes adult it leaves the household in which it was born, and pairs with another adult of the same age and the opposite sex to form a new household of age 1. The household formation process is exogenous. Only households make decisions.

There are two sources of uncertainty. At the aggregate level the economy evolves through periods of war and peace, and at the household level the number of adults is also a random variable whose probability distribution depends upon the aggregate state of the economy, i.e., whether it is peace or war. Let $\omega_t \in \Omega = \{\text{war}, \text{peace}\}$ be a random variable describing whether the economy is in a state of war or peace. At date t the current state ω_t is realized before any decisions are made. The households' perception, at date t, of the likelihood of war or peace at $t + 1$ is summarized by the probability distribution $q_t(\omega')$:

$$q_t(\omega') = \Pr\left(\{\omega_{t+1} = \omega'\}\right).$$

Let $m_j \in M = \{1, 2\}$ denote the number of adult(s) in an age-j household. Assume that m_j is realized at the beginning of the period, before any decisions are made, and that it is described by a Markov chain with a transition function depending upon whether the economy is in a state of peace or war:

$$p_\omega(m'|m) = \Pr\left(\{m_{j+1} = m'\}|\{m_j = m\}\right),$$

and initial condition $m_1 = 2$ since all households are formed with two adults. Assume that during peacetime the number of adults is constant so that

$$p_{\text{peace}}(m'|m) = \mathbb{I}(\{m' = m\})$$

while during a war there is a non-zero probability that a wife remains alone in the next period:

$$p_{\text{war}}(1|2) > 0.$$

The exact value of $p_{\text{war}}(1|2)$ is determined in Section 4.2. Since households are formed with two members and remain as such during peacetime there are no one-adult households when the war breaks out. Assume that $p_\omega(1|1) = 1$, i.e., a wife does not remarry once she is alone. One can interpret $p_{\text{war}}(1|2)$ as the probability that a husband dies during the war and his wife does not remarry. Therefore, the probability $p_{\text{war}}(2|2)$ is either that of a husband surviving the war or dying but his wife re-marrying.

A household is fecund twice during its life, at age 1 and 2. That is, it chooses how many children to give birth to only at age 1 and 2, and only if there are two adults. The number of children born to an age-j ($j = 1, 2$) household is denoted b_j. They remain present until the household reaches age $I + j - 1$. The stock of children present in an age-j household, denoted by n_j, is

$$n_j = b_1 \mathbb{I}\{1 \leq j \leq I\} + b_2 \mathbb{I}\{2 \leq j \leq I + 1\}. \tag{1}$$

A household's preferences are represented by

$$E\left\{\sum_{j=1}^{J} \beta^{j-1} \tilde{U}\left(c_j, n_j, m_j\right)\right\}$$

where

$$\tilde{U}(c, n, m) = U\left(\frac{c}{\phi(n, m)}\right) + \theta V(n, m)$$

and E is the expectation operator. The parameter $\beta \in (0, 1)$ is the subjective discount factor, c_j is total household consumption at age j and $\phi(n, m)$ is an adult-equivalent scale. The parameter θ is positive. Assume the following functional form:

$$U(x) = \frac{x^{1-\sigma}}{1-\sigma} \quad \text{and} \quad V(n, m) = (n^\rho + m^\rho)^{1/\rho}$$

with $\sigma > 0$ and $\rho \leq 1$.

At this stage a few observations are in order. First, a household values consumption per (adult equivalent) member and not total consumption. Thus, one of the costs of having a child is a reduction of consumption per (adult equivalent) member. Note also that the introduction of the adult-equivalent scale affects the way the marginal cost of a child changes when the number of adult decreases. To understand this, remember that the marginal utility of consumption measures the cost of diverting resources away from consumption and into childrearing. Suppose now that an adult disappears. Then, total consumption decreases and if a household valued total consumption the marginal cost of a child would increase by a magnitude dictated by the slope of U. Since instead a household values consumption per (adult equivalent) member, this effect is mitigated by the fact that the decrease of total consumption *together* with a decrease of the number of adults implies less of a reduction of the consumption per (adult equivalent) member and, therefore, less of an increase in the marginal cost of a child. Second, children of the same age (born in the same period) and of different age (born in different periods) are perfect substitutes in utility. This assumption is made for simplicity. Third, the parameter ρ controls the marginal utility of a child when the number of adult is constant, as I assume it is in the pre-war period. It also controls the substitutability between children and adults when the number of adults becomes variable, as I assume it is in war times. Fourth, the number of adults acts as a preference shock through two channels: (i) a decrease of the number of adults directly affects utility and, in particular, it reduces the marginal utility of children through V; (ii) a decrease of the number of adults implies an increase in consumption per (adult equivalent) member, holding everything else constant. Beside the effect of m on preferences, a decrease of the number of adults also acts as an income shock as will transpire in the description of a household's income.

Adults are endowed with one unit of productive time per period. A husband supplies his time inelastically while a wife allocates hers between raising children and working. A child requires τ units of a wife's time and e units of the consumption good for each period during which it is present in the household. The parameter τ represents the state of the "childrearing" technology and, therefore, is not a control variable. Thus, a wife's time allocation is indirectly controlled through the number of children she gives birth to. The wage rate for a husband is denoted by w_t^m and is assumed to grow at the constant (gross) rate $g > 1$ per period: $w_{t+1}^m = g w_t^m$. Similarly, the wage rate for a wife is denoted w_t^f and is assumed to grow at rate g too. It is convenient to define the function

$$L_t(m, \omega) = \begin{cases} w_t^f + w_t^m(1 - \delta_\omega) & \text{when } m = 2 \\ w_t^f & \text{when } m = 1 \end{cases}$$

as the "potential" labor income of a household, i.e., the labor income it would receive if no time was devoted to raising children. Note that when there is one adult in the household it is assumed to be the wife. When there are two adults but there is a war the husband's income is reduced by a fraction $\delta_{\text{war}} \in (0, 1)$. Thus, $1 - \delta_{\text{war}}$ measures the compensation received from the government during a war, when the husband is mobilized and cannot perform his regular job. In the case where $\delta_{\text{war}} = 1$ there is no compensation and the husband's income is totally lost to the household. If $\delta_{\text{war}} = 0$ the husband's income loss is totally compensated. Let $\delta_{\text{peace}} = 0$. A household has access to a one-period, risk-free bond with (gross) rate of interest $1/\beta$. It can freely borrow and lend any amount at this rate. It owns no assets at the beginning of age 1.

3.2 Optimization

At date t an age-1 household is made of 2 adults. It has no assets and no children. It decides to consume (c) save (a') and how many children to give birth to (b_1). Its value function writes

$$W_{1,t}(\omega) \quad = \quad \max_{c,b_1,a'} \quad \tilde{U}(c, b_1, 2) \; + \; \beta \sum_{m' \in M} \sum_{\omega' \in \Omega} W_{2,t+1}\left(a', b_1, m', \omega'\right) p_\omega(m'|2) q_t(\omega') \tag{2}$$

subject to

$$c + a' + b_1 \left(e + \tau w_t^f\right) = L_t(2, \omega) \tag{3}$$

The only relevant state variable for a household, beside time, is the aggregate state of the economy, ω.[11] The right-hand side of the budget constraint (3) shows the "potential" labor income of a household. The time cost of raising b_1 children appears as an expenditure on the left-hand side: $\tau w_t^f b_1$. Thus, the effective labor income is $L_t(2,\omega) - \tau b_1 w_t^f$. The function $W_{2,t+1}(a', b_1, m', \omega')$ is the value function of a household of age 2 with a' assets accumulated, b_1 children born at age 1, m' surviving adults, and facing the aggregate state ω'. Note that at age 1 the number of children born and the number of children present in the household are the same since $n_1 = b_1$, as per Equation (1). Note, finally, that b_1 is a relevant state variable for an age 2 household whenever $I \geq 2$, as assumed.

An age-2 household at date t learns its number of adults, m, and the aggregate state of the economy, ω, and decides to consume (c) save (a') and how many children to give birth to (b_2). Its optimization problem writes

$$\begin{aligned} W_{2,t}\left(a, b_1, m, \omega\right) = \max_{c,b_2,a'} \; & \tilde{U}(c, b_1 + b_2, m) \\ & + \beta \sum_{m' \in M} \sum_{\omega' \in \Omega} W_{3,t+1}\left(a', b_1, b_2, m', \omega'\right) p_\omega(m'|m) q_t(\omega') \end{aligned} \tag{4}$$

[11]Since wages are deterministic, time is the only state variable needed to know the current and future wages.

subject to

$$c + a' + (b_1 + b_2)\left(e + \tau w_t^f\right) = L_t(m, \omega) + \frac{a}{\beta} \tag{5}$$

and $b_2 = 0$ whenever $m = 1$. The right-hand side of the budget constraint represents total income: the sum of "potential" labor income as well as income from assets accumulated during the previous period. The time cost of raising the children present in the household at age 2 appears as an expenditure on the left-hand side. As per Equation (1) the number of children present in the household at age 2 is $n_2 = b_1 + b_2$. The function $W_{3,t+1}(a', b_1, b_2, m', \omega')$ is the value function of an age 3 household at date $t+1$ with a' assets accumulated, m' adults, b_1 children born at age 1, b_2 children born at age 2 and facing the state ω'. Note that, even though there are no births after age 2, the household must keep track of the number of children born at age 1 and 2 in order to assess the childrearing cost it is facing each period, as well as to compute its (adult equivalent) size.

From age 3 onward the only choices are consumption (c) and savings (a'). The number of children, n_j, evolves in line with the law of motion described by Equation (1). Formally, the optimization problem writes

$$\begin{aligned} W_{j,t}(a, b_1, b_2, m, \omega) = \max_{c,a'} \; & \tilde{U}(c, n_j, m) \\ & + \beta \sum_{m' \in M} \sum_{\omega' \in \Omega} W_{j+1,t+1}\left(a', b_1, b_2, m', \omega'\right) p_\omega(m'|m) q_t(\omega') \end{aligned}$$

subject to

$$\begin{aligned} c + a' + n_j\left(e + \tau w_t^f\right) &= L_t(m, \omega) + \frac{a}{\beta} \\ n &: \text{given by Equation (1)} \\ j &> 2 \end{aligned} \tag{6}$$

and $a' = 0$ when $j = J$.

3.2.1 Optimality Conditions

The first order conditions for consumption and savings at age 1 imply the Euler equation:

$$U'\left(\frac{c}{\phi(b_1, 2)}\right)\frac{1}{\phi(b_1, 2)} = \beta E_{1,t}\left[\frac{\partial}{\partial a'} W_{2,t+1}(a', b_1, m', \omega')\right] \tag{7}$$

where $E_{1,t}$ is the expectation operator, conditioning on the information available to an age-1 individual at date t, and derived from the probability distributions q_t and p_ω as described in problem (2). The marginal cost of a reduction in household consumption, measured on the left-hand side, is the marginal utility of consumption per (adult equivalent) member. The marginal benefit is the expected marginal gain at age 2, measured on the right-hand side of the equation. The first order conditions for consumption and fertility can be rearranged into

$$\theta \frac{\partial}{\partial b_1} V(b_1, 2) + \beta E_{1,t} \left[\frac{\partial}{\partial b_1} W_{2,t+1}(a', b_1, m', \omega') \right] = \\ U' \left(\frac{c}{\phi(b_1, 2)} \right) \frac{1}{\phi(b_1, 2)} \times \left(e + \tau w_t^f + \frac{c}{\phi(b_1, 2)} \frac{\partial}{\partial b_1} \phi_1(b_1, 2) \right) \tag{8}$$

where the left-hand side is the marginal benefit of a child born at age 1, and the right-hand side is the marginal cost. The marginal benefit comprises two parts: the instantaneous benefit at age 1, measured by $\theta \partial V(b_1, 2)/\partial b_1$, and the expected marginal benefit (net of future costs) from age 2 onward measured by $\beta E_{1,t} [\partial W_{2,t+1}(a', b_1, m', \omega')/\partial b_1]$. The marginal cost comprises three elements. The first two are the resource cost of raising the child, e, and the time cost, i.e., the loss of a fraction of the wife's labor income, τw_t^f. The third element is the allocation of consumption to the newborn. The new child represents an increase of $\partial \phi(b_1, 2)/\partial b_1$ adult-equivalent, thus it receives $c/\phi(b_1, 2) \times \partial \phi(b_1, 2)/\partial b_1$ units of consumption. These three costs, expressed in consumption units, are weighted by the marginal utility of consumption per (adult equivalent) member, $U'(c/\phi(b_1, 2))/\phi(b_1, 2)$.

At age 2 the Euler Equation and optimality condition for fertility are

$$U' \left(\frac{c}{\phi(b_1 + b_2, m)} \right) \frac{1}{\phi(b_1 + b_2, m)} = \beta E_{2,t} \left[\frac{\partial}{\partial a'} W_{3,t+1}(a', b_1, b_2, m', \omega') \right] \tag{9}$$

and

$$\theta \frac{\partial}{\partial b_2} V(b_1 + b_2, m) + \beta E_{2,t} \left[\frac{\partial}{\partial b_2} W_{3,t+1}(a', b_1, b_2, m', \omega') \right] = \\ U' \left(\frac{c}{\phi(b_1 + b_2, m)} \right) \frac{1}{\phi(b_1 + b_2, m)} \times \left(e + \tau w^f + \frac{c}{\phi(b_1 + b_2, m)} \frac{\partial}{\partial b_2} \phi(b_1 + b_2, m) \right) \tag{10}$$

which have the same interpretations as Equations (7) and (8). When $m = 1$ a household cannot have children, therefore $b_2 = 0$ and Equation (10) does not hold with equality.

At age 3 and above the only choice faced by a household is that of consumption and savings. The optimality conditions for consumption and savings are then summarized by the Euler equation

$$U'\left(\frac{c}{\phi(n_j,m)}\right)\frac{1}{\phi(n_j,m)} = \beta E_{j,t}\left[\frac{\partial}{\partial a'}W_{j+1,t+1}(a',b_1,b_2,m',\omega')\right].$$

3.3 Discussion

There are two mechanisms through which the war affects fertility, the second magnifying the effect of the first. First, the expected marginal benefit of a child (left-hand sides of 8 and 10) decreases during the war. This is because the war implies a reduction of the expected number of adults and because the marginal utility of a child is increasing in the number of adults: $V_{nm} > 0$. Second, the war implies an increase of the marginal cost of raising a child. This increase occurs because consumption decreases during the war and, therefore, its marginal utility increases, i.e. the cost of diverting resources away from consumption and toward raising a child increases. The decrease in consumption results from (i) the decrease in expected income due to the probability that the wife remains alone after the war; (ii) the decrease in contemporaneous income due to the husband's mobilization and loss of labor productivity; (iii) the increase in savings due to increased risk with respect to m. Note that the decrease in productivity during the war mitigates the increase in the marginal cost of a child by lowering the opportunity cost of time.

There are two important points to emphasize at this stage. The first is that the functions U and V determine the quantitative effect of the war on fertility and, more precisely, the parameter σ which controls the marginal utility of consumption, and the parameter ρ which controls the marginal utility of a child and the substitutability between adults and children. Second, the war is not just an increase in income risk, but also a shock to expected income. This is because the difference between war and peace, in the model, is not a mean-preserving spread of the distribution of m, the number of adults. The war does increase the income risk of a household, but it also reduces expected income since the expected number of adults becomes less than 2 once it breaks out.

In Section 4.1 the model's parameters are calibrated to fit the time trend of fertility before the war. It is worth, then, discussing the mechanism through which the model is able to generate a downward slopping trend in fertility. It is also important to understand why this trend is relevant to impose discipline on the parameters that are critical for the effect of the war: ρ and σ. Following the approach in Greenwood et al. (2005), the mechanism leading to a long-run decline in fertility is an increase in the opportunity cost of raising children resulting from wage growth. Note that growth in a wife's wage implies both an income and a substitution effect while growth in a husband's wage only implies an income effect. As is common in a time allocation problem the final effect of wage growth on fertility depends upon preferences and, in particular, the marginal utility of consumption and the marginal utility of a child. For fertility to decline at the same pace in the model and the data, the income effect resulting from the growth of both w^m and w^f needs to be more than offset by the substitution effect resulting from the increase in w^f. Thus, the trend in fertility imposes a limit on the rate at which the marginal utility of consumption can decrease, and the rate at which the marginal utility of a child can increase, that is the trend imposes discipline on ρ and σ, the parameters that are critical for the effect of the war on fertility. In short, the time series of fertility is used to restrict size of the income effect on fertility, which depends on ρ and σ, and this discipline is then used to assess the effect of a particular income shock: the war.

4 Quantitative Analysis

In this section I calibrate the model's parameters to fit the time series of the French fertility rate from 1800 until the eve of World War I. This time series, and in particular the pace at which it declines through time, is informative to restrict the parameters of the model –see Section 3.3. Using the calibrated parameters I conduct a set of experiments where I compute the optimal decisions of the generations reaching their childbearing years during an unanticipated war and after. In the first experiment, which I refer to as the "baseline," the generations reaching their childbearing years during the war experience three shocks that their predecessors did not: a higher risk that a wife remains alone in the household at the beginning of the next period, a partially-compensated loss of a husband's income during the war, and a permanent drop in labor productivity. This experiment provides a quantitative assessment of the effect of the war on optimal fertility. I also conduct counterfactual experiments to decompose the contribution of the shocks. First, I report the optimal fertility implied by the model when abstracting from the income loss during the war while maintaining the increased risk that a wife remains alone as well as the loss of labor productivity. Second I report the results of an exercise where both the income loss during the war, and the reduction in labor productivity are as in the baseline, but the risk that a wife remains alone is nil. Finally, I compute the optimal fertility that would prevail had there been no loss of labor productivity. Finally, I also discuss the sensitivity of the baseline results with respect to the choice of some parameters.

4.1 Calibration

A model period is 5 years. Thus, an individual of age 1 in the model can be interpreted as a child between the age of 0 and 5 in the data. Let $I = 4$ and $J = 7$ so that an individual remains in the household in which it was born until it reaches the age of 15-20, and a young household is composed of two individuals between the age of 20 and 25. Households in the model have their children during the first and second period of their adult lives, which correspond to their 20s in the data. Life ends between the age of 50 and 55. An optimal path of fertility is a vector of 26 observations corresponding the the calendar years $1806, 1811, \ldots, 1931$.

Let the rate of interest on the risk free asset be 4% per year. This implies a subjective discount factor $\beta = 1.04^{-5}$. I assume that w^m and w^f grow at the same, constant (gross) rate g from some initial conditions. I use the rate of growth of the Gross National Product per capita in the 19th century, 1.6% per year, to calibrate g –see Carré et al. (1976, Tables 1.1 and 2.3). Thus, $g = 1.016^5$. I normalize the initial condition (corresponding to 1806 in the data) for w^m to 1 and I assume a constant gender gap in wages w^f/w^m. Huber (1931, pp. 932-935) reports figures for the daily wages for men and women in agriculture, industry and commerce in 1913. In industry, a woman's wage in 1913 was 52% of a man's. In agriculture the gap was 64%, and in commerce it was 77%. Since commerce was noticeably smaller than agriculture and industry I use $w^f/w^m = 0.6$. In Section 4.4 I present sensitivity results with respect to w^f/w^m. Note that a gender gap in earnings of 60% is consistent with the findings of the more recent literature studying the United States. Blau and Kahn (2006, Figure 2.1) report that women working full-time earned between 55% and 65% of what men earned from the 1950s to the 1980s. Knowles (2010) reports that, throughout the 1960s, the ratio of mean wages of women to those of men was slightly below 60% in the U.S.

For ϕ, the adult-equivalent scale, I use the "OECD-modified equivalence scale" which assigns a value of 1 to the first adult member in a household, 0.5 to the second adult and 0.3 to each child:

$$\phi(n, m) = \frac{1}{2} + \frac{m}{2} + 0.3n.$$

There are four remaining parameters: σ, θ, ρ, and τ. I calibrate them to minimize a distance between the model's predicted time series of fertility and the actual time series in France before the war. In the model the war breaks out in 1916. Since the 1911 generation gives birth to children in 1911 and 1916 it is only affected by the war, which I assume to be unanticipated, in 1916. Thus, for this procedure I use data up to and including the fertility rate in 1911 and I assume that there are no wars and that individuals do not anticipate any:

$$\omega_t = \text{peace and } q_t(\text{peace}) = 1 \text{ for } t = 1806, 1811, \ldots, 1911.$$

Formally, let $\alpha = (\sigma, \theta, \rho, \tau)'$ be the vector of remaining parameters. I chose them to solve the following minimization problem:

$$\min_{\alpha} \sum_{t \in \mathcal{I}} (f_t(\alpha) - \mathbf{f}_t)^2 + (\tau \times n_{1911}(\alpha) - 0.1)^2 \tag{11}$$

where $\mathcal{I}$ is an index set: $\mathcal{I} = \{1806, 1811, 1816, \ldots, 1911\}$. This objective function deserves a few comments. First, $f_t(\alpha)$ is the fertility rate implied by the model for a given value of α. Since women in households of age 1 and 2 give births at each date, $f_t(\alpha)$ is the sum of births from these two generations at date t, divided by 2. Second, $\mathbf{f}_t$ is the empirical counterpart of $f_t(\alpha)$.[12] Third, $n_{1906}(\alpha)$ is the total number of children born to the 1906 generation. Thus, the second part of the objective function is the distance between the time spent by this generation raising its children and its empirical counterpart, 10%. The latter figure comes from Aguiar and Hurst (2007, Table II). They report that in the 1960s a woman in the U.S. spends close to 6 hours per week on various aspect of childcare, that is primary, educational and recreational. This amounts to 10% of the sum of market work, non-market work and childcare (61 hours). Thus, τ is set to imply that the time spent by a women on childcare, on the eve of the war, is 10% as well. The good cost of raising a child is assumed to be zero, i.e., $e = 0$. Note that if e was proportional to w^f that is, if the good cost of raising a child was growing at rate g, then setting e to 0 would be innocuous since e could be subsumed into τ. In Section 4.4 I present sensitivity results with respect to the target figure for the time cost of raising a child.

[12] I construct a time series of the French fertility rate using the birth rate and the proportion of women between the age of 15 and 44 from Mitchell (1998).

Although σ, θ, ρ and τ are determined simultaneously, some aspects of the data are more important than others for some parameters. The level of fertility, in particular, is critical to discipline the parameter θ which measures the intensity of a household's taste for children. The time cost of a child, that is 10% of a woman's time, is critical in determining the value of τ. The parameter σ determines the curvature of the marginal utility of consumption and, since the number of adults in a household in constant, the parameter ρ determines the curvature of the marginal utility of fertility. Thus the decline in fertility which results from a comparison between its marginal cost (partly driven by the marginal utility of consumption) and its marginal benefit, disciplines the parameters ρ and σ. As discussed in Section 3.3, the discipline imposed by the time series of fertility on these parameters is relevant to assess the effect of the war on fertility. The calibrated parameters are displayed in Table 2. Figure 8 displays the computed and actual fertility rate for the pre-war period.

4.2 Baseline Experiment

In the experiment I assume that the war breaks out in 1916 and that it lasts for one period:

$$\omega_{1916} = \text{war and } \omega_t = \text{peace for } t > 1916.$$

I use three different values for $q_{1916}(\text{war})$, i.e., the perceived likelihood that the war will lasts one more period: 0, 10 and 20%. I use these values to evaluate the quantitative importance of this parameter which is difficult to discipline empirically.[13]

I calibrate $p_{\text{war}}(1|2)$, the probability that a wife is alone in the next period as

$$p_{\text{war}}(1|2) = \frac{\text{military losses of World War I}}{\text{total men mobilized}}.$$

The military losses where 1.4 millions while 8.5 million men were mobilized. Thus, I use $p_{\text{war}}(1|2) = 1.4/8.5 = 0.16$. This figure is not perfect. On the one hand it might exaggerate the risk from the perspective of a wife since she has the possibility of remarrying after the war if her husband died. This possibility would allow a wife to raise her children with hers and another husband's income. On the other hand the probability may underestimate the risk since the husband may survive the war but come home disabled. In the case of World

[13]The literature on disasters, such as Barro (2006) and Barro and Ursúa (2008), emphasizes the importance of the probability of a disaster occurring, while $q_{1916}(\text{war})$ is the probability that the war goes on for one more period conditional on being ongoing already.

War I this was a distinct possibility since the massive use of artillery and gases made this conflict quite different from any other conflict before. Huber (1931, p. 448) reports 4.2 million wounded during the war: half of the men mobilized. The number of invalid was 1.1 million among which 130,000 were mutilated and 60,000 were amputated. In Section 4.4 I present sensitivity results with respect to $p_{\text{war}}(1|2)$ to address these concerns. Note that I assume that all men in their childbearing years are mobilized. This is because the size of the mobilization was massive: 8.5 out of 8.7 million men between the age of 20 and 50 were mobilized.

Households did not get fully compensated for the income loss they incurred while the men were mobilized. Downs (1995) cites a compensation amounting to somewhere between 35 and 60% of a man's pre-war salary in agriculture or industry.[14] To represent this loss, I set $\delta_{\text{war}} = 0.5$. In Section 4.4 I present sensitivity results with respect to the magnitude of the income loss of the husband.

There is evidence that macroeconomic aggregates fell during the First World War. Using data from the French national accounts, I compute a time series of real output per worker and found that it is 28% lower in 1919 than in 1913.[15] Figure 11 shows an index of this time series. Note that this figure is consistent with Barro (2006, Table 1)'s reporting of a drop of 31% in real Gross Domestic Product per capita in France (29% in Germany). I model this shock as permanent. That is, I impose that in 1916 wages drop by a fraction π below their trend:

$$w^m_{1916} = (1-\pi)gw^m_{1911} \text{ and } w^f_{1916} = (1-\pi)gw^f_{1911}$$

and that from this date onward they grow a the constant rate g. I use $\pi = 0.3$.

The results of this experiment are reported in Figure 9 and Table 3 for three values of $q_{1916}(\text{war})$: 0, 10% and 20%. Consider the case where $q_{1916}(\text{war}) = 0$, that is when households anticipate that the war lasts for one period only. The fertility rate predicted by the model falls by 54% in 1916 relative to 1911, versus 49% in the data. Thus, the model over-predicts the decline in fertility by 10% ($54/49 = 1.10$). After the war fertility increases by 154% in the model versus 118% in the data. Thus the model over-predicts the post-war increase by 31% ($154/118 = 1.31$). Figure 10 helps interpreting these results. It shows

[14] See Downs (1995, p. 49) and Huber (1931, pp. 932-935).

[15] The data is from CEPII. It is available upon request or at can be downloaded at: http://www.cepii.fr/francgraph/bdd/villa/serlongues/crois.xls

fertility by age at different point in time, as predicted by the model. Observe that during the war households of age 1 and 2 reduce their fertility since they are both affected by the shocks associated with the war. After the war fertility rises for households of age 1 and 2. There are two points deserving a discussion at this stage. First, since the war is over in 1921, age 1 and 2 households at this time have fertility decisions that are consistent with the trend in wages. Since the shock to wages is permanent, however, their fertility reaches higher trends than before the war. Second, the fertility of age 2 households in 1921, that is the 1916 generation who was of age 1 during the war, rises above trend. This is because this generation postponed giving birth during the war and is catching up after. A fact consistent with the pattern observed in the data of figure 6. This catch-up effect does not compensate for the deficit of births during the war, though. Thus, the model predicts that the completed fertility of the 1916 generation is 25% below trend. A fact that is consistent with the completed fertility data of Figure 3.

Turning to the cases where households expect that the war might last longer than one period, that is when $q_{1916}(\text{war}) = 10\%$ and 20%, Table 3 reveals that both the decline of fertility during the war, and the subsequent increase are exacerbated in comparison with the case where households anticipate the war to last only one period. When $q_{1916}(\text{war}) = 10\%$, fertility decreases by 55% vis-à-vis 49 in the data, therefore exceeding the actual decline by 12%. When households perceive that the war has a 20% probability of still being on in the next period, the fertility decline is 56%. In these cases the increases in fertility between 1916 and 1921 are 162 and 169%, respectively (v. 118% in the data). It should be noted that there are two effects of an increase in $q_{1916}(\text{war})$ that are offsetting each other. On the one hand, an increase in $q_{1916}(\text{war})$ magnifies the risk associated with the war and, therefore, exacerbates the fertility adjustment caused by it. On the other hand, when a young household expects the war to be over in the next period it has an incentive to reallocate births into the future. This incentive is weakened by increases in the probability that, in the future, the war can still be on. The results displayed in Table 3 show that this mechanism is dominated by the first one.

As transpires from the previous discussion, the assumption that the decline in wages during the war is permanent is not innocuous. To assess its importance I conduct an experiment where I assume that the decline in wages during the war is temporary. That is, I assume $w^m_{1916} = (1-\pi)gw^m_{1911}$ and $w^f_{1916} = (1-\pi)gw^f_{1911}$ as above, but I also assume that $w^m_{1921} = g^2 w^m_{1911}$ and $w^f_{1921} = g^2 w^f_{1911}$. I find that in such case the decline in fertility during the war is 54% as in the baseline and that the increase after the war is 139% (v. 154 in the baseline). With a temporary drop in wages, the opportunity cost of raising chidden after the war is higher than in the baseline, thus the catch-up of fertility is less pronounced.

This exercise shows that the combination of three shocks, the increase probability that a wife remains alone after the war, the husband's inability to earn income during the war, and the decrease in labor productivity imply large changes in optimal fertility, over-predicting both the decrease observed during the war and the catch-up observed after. Note again that although, in the model, husbands are unable to receive income during the war, there are no physical separations of couples.

4.3 Decomposition

To evaluate the relative contributions of the shocks faced by households exposed to the war during their fertile years I conduct three counterfactual experiments. Remember that in the baseline the three shocks representing the war are $(\delta_{\text{war}}, p_{\text{war}}(1|2), \pi) = (0.5, 0.16, 0.3)$. In each counterfactual experiment I abstract from one of these shocks while leaving the two others achieve their baseline value. So, in the first experiment I abstract from the contemporaneous loss of income: $(\delta_{\text{war}}, p_{\text{war}}(1|2), \pi) = (0, 0.16, 0.3)$. In the second I abstract from the risk that a wife is alone after the war: $(\delta_{\text{war}}, p_{\text{war}}(1|2), \pi) = (0.5, 0, 0.3)$. In the last experiment, I abstract from the permanent decrease in labor productivity: $(\delta_{\text{war}}, p_{\text{war}}(1|2), \pi) = (0.5, 0.16, 0)$

Figure 12 and Table 3 show the results of these experiments for different values of $q_{1916}(\text{war})$. In Experiment 1, that is when households are faced with the same risk of loosing their husbands as in the baseline and the same decline in labor productivity, but no contemporaneous income loss, i.e. $(\delta_{\text{war}}, p_{\text{war}}(1|2), \pi) = (0, 0.16, 0.3)$, and when $q_{1916}(\text{war}) = 0$, the decrease of fertility between 1911 and 1916 is 44% versus 54 in the baseline case. The post-war increase is 111% (v. 154 in the baseline). Although, these figures vary as $q_{1916}(\text{war})$ changes, they remain proportional to the changes generated by the baseline experiment. As Table 3 shows, the decline in fertility in this experiment represents 80-81% of the decline generated by the baseline, regardless of the value of $q_{1916}(\text{war})$. The increase in fertility in this experiment amounts to 70-72% of the increase generated by the baseline experiment, regardless of the value of $q_{1916}(\text{war})$. This result suggests that the bulk of the fertility changes caused by the war can be attributed to the increased risk that wives would remain alone after the war, and that this conclusion is robust to how likely households perceived that the war would keep going.

When abstracting from the loss of expected income due to the risk that a wife remains alone after the war (Experiment 2), and when $q_{1916}(\text{war}) = 0$, the fertility decline generated by the model amounts to 9% of the decline generated in the baseline, and the post-war increase 6%. As with the first experiment, these results are fairly robust to the value used for $q_{1916}(\text{war})$. It is not surprising that the risk that a wife remains alone plays a larger role than the contemporaneous income loss for a household. The latter is a temporary shock while the former is a permanent income shock. But, in addition to being an income shock, a reduction of the number of adults is also a preference shock, as discussed in Section 3.1, which also reduces the expected marginal benefit for a child.

The figures of Experiment 2 can be used to evaluate the decline in fertility that would have occurred if households anticipated to replace deceased husbands for sure. Such calculation is relevant because, as noted in Section 2.3, the women whose fertility was affected by the war eventually married as the women of any other generations. Experiment 2 shows that if these women perceived no risk of raising their children alone, then their fertility would have decreased by $5/49 = 10\%$ of the actual decline observed in the French data when $q_{1916}(\text{war}) = 0$. This figure increases to 12 and 14% when $q_{1916}(\text{war})$ increases to 10 and 20%, respectively.

Experiment 3 shows how optimal fertility would have declined in the absence of the drop of labor productivity during the war. The result is that fertility would have declined more than in the baseline: 57% (v. 54 in the baseline) when $q_{1916}(\text{war}) = 0$. Thus the decline in labor productivity mitigates the effect of the war on fertility. This results follows from the discipline imposed by the calibration of Section 4.1 on the relative strength of income and substitution effects when wages are changing. In particular, when both wages are growing at the same rate the substitution effect dominates to yield the downward slopping trend in fertility. During the war, where the experiment consists in a proportional reduction of both w^m and w^f, the substitution effect dominates too, but in the opposite direction: the reduction of labor productivity reduces the opportunity costs of having a child and, therefore, mitigates the decline in fertility implied by the war.

4.4 Sensitivity

I consider alternative values for (i) the probability that a woman remains alone after the war, $p_{\text{war}}(1|2)$; (ii) the magnitude of the husband's income loss during the war, δ_{war}; (iii) the time cost of raising children, τ; and (iv) the gender wage gap in earnings, w^f/w^m.

Consider two alternative values for $p_{\text{war}}(1|2)$, the probability that a woman remains alone after the war: 10 and 20% instead of 16 in the baseline. In both cases the baseline experiment of Section 4.2 is performed with the new value of $p_{\text{war}}(1|2)$, while assuming that $q_{1916}(\text{war}) = 0$, that is households expect the war to last for one period only. Table 4 reports the results. It transpires that this probability matters noticeably for the results of the exercise but that, even in the conservative case where the risk for a wife to remain alone is 10%, the model generates a strong decline in fertility: 41% versus 54 in the baseline and 49 in the data.

In the experiment of Section 4.2 a household loses 50% of a husband's income because of mobilization. I consider two alternative values: one where the loss of income is 25% and one where it is 75%. Performing the same experiment as in Section 4.2 with these values implies results that are reported in Table 4. As the income loss gets smaller, the model generates smaller decline in fertility and, consequently smaller increase after the war. In the case of an income loss of 25% during the war, the model still implies a strong decline in fertility: 49%.

Consider now alternative targets for the time cost of raising children. For each new target the model needs to be calibrated again in exactly the same fashion as in Section 4.1 with the exception of the target in the second component of the objective function (11). Then the experiment of Section 4.2 is performed. I consider two alternative targets: a time cost of 5% and a time cost of 20%. The results are displayed in Table 4. The model's prediction for the change in fertility is not monotonic in the time cost of a child. It may appear "counter-intuitive" that the effect of the war on fertility is not exacerbated when the cost of a child is larger than in the baseline, e.g., when it is 20%. The reason for this result is that, as the target figure for the time cost of a child changes, other parameters change too. In particular, a larger-than-baseline time cost of raising a child implies, through the calibration procedure, a higher value for ρ. This can be understood as follows: as the opportunity cost of raising a child increases the marginal cost increases too. Since the model is calibrated to fit the fertility data, marginal cost and marginal benefit must be equalized at the same fertility level. This implies that the marginal benefit of a child must also increase, which is achieve through higher values for ρ and θ. Higher values for ρ, however, imply less complementarity between adults and children in utility. This, in turn, makes the war less costly.

Finally, In Table 4 I report the results of an exercise where I consider alternative values for w^m/w^f, the gender earning gap: 40 and 80%. As for the sensitivity analysis with respect to τ, the model's parameters are calibrated again for each alternative value of w^m/w^f and the experiment of Section 4.2 is performed. The model generates large variations in fertility in these experiments.

5 The Quality-Quantity Tradeoff

In the model described and used above the long-run decline in fertility results from an increase in the opportunity cost of raising children when wages are growing. In this section I show that the analysis carries over to a different framework, often found in the literature, where parents value both the quality and quantity of their children. A simple setup, inspired from Jones et al. (2008), is enough to show this.

Consider a household composed of a husband and a wife. Each is endowed with one unit of productive time per period. Let w^m and w^f represent their wage rates, and let $g > 1$ be their common (gross) rate of growth. Let η denote the ratio w^m/w^f. The household is alive for two periods but can give birth to children only during the first period. There are two types of costs associated with children. First they must be produced, which requires that τ units of a wife's time be spent at home for each child. As in Section 3 the parameter τ is not a choice, but rather a description of the household technology. Second children must be educated. This implies another cost over which the household has a choice: the quality of the education. Let e be the resources, measured in goods, invested by the household in a child's education, then the average quality of a child is

$$q = Q(e). \tag{12}$$

Let the household's preferences be represented by

$$U(c, b, q, c') = \alpha \ln(c) + \gamma \ln(b) + \delta \ln(q) + \beta E[\alpha \ln(c')] \tag{13}$$

where $\alpha, \gamma, \delta > 0$ and c and c' represent current and future consumption, respectively. The variable b is the number of children and the variable q the average quality of children. The operator E is the expectation operator. The household has access to a one-period, risk-free bond with (gross) rate of interest $1/\beta$. It can freely borrow and lend any amount at this rate. It owns no assets at the beginning of the first period.

During the first period there are two adults in the households. Thus, the budget constraint is

$$c+b\left(e+\tau w^f\right)+a'=w^m+w^f, \tag{14}$$

where a' represent savings. In the second period the number of adults is a random variable. If there is only one adult it is the wife, and the probability of that event is denoted by p_ω where $\omega \in \Omega = \{\text{war}, \text{peace}\}$. Thus, consumption during the second period is

$$c' = \begin{cases} a'/\beta + g(w^m+w^f) & \text{with probability } 1-p_\omega \\ a'/\beta + gw^f & \text{with probability } p_\omega \end{cases} \tag{15}$$

The optimization problem of the household is to choose its consumption c, savings a', number of children b and investment in children's quality e, in order to maximize its objective (13) subject to the technology (12) and the budget constraints (14) and (15). The first order conditions for this problem are

$$\begin{aligned} c &: \quad 0=\alpha/c-\lambda \\ a' &: \quad 0=E[\alpha/c']-\lambda \\ b &: \quad 0=\gamma/b-\lambda\left(e+\tau w^f\right) \\ e &: \quad 0=\delta Q'(e)/Q(e)-\lambda b \end{aligned}$$

The solution of this system of equations can be characterized as

$$\begin{aligned} c &= \theta_c(w^m+w^f) \\ a' &= \theta_a(w^m+w^f) \\ b\left(e+\tau w^f\right) &= (1-\theta_c-\theta_a)(w^m+w^f) \end{aligned}$$

where θ_c and θ_a are constants that depend upon the parameters of the model. (See the Appendix for a characterization of these constants).

An important difference between this model and that of Section 3 transpires through these equations. In the absence of the education margin, that is when e is exogenously set to zero, the model predicts that fertility is independent of the level of wages during peace times:

$$b\Big|_{e=0} = \frac{1-\theta_c-\theta_a}{\tau}\left(1+\eta\right).$$

This property is a standard consequence of logarithmic utility and the motivation for using it in the specification of preferences in (13). Hence, if this model delivers the decreasing relationship between fertility and wages during peace times it is because the education margin is relevant for the choice of b.

Using the functional form for $Q(e)$ proposed by Jones et al. (2008), i.e. $Q(e) = \kappa_0 + \kappa_1 e$, and combining the first order condition for b and e yields

$$e = \frac{w^f \tau\delta/\gamma - \kappa_0/\kappa_1}{1 - \delta/\gamma} \tag{16}$$

and using the first order condition for b yields

$$b = \frac{\gamma - \delta}{\alpha} \times \frac{c}{w^f} \times \frac{1}{\tau - \frac{\kappa_0/\kappa_1}{w^f}}. \tag{17}$$

There are a few points worth commenting at this stage. Assume that $\gamma - \delta > 0$ and consider peace times, that is when both w^f and w^m grow at the same rate. Then the rate of fertility is decreasing as per Equation (17). This transpires since the ratio c/w^f is constant. Note also that Equation (16) implies that, at the same time, the average quality of a child is increasing. Thus, households are tradding off the quantity for the quality of their children.

Consider now the effect of a war. As in the model of Section 3 the war is a combination of various shocks. First, there is a shock to the expected number of adults in the future, i.e. an increase in p_ω. As per Equation (15), this reduces expected consumption in the second period and, therefore, raises the expected marginal utility of consumption. The Euler Equation, derived from the first order conditions for consumption and savings, implies that

$$\frac{1}{c} = E\left[\frac{1}{c'}\right]$$

thus, consumption c decreases when the war breaks out. Equation (17) shows, then, that fertility decreases at the outset of the war.[16] Note that this mechanism is the same as in the model of Section 3: when the war breaks out the loss of expected income induces the household to reduce its current consumption, thereby raising the cost of diverting resources away from consumption and into child rearing. Observe that the average quality of children is not affected by changes in p_ω. This is a result of the simplifying assumption that only current resources are invested into a child's education. Second, the war also implies a

[16]This is not a contradiction to the fact that the ratio c/w^f is constant in peace times. The ratio depends upon the parameters of the model, such as p_ω. Thus, it is constant in peace times because p_ω is constant.

loss of current income because the husband is mobilized. Since current consumption is proportional to total income in the first period, this yields a further decline in current consumption, magnifying the effect discussed above. Third, the war also entails a decline in labor productivity. As in the model of Section 3, this mechanism works in the opposite direction, inducing a household to increase its fertility.

This discussion showed that a model of fertility choices embodying the quality-quantity tradeoff can be used to carry out the same analysis as in Sections 1-4. Such a model has the potential to generate a decline in fertility during periods of peace, and a collapse of fertility associated with the loss of a husband's income (contemporaneous and/or expected) during the war.

6 Conclusion

The human losses of World War I were not only on the battlefield. In France, the number of children not born during the war was as large as military casualties (larger in the case of Germany). The age structure of population in France and other European countries was significantly changed by this event, and the effect lasted for the rest of the Twentieth century. In this paper I argue that this phenomenon is more than accounted for by the optimal decisions of households facing three shocks: an increased risk that women remain alone after the war, a loss of income during the war due to the mobilization of men, and a reduction in labor productivity. These shocks imply that young adults during the war see their contemporaneous and expected income decline. As a result they save more and consume less which increases their cost of having children. The resulting drop in fertility is 10% larger than the actual decline. The model is also able to generate the strong catch-up of fertility after the war, mostly because of the inter temporal reallocation of births done by the young generations during the war. The physical separation of couples which is often cited to explain the fertility decline during the war may have been a factor of secondary importance. This finding is consistent with a general pattern exhibited by fertility, across countries and over time, i.e., it tends to decline during periods of significant unrest even though there may be no physical separations of couples.

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A The Quality-Quantity Model

Consider the model described in Section 5. Guess that the solution is of the form

$$
\begin{aligned}
c &= \theta_c(w^m + w^f) \\
a' &= \theta_a(w^m + w^f) \\
b\left(e + \tau w^f\right) &= (1 - \theta_c - \theta_a)(w^m + w^f)
\end{aligned}
$$

Then first order conditions with respect to c and b imply

$$\frac{\gamma}{\alpha}\theta_c = (1 - \theta_c - \theta_a). \tag{18}$$

The first order conditions for consumption and savings yield the Euler equation which can be written as

$$\frac{1 - p_\omega}{a'/\beta + g(w^m + w^f)} + \frac{p_\omega}{a'/\beta + gw^f} = \frac{1}{c}.$$

Using the guessed solution of c and a' imply

$$\frac{1 - p_\omega}{\theta_a/\beta + g} + \frac{p_\omega}{\theta_a/\beta + g/(1 + \eta)} = \frac{1}{\theta_c}. \tag{19}$$

Equations (18) and (19) form a system of two equations in θ_c and θ_a, and characterize the solution of the model.

Table 1: Changes in Fertility for Countries Experiencing Major Social Upheavals

Country	Episode	Period	Change in CBR (%)
England	Civil War, Commonwealth,		
	and early Restoration	1641-66	−17.3
France	Revolution	1787-1804	−22.5
USA	Civil War	1860-70	−12.8
Russia	WWI and Revolution	1913-21	−24.4
Germany	War, revolution, defeat, inflation	1913-1924	−26.1
Austria	War, defeat, empire dismembered	1913-24	−26.9
Spain	Civil war and dictatorship	1935-42	−21.4
Germany	War, defeat, occupation	1938-50	−17.3
Japan	War, defeat, occupation	1940-55	−34.0
Chile	Military coup and dictatorship	1972-78	−22.3
Portugal	Revolution	1973-85	−33.3
Spain	Dictatorship to democracy	1976-85	−37.2
Eastern Europe	Communism to capitalism	1986-98	
	Russia		−56.0
	Poland		−40.0
	Czechoslovakia (Czech Republic)		−38.0

Source: Caldwell (2004, Table 1).

Note: CBR stands for Crude Birth Rate. Caldwell reports that when fertility was already experiencing a declining trend, the reductions observed during the periods of unrest are significantly more pronounced than before and after. For example, the Spanish birth rate fell as much during the Civil War (1935-42) than during the 35 years before.

Table 2: Calibration

Preferences	$\beta = 1.04^{-5}$, $\theta = 0.41$, $\rho = -0.13$, $\sigma = 0.86$
Wages	$w^m = 1, w^f = 0.6$ for initial (1806) generation
	$g = 1.016^5$
Cost of children	$\tau = 1.01$, $e = 0$
Adult equivalent scale	$\phi(n, m) = 1/2 + m/2 + 0.3n$
Demography	$I = 4$, $J = 7$

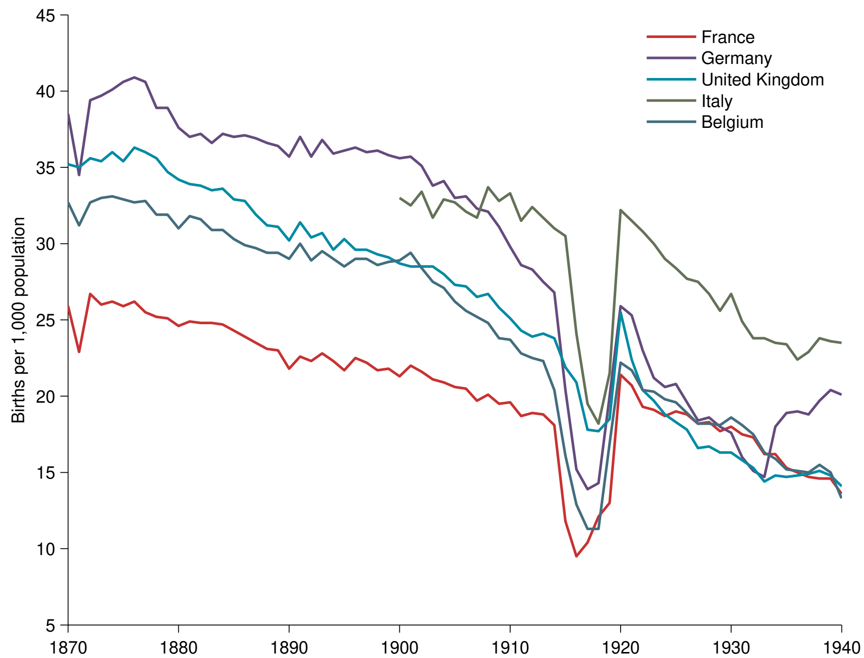
Table 3: Main Experiments: Changes in Fertility During and After the War, Model and French Data, %

	$q_{1916}(\text{war}) =$					
	0%		10%		20%	
	1911-16	1916-21	1911-16	1916-21	1911-16	1916-21
Data	−49	+118	−49	+118	−49	+118
Baseline	−54	+154	−55	+162	−56	+169
Baseline / Data	1.10	1.31	1.12	1.37	1.14	1.43
Exp. 1 ($\delta_{\text{war}} = 0$)	−44	+111	−44	+115	−45	+119
Exp. 1 / Baseline	0.81	0.72	0.80	0.71	0.80	0.70
Exp. 2 ($p_{\text{war}}(1\|2) = 0$)	−5	+9	−6	+11	−7	+12
Exp. 2 / Baseline	0.09	0.06	0.11	0.07	0.13	0.07
Exp. 3 ($\pi = 0$)	−57	+149	−58	+157	−59	+165
Exp. 3 / Baseline	1.06	0.97	1.05	0.97	1.05	0.98

Table 4: Sensitivity Analysis: Changes in Fertility During and After the War when $q_{1916}(\text{war}) = 0$, Model and French Data, %

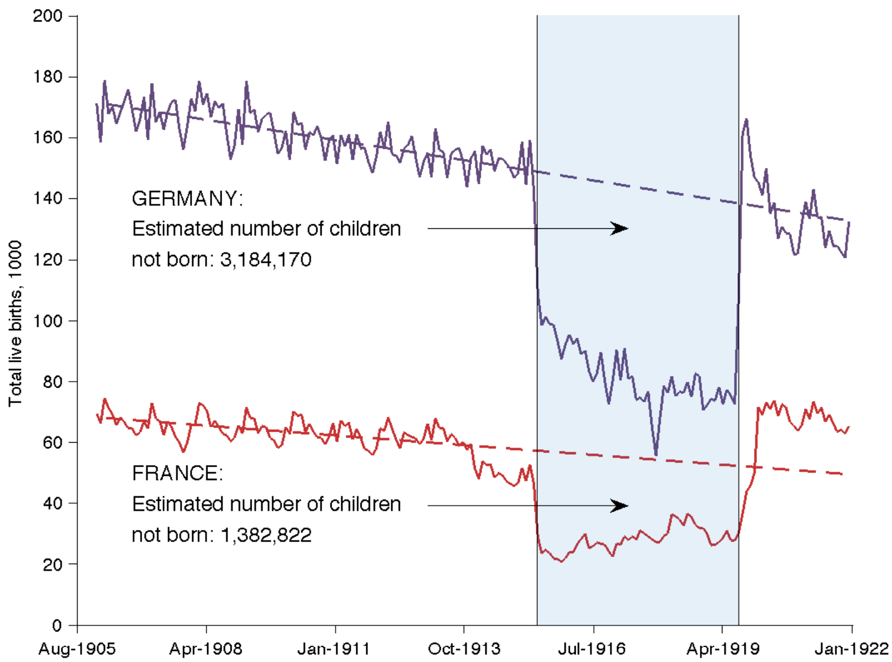
	1911-16	1916-21
Data	−49	+118
Baseline	−54	+154
$p_{\text{war}}(1\|2) = 10\%$	−41	+97
$p_{\text{war}}(1\|2) = 20\%$	−58	+185
$\delta_{\text{war}} = 25\%$	−49	+131
$\delta_{\text{war}} = 75\%$	−59	+183
Time cost of children 5%	−46	+111
Time cost of children 20%	−52	+145
$w^f/w^m = 0.4$	−64	+236
$w^f/w^m = 0.8$	−47	+118

Figure 1: Birth Rates in Some European Countries



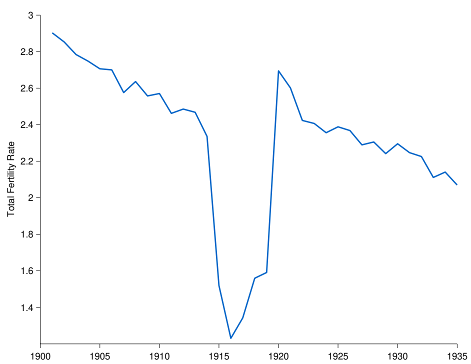
Source: Mitchell (1998).

Figure 2: Number of Births per Month in France and Germany

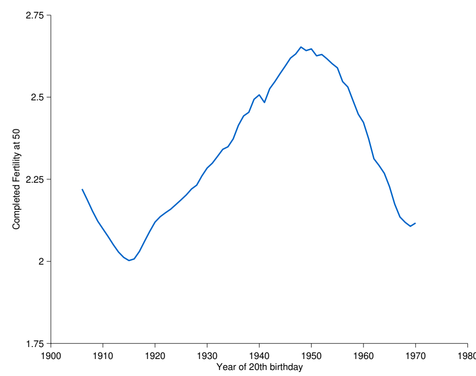


Note: The source of data is Bunle (1954, Table XI). The linear trends are estimated using the data from January 1906 until July 1914. The shaded area is from May 1915, that is 9 months after the declaration of War between France and Germany in August 1914, until August 1919 that is 9 months after the armistice was signed in November 1918.

Figure 3: Total Fertility Rate and Completed Fertility in France



Total Fertility Rate

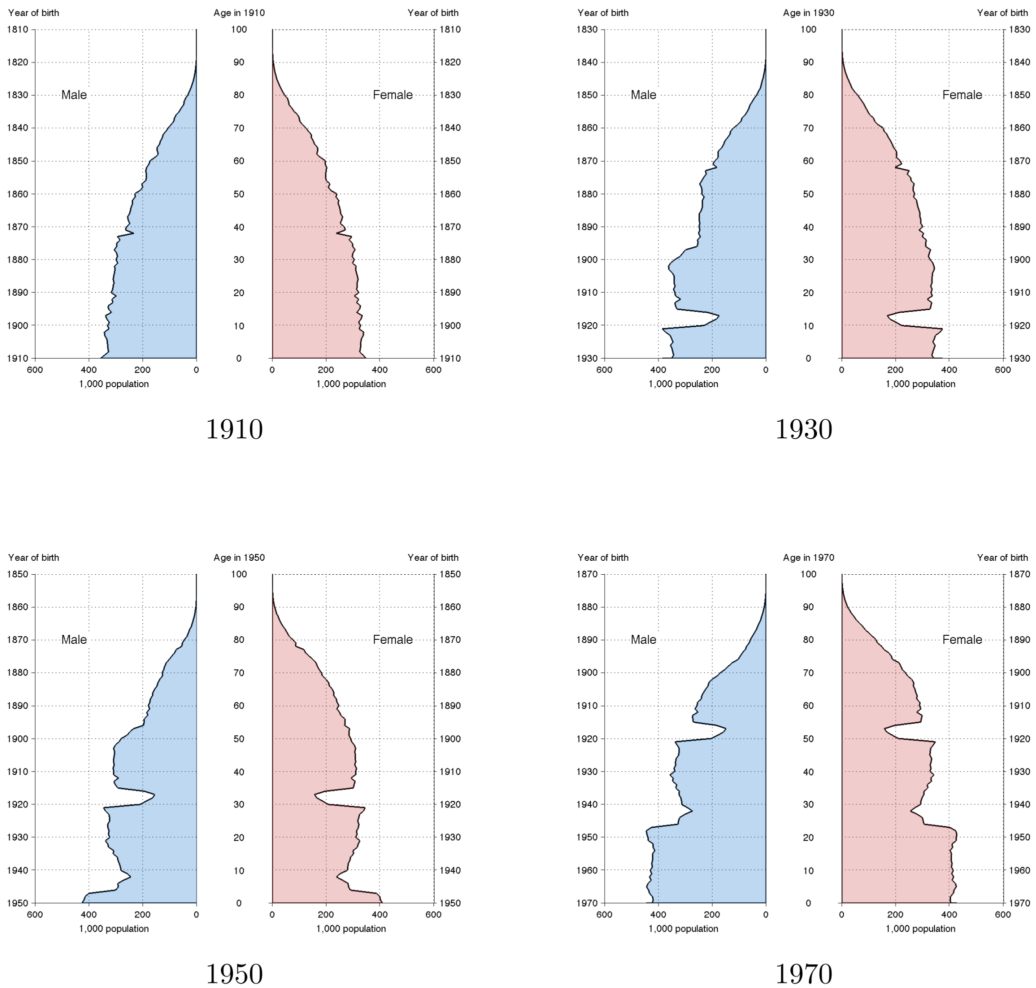


Completed Fertility

Source: Insee, état civil et recensement de population.

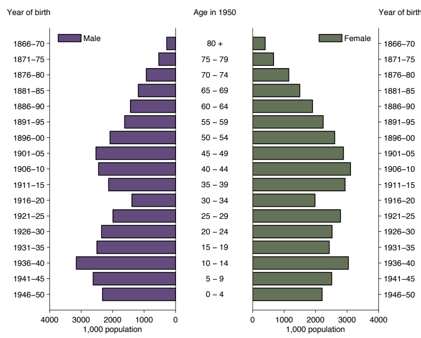
The total fertility rate in a given year measures the average number of children that would be born to a women if she experienced, throughout her fertile life, the age-specific fertility rate observed that year. Completed fertility is the average number of children born to a woman of a particular cohort, once she has reached age 50.

Figure 4: French Population by Age and Sex, January 1, Selected Years

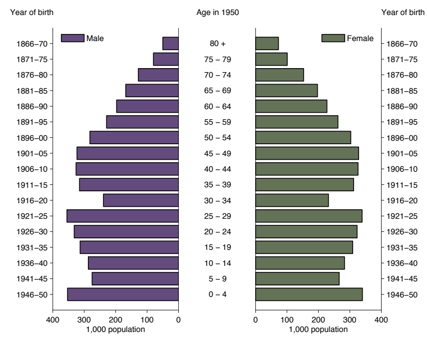


Source: Insee, état civil et recensement de population.

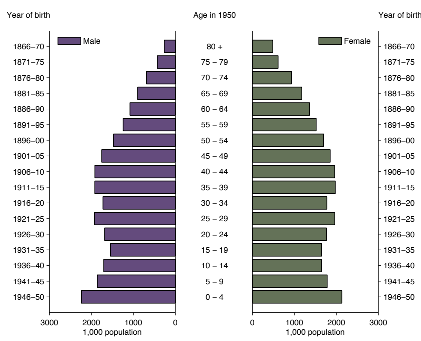
Figure 5: Population by Age and Sex, Selected Countries, 1950



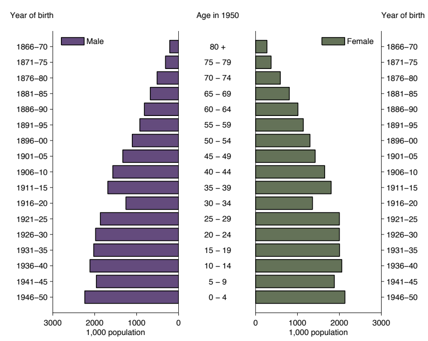
Germany



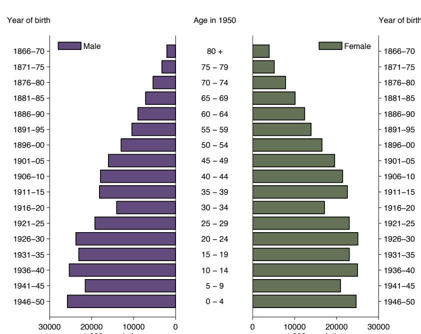
Belgium



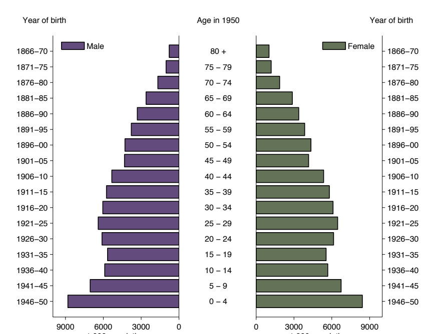
United Kingdom



Italy



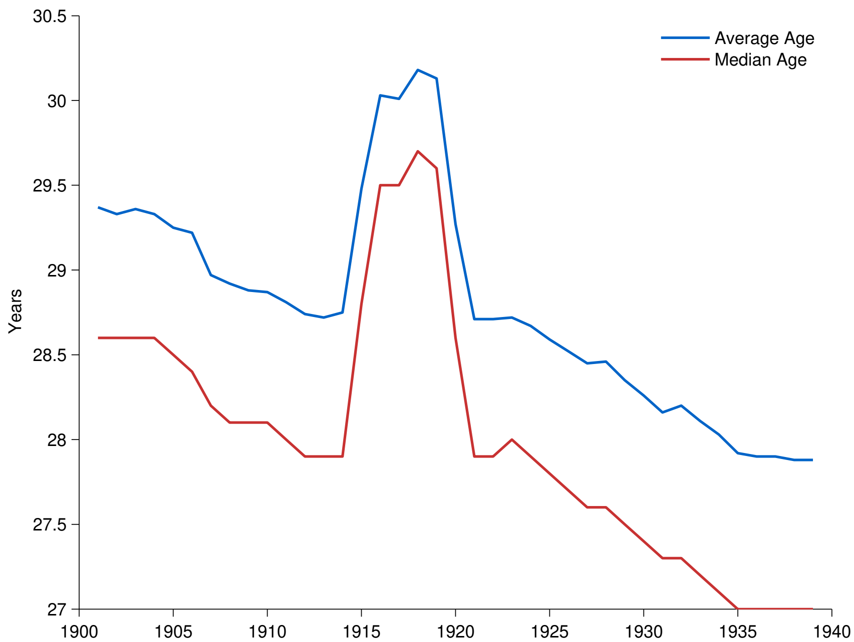
Europe



United States

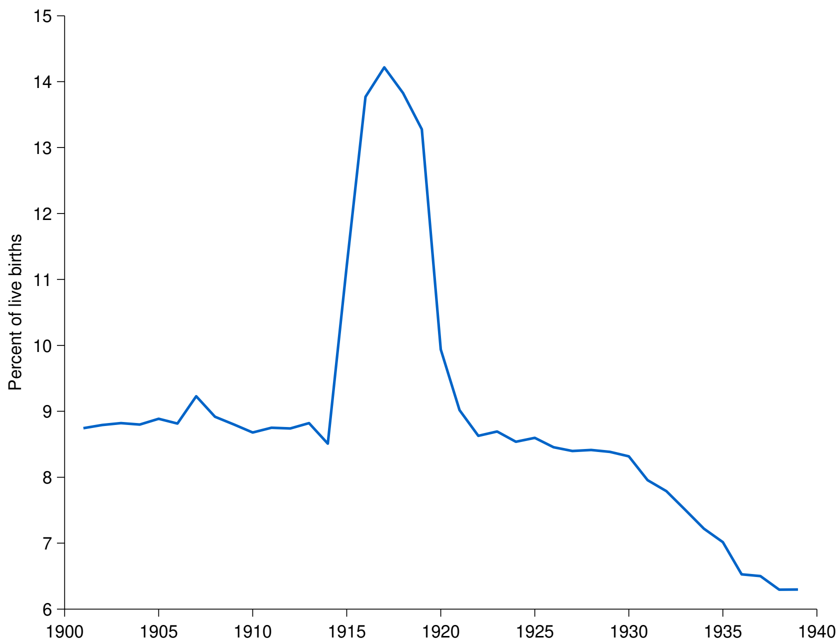
Source: United Nations, Department of Economic and Social Affairs, Population Division.

Figure 6: Average and Median Age at Birth in France



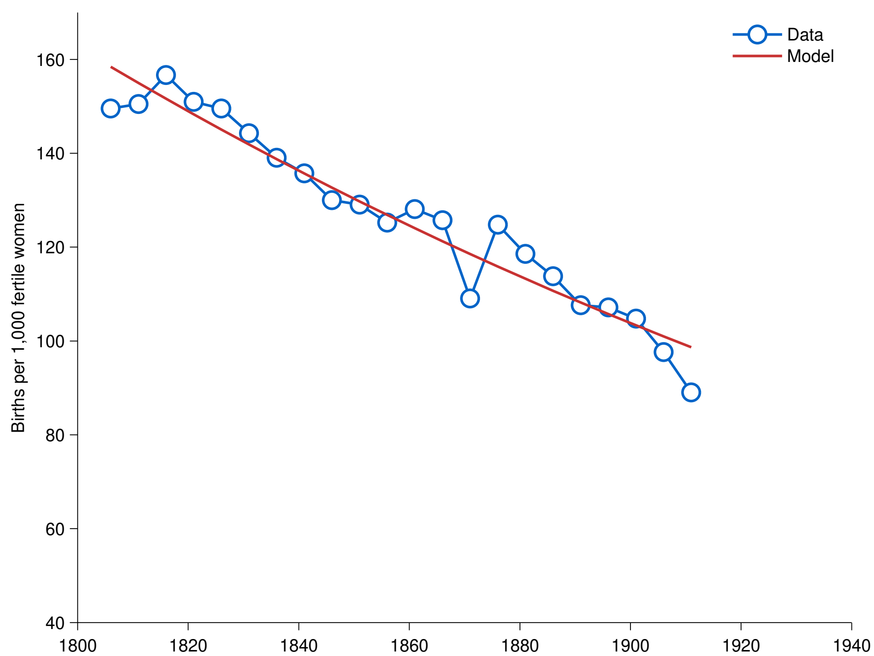
Source: Insee, état civil et recensement de population.

Figure 7: Proportion of Out-of-Wedlock Live Births in France



Source: Insee, état civil et recensement de population.

Figure 8: Fertility Rate in France, Model and Data, 1806–1911



Note: This figure displays the result of the calibration procedure where the model parameters are chosen to fit the time series of fertility during the pre-war period.

Figure 9: Fertility Rate in France, Baseline Experiment and Data, 1806–1931, $q_{1916}(\text{war}) = 0$

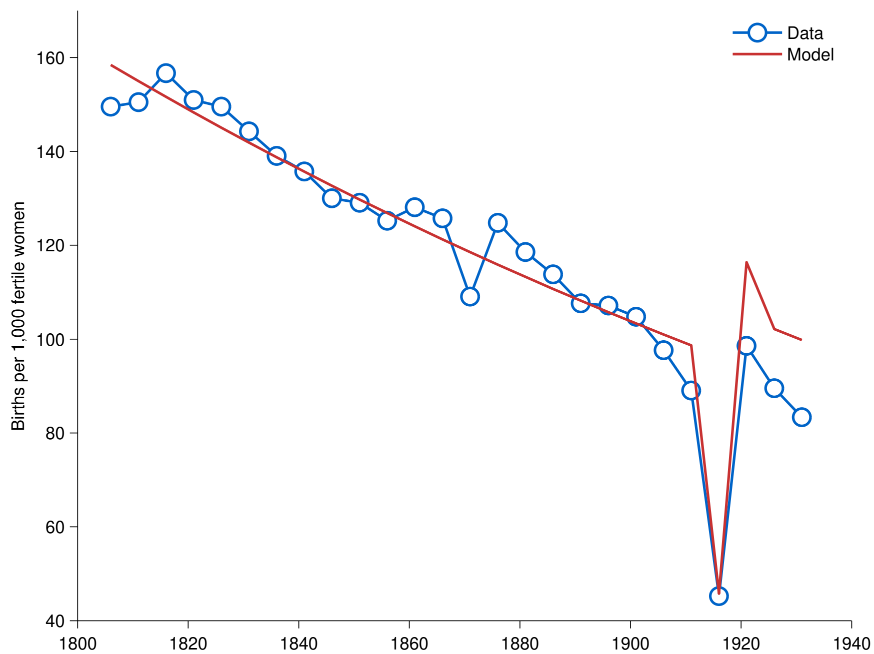


Figure 10: Fertility Rate Predicted by the Model by Age, Baseline Experiment, 1806–1931, $q_{1916}(\text{war}) = 0$

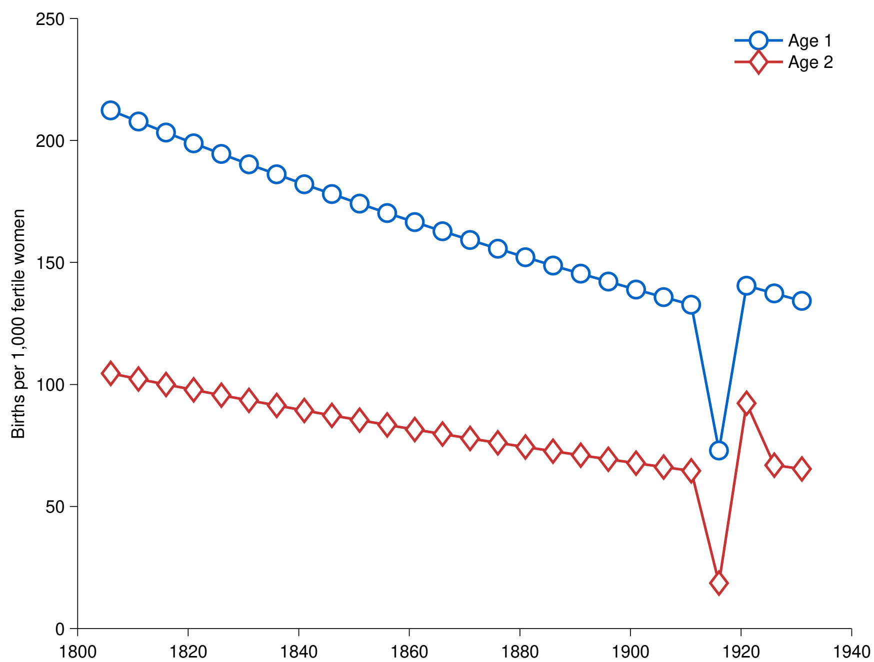


Figure 11: Index of Output per Worker in France, 1896–1935

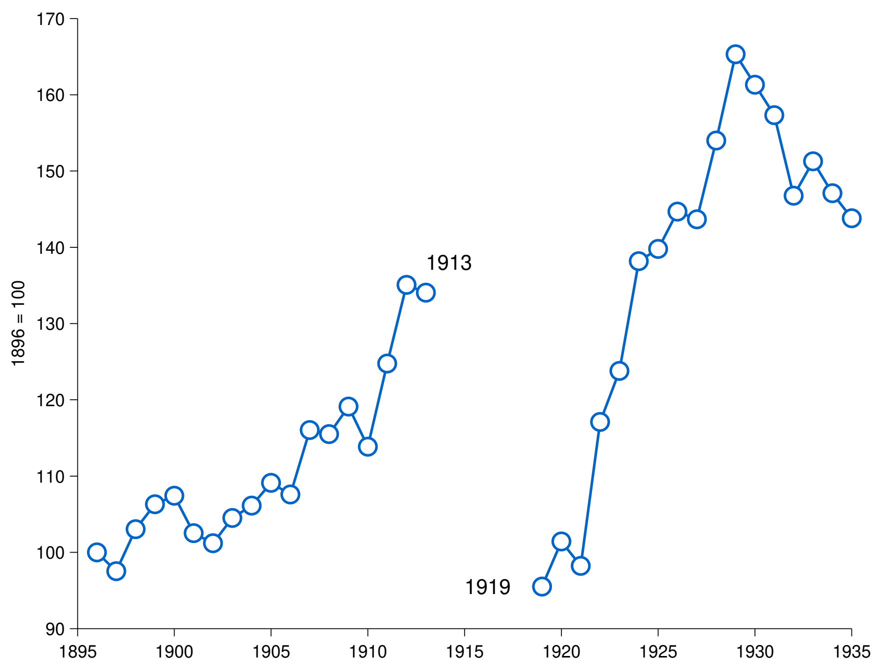


Figure 12: Fertility Rate Predicted by the Model, Baseline and Counterfactual Experiments, 1806–1931, $q_{1916}(\text{war}) = 0$