The Macroeconomic Impact of the 1918–19 Influenza Pandemic in Sweden

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Abstract

What is the economic cost in the medium to long run of an epidemic that kills a large part of the labor force? To answer this question we build an overlapping generations model and calibrate it to the Swedish economy before the 1918–19 influenza pandemic. In the medium run the epidemic, which reduced the population by 0.66%, produces a modest increase in per capita consumption of survivors by 0.45%; however, the benefits are unevenly spread across cohorts. We also find that aggregate labor supply responds elastically while aggregate consumption and investment respond inelastically to the population decline. The aggregate consumption, for example, reduces by 0.27% only for each percentage point decrease in population over the following 10 years. Finally, we document that in the long run, the epidemic has a large cumulative effect over the following century.

JEL classification numbers: I15, E21

Keywords: Epidemics, Overlapping Generations Models

1 Introduction

Following the recent COVID-19 epidemic international organizations have expressed concern that developed and developing countries are insufficiently prepared for pandemic outbreaks with potentially large death tolls. This concern seems appropriate considering that the world has witnessed a steady increase in disease outbreaks over the past 30 years. In addition, worrisome trends concerning antimicrobial resistance suggest that our vulnerability to infectious diseases may be increasing. The macroeconomic implications of these trends are believed to be massive, and a recent report suggests that a pandemic disease outbreak in the future could lead to a decline in the GDP comparable to that of the Great Recession starting in 2008 (Adeyi et al., 2017).

Despite these seemingly well-founded warnings, the macroeconomic implications of global pandemics are still very poorly understood. This is due to some extent to the fact that pandemics affect the global economy via several different channels – including the costs of avoidance behavior and worker morbidity – and the fact that different channels operate over different time horizons. In this paper, it is our aim to evaluate the 1918–19 influenza pandemic from a macroeconomic point of view, focusing on the consequences of a sudden mortality shock. The 1918–19 influenza pandemic is suitable for such an analysis given that it was of relatively short duration and struck unexpectedly, so that its main and lasting impact on the economy was a mortality and hence labor supply shock.

To the best of our knowledge, this is the first paper that develops and calibrates an overlapping generations model to study the 1918–19 influenza pandemic. Karlsson et al. (2014) estimated the short-run reduced form effects of the pandemic using regional-level data from the period. But how can one assess the medium- and long-run equilibrium effects of the epidemic in the absence of counterfactual empirical evidence? Specifically, even from the perspective of 20 to 40 years a number of underlying economic and worldwide characteristics changed dramatically. One can think of the Second World War, the increased labor force participation of women, the introduction of old-age social security and the reduction in working hours as just a few examples of major exogenous shifts that make it impossible to separate the impact of the epidemic from the impact of other major factors.

To overcome this difficulty, we construct an artificial economy that resembles Sweden before the epidemic and then study how it adjusts following an exogenous influenza pandemic. To understand the implications of epidemics, one needs to rely on a dynamic general equilibrium model in which changes in the incentives and available factors of production affect the optimal choices. An overlapping generations model appears to be a natural choice when the relative productivity (as reflected in wages) as well as the capital holdings differ by age. This thought experiment allows us to separate the impact of the epidemic from all other influences in a medium- to long-run perspective of a few decades after the event.

Our paper extends the existing literature in a number of important dimensions.[1] Although the economic literature on epidemics was initially limited, economists' interest in the topic was sparked by the HIV/AIDS pandemic (Boucekkine, 2012). Specifically, the first important contribution was Cuddington and Hancock (1994) who adapted a Solow growth model to evaluate the reduction of the average real GDP growth in Malawi due to AIDS.[2] Corrigan et al. (2005) developed a theoretical OLG economy in which the AIDS epidemic affects human capital accumulation and growth by creating a large number of orphans. Bell et al. (2006) calibrated the OLG model for South Africa with simulations showing that the economy could shrink to half in about four generations without interventions to reduce the 20% HIV prevalence rate.[3]

As is made clear by Boucekkine et al. (2008) in a seminal contribution, the 1918–19 influenza pandemic differs from the HIV epidemic in several key respects. Most importantly, it represents a transitory mortality shock – with only minor (if any) effects on long-term health and survival probabilities. For our purposes, it means that some important mechanisms are closed down: for example, the effective discount rate of survivors is not affected, and there is no surge in health care spending in the medium term. These important simplifications enable us to focus on accuracy in some other respects. The advantage of our approach compared with earlier theoretical papers is careful calibration of the model to the actual Swedish economy using censuses and other detailed historical statistics. Thus, we are able not only to obtain qualitative effects but also to quantify the effects with a high degree of accuracy.

There are also papers that have specifically studied the effect of the 1918–19 influenza on the economy (Brainerd and Siegler, 2003; Garrett, 2009; Karlsson et al., 2014) but these are not set in general

[1]This paper is also a contribution to the growing literature of OLG applications in health such as Bagchi and Feigenbaum (2014).

[2]The model in the paper is set in per effective unit of labor terms abstracting from productivity growth. Voigtländer and Voth (2013) show that population dynamics were far more important than productivity growth for increasing per capita incomes and urbanization in 1350–1700 Europe following the Black Death.

[3]There is also large econometric literature on the effects of epidemics on economic growth including Bloom and Mahal (1997), Lorentzen et al. (2008), Bloom et al. (2014) etc.

equilibrium. This literature has estimated the reduced-form effect on wages and other economic indicators. It is, however, very likely that the main effects of a pandemic of this scale are a general equilibrium effect – which makes reduced-form estimates difficult to interpret and introduces a bias of unknown magnitude. Besides, the American studies rely on data for a country that was actively participating in the First World War. The war obviously represents a confounding factor in various dimensions – regarding fertility choices, labor supply and so forth.

A number of papers have estimated the macroeconomic impact of epidemics (i.e. Keogh-Brown et al., 2010; Smith et al., 2011) using computable general equilibrium models. Unlike those earlier approaches our model is not subject to the Lucas (1976) critique. Specifically, we do not rely on the assumption of a static relationship between aggregate variables but rather start from microfoundations so that economic agents can adjust their individual choices of consumption, savings and labor supply following the exogenous influenza mortality shock. Next, we aggregate these individual changes to obtain the overall impact in terms of lost output and other macroeconomic variables.

From a macroeconomic point of view, the 1918–19 epidemic is an unanticipated, uncorrelated one-time mortality shock that hits the economy. The effect of this shock can be simulated by removing part of the population from the respective cohorts, holding fertility rates exogenous. This approach allows us to capture the heterogeneous effects of the epidemic.

Three major insights emerge as a result of our study. First, the economic well-being of survivors improves. This is not particularly surprising but we are able to quantify this improvement. Specifically, the population decline of 0.66% during the epidemic increases per capita consumption in the next 10 years by 0.45%. Our second finding implies that aggregate labor supply responds elastically while aggregate consumption and investment respond inelastically to the population decline. The aggregate consumption, for example, reduces by 0.27% only for each percentage point decrease in population over the following 10 years. Finally, and most importantly, over the 100 following years, the epidemic has a large cumulative effect in the long run, with the discounted present value of output loss reaching up to 7.16% of the initial steady state output.

The paper is organised as follows. In the next section, we provide some background information regarding the historical context. In section 3, we outline our overlapping generations model. Section 4 presents the calibration results, which are used in Section 5 to evaluate the overall economic cost of the pandemic. Section 6 concludes.

2 Background

In this section we provide some background information on the influenza pandemic and on the general historical context. More extensive overviews may be found in Karlsson et al. (2014) and Boberg-Fazlić et al. (2016).

2.1 The 1918–19 Influenza Pandemic in Sweden

The 1918–19 influenza pandemic involved three distinct waves that swept the world within the course of one year. The first wave occurred in the spring of 1918 and was characterized by light symptoms and low mortality. By contrast, the second wave, which occurred in the fall of 1918, was remarkably deadly. This wave was responsible for the majority of deaths. More than 2.5% of those infected died, a number that is generally around 0.1% during a normal flu outbreak (Taubenberger and Morens, 2006). The deadly second wave was followed by a milder third wave in early 1919 and in some places by a fourth wave in 1920. Taken together, the first three waves were unprecedented in their swift and destructive effects, and doctors were helpless against the disease. The only effective measures were rest and basic care, the use of hot blankets, cold compresses for headaches and drinking lots of water (cf. Mamelund, 2011).

The influenza pandemic had several unique characteristics compared with previous and subsequent flu epidemics. First, in its most virulent form the flu struck swiftly and unexpectedly. Most people died within 6 to 11 days after contracting the illness (Taubenberger and Morens, 2006). Second, the influenza affected the bronchus and lungs, which induced substantially more pneumonia deaths (Morens and Fauci, 2007). Third, the pandemic was unique in whom it affected, as it primarily killed adults aged 20 to 40. Children also died at a slightly higher rate than usual, whereas the death rates for older adults were almost the same as in normal years.

In Sweden around 10% of the population was infected (Richter and Robling, 2013) and nearly 1% died from the epidemic, accounting for a total of 35,000 to 38,500 deaths (Karlsson et al., 2014). The most affected counties in terms of infections and adult mortality were *Västernorrland* and *Jämtland* (north of Sweden). The death rates among adults in these counties were almost three times higher than those in the least affected counties, *Malmöhus* and *Södermanland* (south and center of Sweden; cf. Åman, 1990). Despite this North/South gradient at the aggregate level, Karlsson et al. (2014) showed that the influenza death toll was uncorrelated with regional observables.

Figure 1 presents the monthly all-cause mortality from 1915 to 1927. We see a clear spike in deaths and flu incidents in the autumn of 1918.[4] The timing and severity of the increase in deaths in late 1918 make it reasonable to assume that most of the excess deaths during this period were caused by the 1918–19 influenza pandemic. All the age groups exhibit a distinct spike during the flu outbreak, but it is less pronounced for infants (aged 0-1).

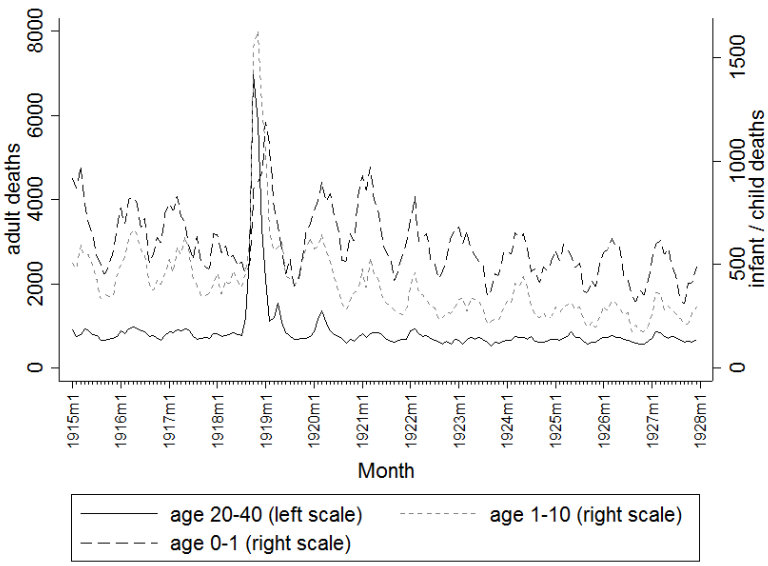


Fig. 1: Monthly all-cause mortality (1915–1927) in Sweden

Several European countries experienced a baby boom during the 1920s, which is often ascribed to the end of the First World War. For example, the U.K. rate jumped from 18.3 births per thousand population in 1919 to more than 23 in 1919. Neutral countries, like Sweden and Norway, however, also exhibited elevated birth rates during these years, although they did not experience the same wartime fertility dip (Chesnais, 1992). As shown in Figure 2 the total and age-specific period fertility rates declined linearly in Sweden over the 1911–19 period, and the World War neither accelerated nor decelerated this gradual decline (Statistics Sweden, 1999). The 1920 baby boom has therefore also been linked to the experience of the 1918–19 influenza pandemic that occurred in all European coun-

[4]Also visible is a mild wave in the early 1920. This wave mostly affected northern Sweden.

tries (Mamelund, 2004). However, Boberg-Fazlić et al. (2016) show that the upsurge in birthrates following the pandemic were reversed in the longer term.

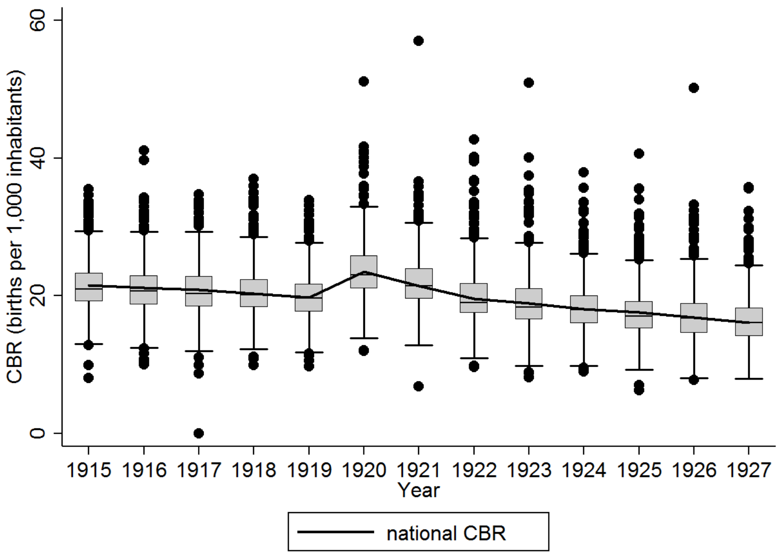


Fig. 2: Crude birth rate, Sweden 1915-1927

Note: The solid curve represents national birth rates. The box plots show the distribution across health districts. Source: Boberg-Fazlić et al. (2016)

2.2 Economic Conditions

In this section we will discuss the overall political, economic and social situation in Sweden before the 1918–19 influenza pandemic. Broadly speaking, Sweden was an industrializing nation at the beginning of the 20th century, with around 29% of the population working in the manufacturing sector – a number that had increased to 36% by 1930 (Statistics Sweden, 1936). In 1917, Sweden had a GDP per capita of 3,022 Geary-Kamis dollars, well below the levels of the U.S. (5,248) and the U.K. (5,421) (Maddison, 2003).

Sweden was neutral during the First World War which implies that the mortality rates were normal in the years prior to the pandemic and that morbidity and mortality record keeping was never interrupted. The war did, however, affect the Swedish economy. The U.K. naval blockade and German naval belligerence hurt Sweden's import trade (Jörberg and Krantz, 1978) and price controls and rationing were introduced. A poor harvest in 1916 led to food shortages in some places and social unrest for a short period, but in general, the wartime period was characterized by an adequate supply of food for the entire population (Nyström, 1994).

At the same time, some sectors of the economy benefited from the war. The raw material exports to belligerent countries increased significantly, and Swedish agriculture performed well because of the lack of competitive imports (Schön, 2010), which led to a large trade surplus (Magnusson, 1996). Conversely, there was a downturn for these same sectors following the end of the war.

Table A1 reports the labor force participation rates and average labor income across all professions based on the data from the 1920 population census (Statistics Sweden, 1927). As one would probably expect, females had substantially lower labor force participation and wage rates than men in all age groups.

The table also indicates high labor force participation rates among older people, which merits some further investigation. In May 1913, the Swedish Parliament approved the first universal public pension system in the World (Hagen, 2013). The retirement age was set at 67 years and the system had two components. The first component was fully funded by individual contributions and remained relatively unimportant for many years to come, so that many participants did not even claim the benefits. The second component, on the other hand, included means-tested benefits that by 1916 were already being paid to as many as 40% of people older than 67 (Hagen, 2013). Despite this rapid increase in participation rates from 2% in 1914, and perhaps because of the relatively low means-tested pensions, the labor force participation rates remained high for people older than the official retirement age. For example, according to the 1920 Census, 36.2% of men and 10.0% of women above 70 years old remained in the labor force.

3 Model

One striking characteristic of the 1918–19 influenza pandemic was the the uneven mortality between age groups, where young adults were particularly affected. These age groups are also characterized by high labor supply and low physical capital holdings. In order to study how the mortality shock translates into aggregate and per capita effects among affected cohorts, we develop an OLG model which is able to take these key features into account.

3.1 Individual choices

A seminal contribution on the application of OLG models to study economies from the long-run perspective was made by Auerbach and Kotlikoff (1987). The entering cohort in their work is represented by 20-year-old agents entering the job market, and at age 75 all agents die. At every point in time, there are 55 generations of representative agents who are different between age cohorts. We simplify the model of Auerbach and Kotlikoff (1987) in order to include only the elements that are relevant to our study. Our model is very close to that of Heer and Maussner (2009), but we add some features that characterize Sweden in 1918. First, we modify the budget constraints in the retirement periods to include also labor income to account for the high labor force participation rates among older Swedes.

Second, in addition to the life cycle savings, we introduce bequests as another source of wealth. Kotlikoff and Summers (1981) show that intergenerational transfers to a large extent determine capital accumulation and also allow to produce plausible capital levels in finite horizon models.[5] We incorporated bequests through "warm glow" altruism, in which case households draw utility from the act of giving (Andreoni, 1990; Acemoglu, 2008). This type of preferences allows to abstract from identification of ancestor-descendant relationship (crucial in dynastic altruism) and is thus convenient for our analysis.[6]

There are 7 periods in the model: $(10-20),(20-30),\ldots,(70-80)$, each covering an age span of ten years.[7] A period has a duration of 10 years because many historical statistics are available in such intervals. Each agent chooses streams of consumption c^s_{t+s-1}, leisure ℓ^s_{t+s-1} and investment k^s_{t+s} over the life-time $s=\{1,...,7\}$ to maximize expected utility as of period t

$$\sum_{s=1}^{7}\beta^{s-1}\theta_s\left[\gamma\ln c^s_{t+s-1}+(1-\gamma)\ln\ell^s_{t+s-1}+\left(1-\frac{\theta_{s+1}}{\theta_s}\right)\ln k^s_{t+s}\right], \tag{1}$$

[5] Notice that in case of pure altruism bequests model of Barro (1974) OLG model becomes consistent with an infinite horizon framework (Carmichael, 1982).

[6] We considered some alternatives to this assumption, which were decisively rejected by the data. Starting from an assumption of unplanned bequests, our model failed to produce plausible levels of capital even with very high values of the time preferences rate. Low survival probabilities lead to very high discounting of future utility implying that individuals have no incentives to save in the amounts needed to match the capital-to-output ratio. Allowing for a mixture of intended and unintended bequests also failed to produce required saving levels. Hence, the only assumption which generates reasonable levels of capital accumulation without unnecessary complication of the analysis are "warm glow" preferences.

[7] Children under 10 years are not included and people older than 80 years are added to the group of 70-80 year olds. Cohort of 10-20 year olds is used instead of 15-20 year olds for computational convenience.

where θ_s is the probability of surviving until age s and $0 < \beta < 1$ is the time discount factor.[8] As customary in OLG models, there is no borrowing.

Agents of age s supply labor $n^s_{t+s-1} = 1 - \ell^s_{t+s-1}$ in period t, defined as the fraction of period-t time devoted to work. Labor productivity ε_s of age group s is calibrated to reflect the wage differential and the labor force participation rates by ages in the Swedish data (more on this in section 4.2 below). Each unit of effective labor $\varepsilon_s n^s$ earns a equilibrium wage w_t which is determined in each period. Labor market earnings are also subject to social security tax τ_t which is collected to finance old-age pensions. Another source of income is rents $(1+r_t)$ paid on capital investments k^s_{t+s-1} made by cohort s in the previous period. Economic agents of age s spend income on current-period consumption c^s_{t+s-1} and investment k^s_{t+s} for the next period. After making these decisions a share θ_{s+1}/θ_s of cohort s survives until the next period. The remaining share $(1-\theta_{s+1}/\theta_s)$ obtains utility from giving their unspent capital and dies. So, the wealth accumulation is determined by life cycle savings and impure altruism.

At every point in time t all 7 cohorts co-exist and face the individual constraints described below. The initial cohort is born without any capital $k^1_t = 0$ but agents receive bequests be^1_t from the deceased:

$$k^1_{t+1} + c^1_t = (1+r_t)be^1_t + (1-\tau_t)w_t\varepsilon_s n^1_t. \tag{2}$$

Bequests from deceased agents in this context can be thought of as providing public education (for the first cohort) and other public goods (for other cohorts). Bequests are paid at the beginning of the period and earn rental income as other forms of capital.[9]

Workers from age group $s = 2, ..., 5$ face the following budget constraint

$$k^s_{t+1} + c^s_t = (1+r_t)(be^s_t + k^s_t) + (1-\tau_t)w_t\varepsilon_s n^s_t. \tag{3}$$

Although by the time of the pandemic a pension system had already been introduced in Sweden, the country still had very high labor market participation rates among older workers.Thus, a realistic budget constraint for the two oldest cohorts (aged $60-70$ and $70-80$ respectively) should also

[8] In this notation superscript stands for cohort s and subscript $t+s-1$ denotes time period.

[9] Observe that investment k^s_{t+1} is made by cohort s in period t. When this cohort ages to become cohort $s+1$ in period $t+1$ this investment becomes capital k^{s+1}_{t+1} of that cohort and earns rents.

include current labor market earnings in addition to pension b

$$k_{t+1}^s + c_t^s = (1+r_t)(be_t^s + k_t^s) + (1-\tau_t)w_t\varepsilon_s n_t^s + f_s b, \tag{4}$$

where f_s is the share of retirees who receive a pension in cohorts $s = 6,7$.

3.2 Aggregation

Let P_s represent the number of individuals in cohort s normalized by the number of people of age $10-20$. In the stationary equilibrium $P_s = \theta_s$, however, this will not be true when we study deviations after the flu mortality shock. Then aggregate capital K_t and aggregate labor N_t are determined from age-specific individual choices

$$K_t = \sum_{s=1}^{7} P_t^s k_t^s \tag{5}$$

$$N_t = \sum_{s=1}^{7} P_t^s \varepsilon_s n_t^s. \tag{6}$$

Following a standard assumption in the literature we assume the Cobb-Douglas production function with constant returns to scale

$$Y_t = K_t^{\alpha} N_t^{1-\alpha}, \tag{7}$$

where α is the capital share.[10] The solution to the firm's profit maximization problem equates the wage w_t and the rental rate r_t with their corresponding marginal products

$$r_t = \alpha K_t^{\alpha-1} N_t^{1-\alpha} - \delta \tag{8}$$

$$w_t = (1-\alpha) K_t^{\alpha} N_t^{-\alpha}. \tag{9}$$

Hence, factor prices w_t and r_t in equilibrium equate the aggregate supply and demand of capital and labor and the output is split between factor owners as $Y_t = K_t(r_t + \delta) + N_t w_t$. The capital of deceased agents is divided as bequests in equal shares among population. We denote aggregated bequest of cohort s as BE_t^s.

$$BE_t^s = \frac{\sum_{s=1}^{7}(P_{t-1}^s - P_t^{s+1})k_t^s}{\sum_{s=1}^{7} P_t^s} P_t^s. \tag{10}$$

[10] This production function has been used starting from Cuddington and Hancock (1994) and up to the most recent studies such as Augier and Yaly (2013).

Individual bequest be_t^s can be found by dividing BE_t^s by the size of the corresponding cohort P_t^s.

Finally, the government uses tax revenues from labor income to finance public pensions b

$$\tau_t w_t N_t = (\pi P_t^6 + P_t^7) pb, \tag{11}$$

where π is the proportion of agents between 67 and 70 years old (in the $60-70$ year old cohort) and p is the proportion of age-eligible individuals receiving a pension. The government budget is assumed to be balanced in every period.

The aggregate law of motion for capital equates total investment on the left-hand side in period t

$$\sum_{s=1}^{7} P_t^s k_{t+1}^{s+1} = \sum_{s=1}^{7} P_{t+1}^s be_{t+1}^s + \sum_{s=1}^{6} P_{t+1}^{s+1} k_{t+1}^{s+1} \tag{12}$$

with bequests and total capital of survivors on the right-hand side in period $t+1$.[11]

Finally, the economy-wide resource constraint sets the total investment and consumption on the left-hand side

$$\sum_{s=1}^{6} P_t^s k_{t+1}^{s+1} + \sum_{s=1}^{7} P_t^s c_t^s = Y_t + (1-\delta) K_t \tag{13}$$

equal to the output and capital left after depreciation on the right-hand side.

3.3 Discussion

The main aim of our model is to give an accurate yet simple representation of the performance of the Swedish economy around 1918. Since one main feature of the 1918–18 influenza pandemic was the disproportionate death toll among young adults, we have decided to focus on heterogeneity by cohort in the response to the pandemic. We thereby abstract from other potentially important sources of heterogeneity. For example, OLG models exhibiting within-generation heterogeneity in worker productivity have been considered by Ríos-Rull (1996) and Heer and Maussner (2006). However, both papers conclude that such heterogeneity add little insight compared to one with representative agents. Moreover, the Swedish workforce of 1918 was characterized by very little heterogeneity in terms of qualifications (Fischer et al., 2018). According to the 1930 census, the first one to system-

[11] All agents make their corresponding investment decisions in period t but not all of them survive until period $t+1$.

atically report education, less than 10 per cent of the population had more than primary education (Statistics Sweden, 1937). Another dimension of heterogeneity might be introduced by allowing for different sectors in the economy, as in Galor (1992). Finally, adding two genders as in Galor and Weil (1993) under endogenous fertility rates might be another potential extension. A non-uniform mortality shock in the context of gender heterogeneity may lead to changes in relative wages between men and women and may also have implications for fertility. However, male and female influenza mortality rates were very similar in Sweden (Statistics Sweden, 1923, 1924).

4 Calibration

4.1 Survival probabilities

We calibrate the model to match key characteristics of Sweden right before the 1918–19 influenza pandemic and begin with survival probabilities. Thanks to a very long tradition of keeping highly accurate vital statistics in Sweden (cf. Bhalotra et al., 2017), we can draw pre-influenza survival probabilities by age from official life tables for 1911–1915 from the 1930 Swedish Statistical Yearbook (Statistics Sweden, 1930).

However, actual survival probabilities are inconsistent with the population age structure in 1918 in Table 1, primarily due to migration.[12] Consequently, the economy is not in steady state in 1918 before the pandemic and two processes – mortality effects and convergence to a new steady state – will go in parallel. We explain in Section 5 how we deal with this issue.

Table 1: Calibration inputs: demographics

	Cohorts						
	10-20	20-30	30-40	40-50	50-60	60-70	70-80
Population before the epidemic	1,126,577	927,045	761,338	594,778	526,850	385,165	306,488
Influenza mortality	4676	11042	7106	2780	1744	1576	1497
Survival probabilitiy (θ_s)	1	0.9617	0.9076	0.8529	0.7857	0.6839	0.5049

Note: Data for Population before the pandemic and influenza mortality in 1918-19 are taken from Karlsson et al. (2014).

Table 1 highlights the already-mentioned age gradient in influenza mortality: the most heavily af-

[12] Between 1870 and 1900, about 670,000 individuals out of 4.2 million citizens emigrated, most of them in their twenties (Hagen, 2013). Unfortunately, detailed statistics on migration by cohort and year is not available for the period under study.

fected age groups are 20–30 and 30–40, with influenza mortality rates of 1.2 and 0.9 per cent resepectively. Mortality for older cohorts (aged 40 and older) varies between 0.3–0.5 per cent. This age profile is very different from the mortality profile applying in normal times, as represented by the survival probabilities θ_s, and it has potentially large implications for the macroeconomic response to the shock. This is one main advantage of an OLG model compared to the alternatives imposing an infinite time horizon – and which thus do not allow for a heterogeneous impact of the pandemic. In order to assess the importance of this flexibility, we contrast our baseline model with an alternative model where influenza mortality is uniform across age. In this alternative scenario, we thus subtract identical shares of population from each cohort so that the total mortality is exactly the same as the one actually caused by the pandemic; hence the sum of influenza deaths would be the same as in Table 1.

4.2 Productivities

A key element in our model is the productivity profile by cohort, denoted ε_s. We calibrate this profile to match relative earnings of cohorts at the time of the pandemic. Thus, in a first step, our calibration exercise matches relative earnings profiles $\varepsilon_s n_s$ to historical sources.[13] In this part we rely on information from the 1920 census, which allows us to derive average earnings by cohort (denoted y_s) and labor force participation rates (denoted λ_s) (Statistics Sweden, 1927). Based on this information, we calibrate earnings profiles as

$$\varepsilon_s n_s = \frac{y_s \lambda_s}{\bar{y}\bar{\lambda}} \tag{14}$$

where $\bar{y}$ and $\bar{\lambda}$ denote mean earnings and labor force participation rates, respectively. In Table 2 we present the underlying information available from he 1920 census and from Karlsson et al. (2014), and the calculations we make.[14] The bottom row "*Per capita wage, SEK*" corresponds to the calibrated $\varepsilon_s n_s$, even though it is expressed in SEK and not in normalized units.

[13] We resort to this approach because a representative sample of workers for 1918 does not exist, eliminating the possibility of matching labor supply n_s across cohorts.

[14] The influenza epidemic of 1918–19 clearly affected the age composition of the population, and the 1920 census will be inaccurate as a source for population data in 1918. However, the information in the census was collected just after the end of the pandemic and for our purposes, it is enough to assume that influenza mortality did not affect (i) labor force participation rates across age groups and (ii) wage differentials between age groups (both of which are assumed to depend primarily on experience).

A second aim of the calibration is to make the hours worked match the actual time devoted to work according to historical sources. In order to separate labor supply from productivity for each cohort, we rely on information from Holmlund (2013), according to whom the standard working week in Sweden in 1918 was 57 hours, which implies an average share of working time of 0.1428. Therefore, we calibrate the scaling parameter γ so that the overall labor supply in the model (defined as a share of population time dedicated to work) corresponds to official Swedish data. Workers spent 33.93% (57/24·7) of their total time on work. The total estimated number of workers is 1,947,674 and the total population older than 10 years old is estimated to be 4,628,241. Since we do not distinguish between workers and non-workers and only have influenza statistics on the total population we need to use the share of working time in population (rather than in workers) calibrated as 33.93%·1,947,674/4,628,241 = 0.1428. To match this result, parameter γ measuring the preferences for consumption in the utility function is calibrated at 0.1605.

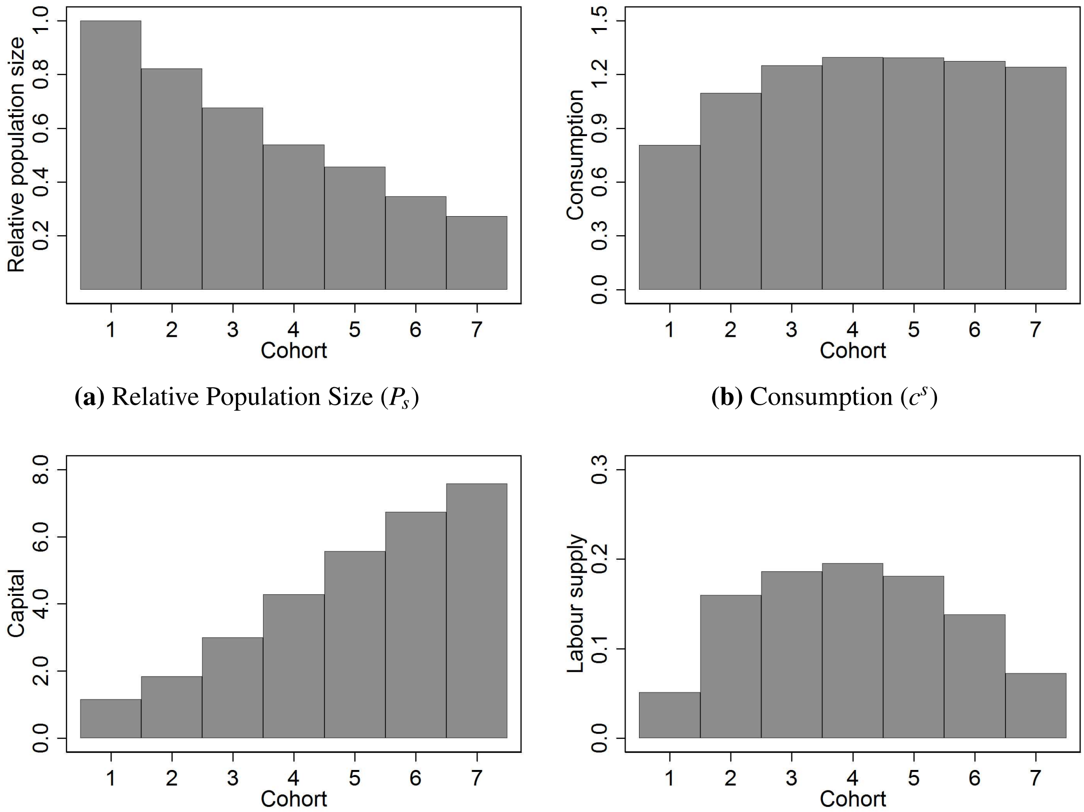
Table 2: Calibration inputs and outcomes: productivities

	Cohorts							
	10-20	20-30	30-40	40-50	50-60	60-70	70-80	**All**
Population	1,126,576	927,044	761,337	594,777	526,849	385,164	306,487	4,628,234
LFPR (λ_s)	0.193	0.608	0.544	0.515	0.465	0.369	0.190	0.420
Workers	217,183	563,834	413,976	306,785	245,273	142,154	58,462	1,947,667
Mean labor earnings (y_s), SEK	1392	2119	3261	3768	3806	3421	3141	2879
Per capita labor earnings ($y_s\lambda_s$), SEK	268	1289	1774	1944	1772	1263	599	1210
Normalized bill ($\varepsilon_s n_s$)	0.222	1.064	1.464	1.605	1.463	1.042	0.495	1
Productivities (ε_s)	4.3325	6.6671	7.8523	8.2226	8.0735	7.5468	6.8307	6.7378

Note: Please consult Appendix Table A1 for sources and for data in their original format.

Thus the calibration approach sets γ to ensure correspondence between the model and official data regarding the total number of hours worked in the economy. At the cohort level, the share of working time is made up of cohort-specific labor force participation λ_s – which is derived from official statistics – and hours worked per worker; supplied endogenously determined based on state of the economic environment and taking individual productivities into account. Any differences in per-capita earnings across cohorts which are not attributable to labor force participation rates, are thus assumed to be driven by differing productivity ε_s.

As reported above, Sweden had a pension system which was in its infancy at the time. Hagen (2013) reported from earlier work by Elmér (1960) that the participation rate in the public pension system was 40% in 1916 and 47% in 1920. Linear interpolation of these data implies that 43.5% of age-eligible respondents received a pension in 1918, so $f_7 = 0.4350$. After we compute the share of 67-70 year olds in the $60-70$ cohort to be 0.2722, we obtain $f_6 = 0.2722 \cdot 0.4350$. The means-tested pension after the appropriate normalization yields $b = 0.0516$.



(a) Relative Population Size (P_s)

(b) Consumption (c^s)

(c) Capital (k^s)

(d) Labor Supply (n_s)

Fig. 3: Initial choices by cohort

The initial state of the economy for each cohort is depicted in Figure 3. The empirical life tables imply that the number of people in each cohort gradually declines from cohort 1 of 10-20 year-olds to cohort 7 of 70-80 year-olds.

Figure 3b depicts consumption which is smoothed at older ages, but not among cohorts 1-3 because of initial capital accumulation. The capital accumulation Figure 3c also does not have the familiar "Modigliani" shape – individuals starting with little capital from unintended bequests increase their savings throughout the life cycle.[15] This result is partially driven by the "warm glow" assumption which is needed to match the observed capital-to-output ratio and partially by high labor force participation and wages of the elderly which is observed in the data.

[15]The optimal capital stock is generated from the model because survey data with wealth levels by age are not available.

Finally, the effective labor supply is shown in Figure 3d. The model produces cohort-specific labor supply that guarantees replication of both the wage bill profile and the average labor supply that is available in the data. The shape of the life-cycle labor profile is different from a standard OLG model given that we normalized all the variables per capita and not per worker. For example, the low labor supply in the first cohort partially reflects the low labor force participation rates of workers under 15 who are the part of this cohort.

Although the initial state of the model economy looks somewhat different from a standard text-book model what is really important is that it accurately reflects the observed economic outcomes in Sweden in 1918 before the influenza pandemic, in a format consistent with available historical data sources.

4.3 Fertility

Most empirical work analysing the influenza pandemic finds a reduction in fertility in the following period (Bloom-Feshbach et al., 2012; Chandra and Yu, 2015b,a; Boberg-Fazlić et al., 2016); however, Donaldson and Keniston (2015) report substantial increases in fertility in India. In view of this uncertainty we have abstained from an explicit modeling of fertility and rely instead on actual fertility in Sweden over the period under study.

According to historical statistics (Table A2), 10-20 year old women were responsible for 3.38% of births, 20-30 years old women were responsible for 44.40% of births and 30-40 years old women were responsible for 41.67% of births. This implies that women aged 40+ were responsible for 10.55% of births. We assume that women after 50 do not give birth, so only four cohorts (10-20, 20-30, 30-40 and 40-50) have children.

Given that the number of men aged 10-20 years in 1918 before the pandemic was 582,195, one can compute the number of boys born to 10-20-year-old women as 582,195·0.0338. We divide this number by the number of 10-20-year-old women before the flu to get their fertility rate of 0.0361 boys per woman of age 10 to 20 years over the 10-year period. The procedure was repeated for the remaining categories to give fertility rates of 0.5512, 0.6019 and 0.11918 boys per 20-30, 30-40 and 40-50-year-old women correspondingly. Similarly, we compute fertility of 0.0338, 0.5154, 0.5628 and 0.1793 girls per 1 woman in 10-20, 20-30, 30-40 and 40-50 age groups.

Using these fertility rates, we can compute the size of the entering cohort in the next period. Specifically, we multiply the number of females in the cohorts 10-20, 20-30, 30-40 and 40-50 years old after the pandemic by the corresponding fertility rates and add up the male and female portions of the population to obtain the new entering cohort.

Having calculated the size of the entering cohort for the next period, we obtain size of cohorts 2-7 by using their conditional probability of survival. Afterwards, we sequentially repeat the exercise using actual fertility rates for 1928, 1938, ..., 2008 in Sweden to obtain the population dynamics for our model. These fertility rates are taken from official statistics (Statistics Sweden, 1969, 2009, 2018).

5 Evaluating the economic cost of the pandemic

To assess the economic consequences of the pandemic, we model the effects of exogenous mortality from the pandemic on individual labor supply, investment and consumption and then aggregate them. The advantage of an OLG model is that it allows for an heterogenous impact of the pandemic itself – allowing, realistically, the death toll to vary by age – and for heterogeneous responses to the shock. In what follows, we will contrast this very flexible approach with one that requires a uniform pandemic mortality, as necessary in an infinite-horizon model. We present three sets of results: (i) per capita effects for survivors, (ii) aggregate effects for the economy and (iii) long-run costs in terms of lost output.

One challenge in the analysis is that the economy is not in a steady state before the pandemic. In addition, the evolution of variables to the new steady state will be on a different scale than the flu mortality shock. Thus, for a meaningful comparison we compute the difference in convergence paths of variables in two models: a model without an influenza mortality shock relative to a model with a mortality shock. In this way we abstract from the convergence to a new steady state but concentrate on the net effect of the pandemic only.

5.1 Per-capita effects

Given the positive distributional consequences of an unexpected mortality shock one would expect improved economic outcomes for survivors. We report changes in per-capita variables (defined as aggregates divided by the population) in Figure 4. The influenza epidemic kills about 0.66% of the population, but the average death rate ranges from 0.33% in the age group 50–60 to 1.19% in the 20–30 age group (Figure 4a). Figure 4 also shows that influenza mortality results in higher per capita bequests, capital and consumption and lower labor supply in the first 10-year period after the pandemic with gradual adjustment to the new steady state.

As mentioned initially, the OLG model also allows us to pin down the effects for each individual cohort. These distributional effects would be masked if we relied on uniform mortality instead, which is inevitable in an infinite-horizon model. Figure 4 also assesses the implications of this modeling choice by contrasting the baseline per-capita results to those that would come out of the analysis if we restricted the death toll to be uniform across ages, as detailed in Section 4.1. This alternative scenario is represented by dashed curves in the figures. Clearly, bequests per capita would follow a completely different trajectory in this alternative scenario, as would per-capita consumption. In the alternative scenario with uniform mortality also the labor supply response is smaller than in our baseline model.

Thus, the differential impact across cohorts clearly matters. In order to better understand the adjustment of different cohorts, Figure 5 shows deviations of capital, consumption and labor supply by cohort in the short and medium runs of 10 and 50 years. Although new factor prices lead to higher savings and consumption among all cohorts (Figures 5a and 5c), younger cohorts enjoy a much higher increase compared to older cohorts in the short run of 10 years while the cohort differences become less pronounced in the medium run of 50 years after the pandemic. When it comes to labor supply older cohorts actually work more in the first period after the pandemic because of the bequest motive.

As a result of the wage increase, individuals adjust their work-leisure choice. As shown in Figure 5e, this adjustment is quite different across cohorts. Since leisure is a normal good the income effect of a wage increase prevails over the substitution effect, and most households indeed decrease their labor supply. However older cohorts put increasing weight on the bequest motive, which leads to the substitution effect eventually prevailing for the oldest cohorts, who increase their labor supply in the first period following the pandemic.

Thus, the adjustment to the pandemic is heterogeneous on a number of margins, and the responses also vary with time. In order to get a summary measure of how each cohort was affected by the pandemic, we also calculate compensating variation, which we define as the average household in the last period of life required in order to achieve the same welfare level as if the epidemic never happened. Results are presented in Appendix Figure A1, which expresses compensating variation as a percentage of average income in the economy. As expected, survivors of all cohorts benefited from the pandemic. However, there are striking differences across cohorts. The generation that entered the labor market in the first post-pandemic period (and died in 1988) received the greatest benefit at 1.85%. After this point the compensating variation exhibits a discontinuity so that the measured benefits are considerably lower. The first and last cohorts we consider both have benefits measured at around 0.5%.

To conclude, the epidemic improves the economic well-being of the survivors, who enjoy higher income and consumption levels partly because of higher windfall capital bequests and partly because of higher wages.

5.2 Aggregate effects

The situation is quite different when we consider the *aggregate* variables, as depicted in Figure 6 when all the aggregate variables fall in the period following the epidemic. Specifically, the model predicts that changes in investment and consumption are inelastic with respect to the population change. In particular, in 10 years after the epidemic the aggregate investment decreases by 0.25% for each percentage point decline in population. This happens because the epidemic disproportionally hits younger generations with smaller capital holdings. Similarly, aggregate consumption also falls inelastically by 0.37% points for each percentage point decline in the population. Aggregate labor, on the other hand, has higher elasticity of 1.25% in the first post-flu period because of the population decline and also because only older cohorts work longer hours as we showed above in Figure 5e.

As it turns out, the possibility of the pandemic having a differential impact across cohorts matters also when aggregate responses are concerned. Figure 6 exhibits dashed curves which show the evolution of the different variables over time under the alternative assumption that the mortality shock is uniform. In fact, the impact on all aggregate variables we consider is biased when imposing this restriction: the negative impact on the total population and on aggregate output and consumption is underestimated. Also the impact on wage rates and rents is underestimated in this alternative scenario.

Finally, Figure A2 in the Appendix shows (as one would expect) initial increase in K/Y and C/Y ratios which gradually converge back. Initially, epidemic-induced windfall bequests lead to an increase of the capital-output ratio and a rental bill in the first period as shown on Figures A2a and A2d. Higher per capita capital results in the drop of interest rates (Figure 6f) which in turn reduces capital income. As a result, households reduce investments (Figure 6d) which gradually brings rental bills and capital-output ratio back to the convergence path.

5.3 Long-term costs

Finally, we quantify the long-term cost of the flu on the economy in terms of the lost output over the following century. We employ the *discounted present value* of all the output losses over the next 10 periods of 10 years each and express it in terms of the output in the first period

$$LTC_Y = \left(\sum_{t=1}^{10} \frac{Y_t - Y^*}{\prod_{m=1}^{t}(1+r_t)} \right) \frac{100\%}{Y^*} \tag{15}$$

where Y^* is the initial level of output and r_t is the market rate of return on capital in the corresponding period t. Using this measure, we find that the cumulative cost of the epidemic in terms of lost output over the following century is 7.16% of the initial output which indicates a tremendous cumulative effect of the flu on the economy in the long-run.

6 Conclusions

In this paper we model the medium- to long-run responses of the economy to a high mortality epidemic relying on a macroeconomic model in the absence of meaningful counterfactuals over prolonged periods of a few decades. We choose the influenza 1918–19 epidemic in Sweden for a number of reasons: first, the high and well-documented influenza-related mortality; second, the availability of high-quality data; and third, the neutrality of Sweden in the First World War, which allows us to abstract from many war-related effects.

Specifically, the dynamic overlapping generations model is based on microeconomic foundations and therefore is not subject to the Lucas (1976) critique. Agents observe changes in factor prices resulting from the capital deepening following the epidemic and adjust their optimal choices of labor supply, investment and consumption. These individual changes are then aggregated to compute the economy-wide impact.

The OLG framework allows us to identify younger survivors as main benefactors of windfall capital and quantify the distributional consequences of the flu. We also show that reliance on uniform mortality by cohort inevitable in a simpler infinite-horizon model will underestimate the true effects of the epidemic.

We find that the pandemic has a moderate positive effect on the well-being of survivors in the medium-run of 10 years. Over the same period, the aggregate variables respond inelastically to the population decline (except for labor). Finally, the pandemic has long-lasting effects on the economy and a large cost in terms of lost output.

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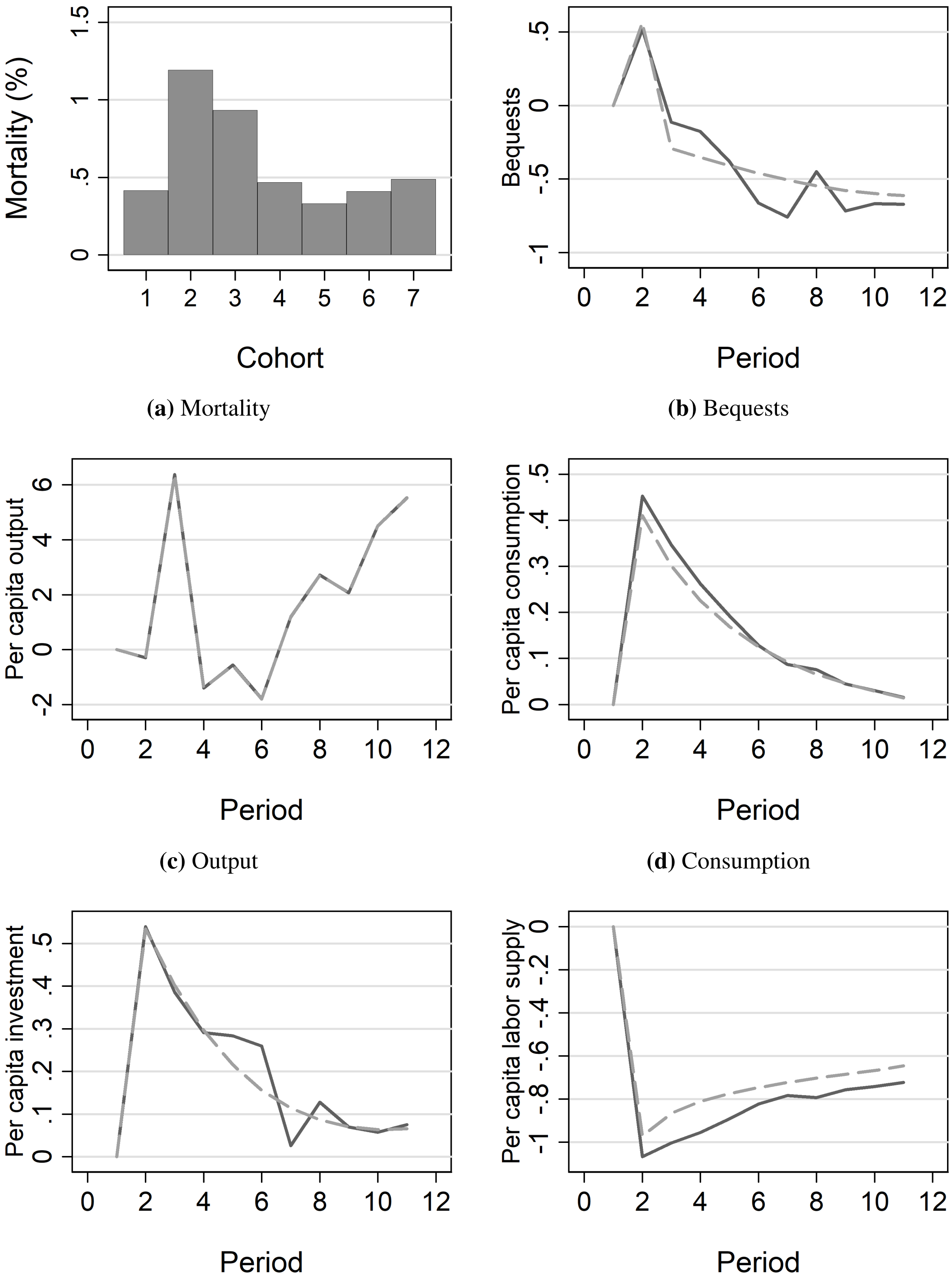
Figures



(a) Mortality **(b)** Bequests

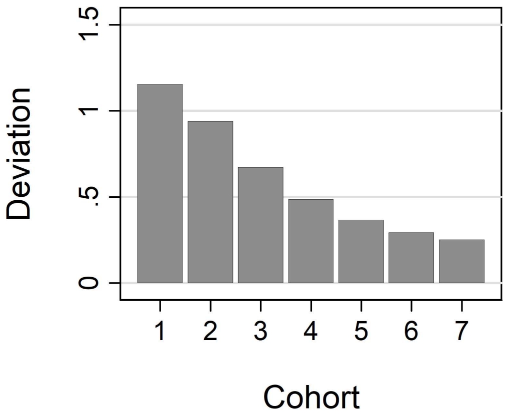
(c) Output **(d)** Consumption

(e) Investment **(f)** Labor Supply

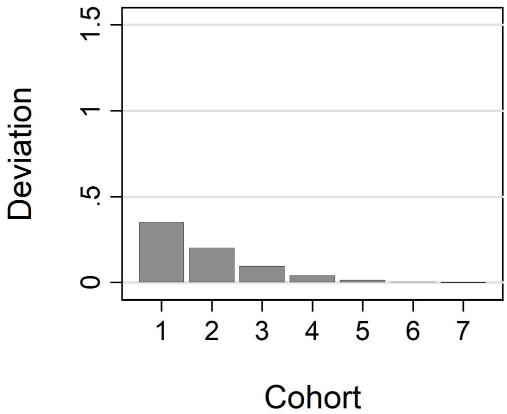
Fig. 4: Adjustment of per capita variables after the flu

Note: Each plot depict percentage deviation from the corresponding convergence path to the new steady state value.

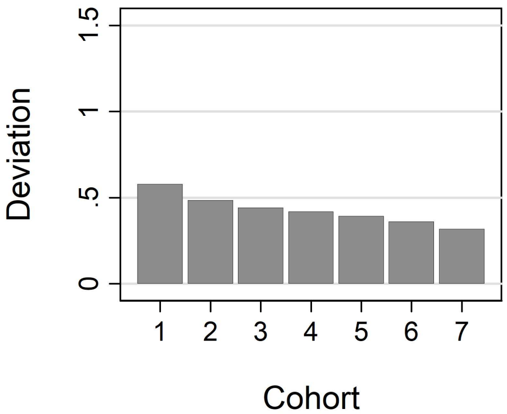
Dashed line shows the counterfactual scenario of uniform mortality across cohorts.



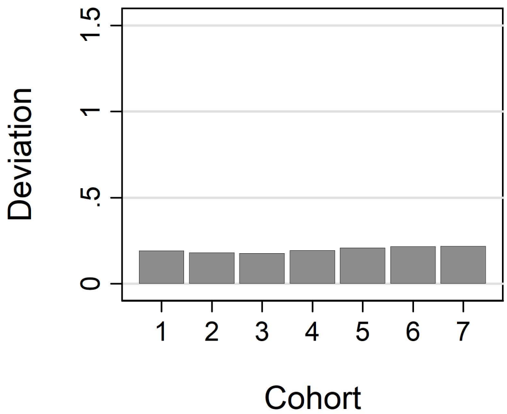
(a) Capital in Period 2



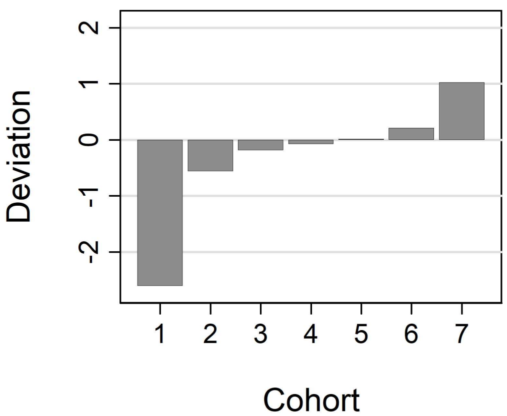
(b) Capital in Period 5



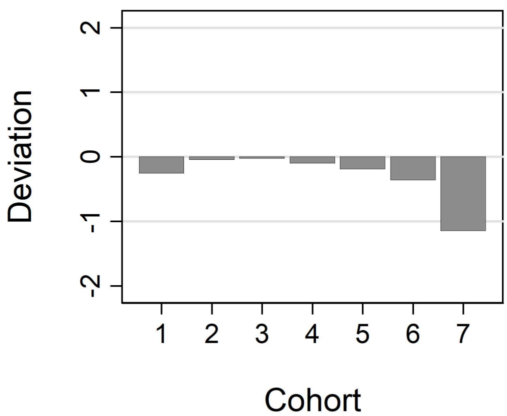
(c) Consumption in Period 2



(d) Consumption in Period 5



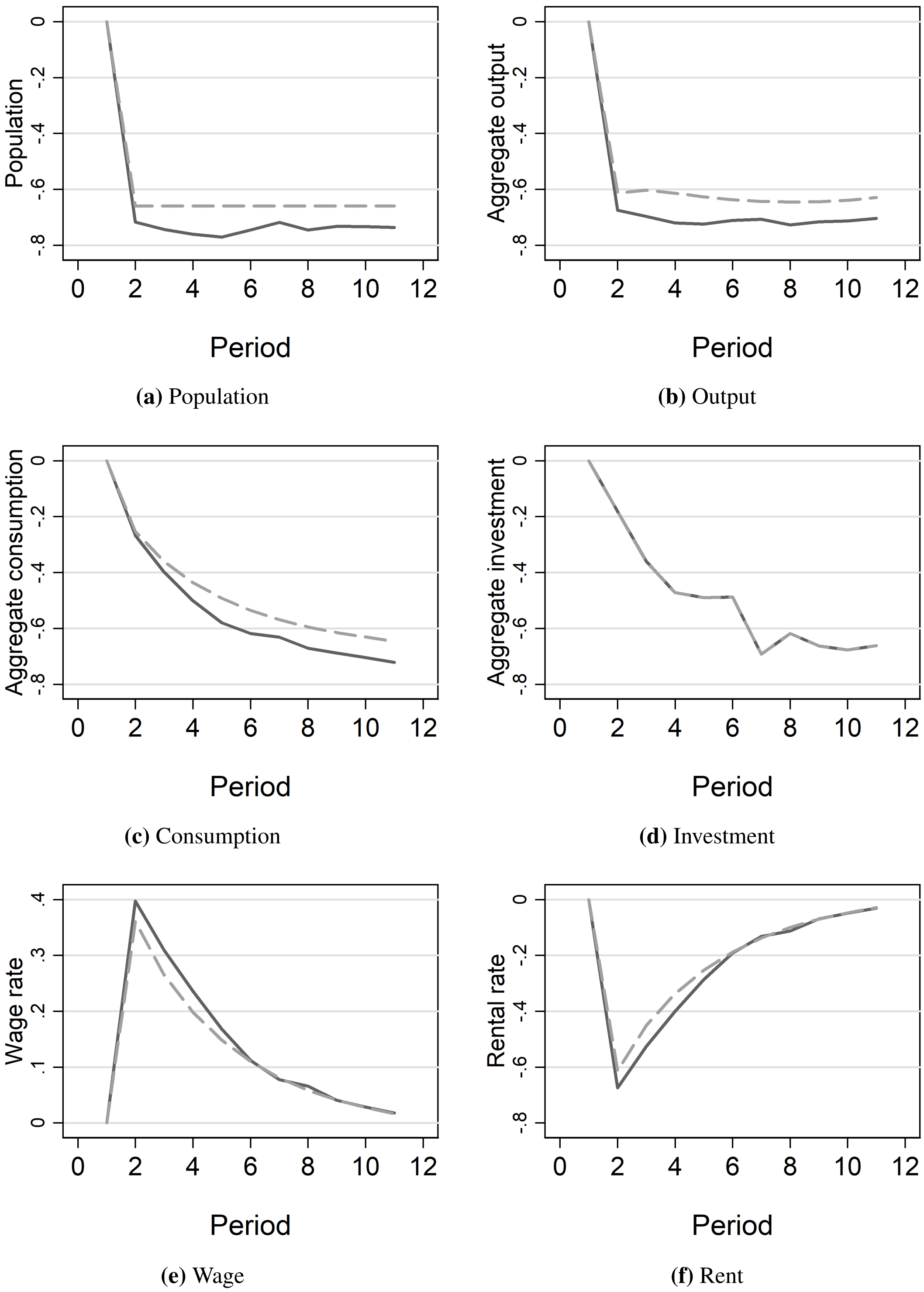
(e) Labor in Period 2



(f) Labor in Period 5

Fig. 5: Adjustments in life cycle profiles of capital, consumption and labor.

Note: Each plot depict percentage deviation from the corresponding convergence path to the new steady state value.



(a) Population **(b)** Output

(c) Consumption **(d)** Investment

(e) Wage **(f)** Rent

Fig. 6: Adjustment of aggregate variables after the flu

Note: Each plot depict percentage deviation from the corresponding convergence path to the new steady state value.

Dashed line shows the counterfactual scenario of uniform mortality across cohorts.

Appendix

Table A1: Calibration inputs

	Cohorts							
	10-20	20-30	30-40	40-50	50-60	60-70	70-80	**All**
Population, male	582,195	458,157	358,275	274,301	223,427	155,228	106,211	2,157,794
Population, female	544,381	468,887	403,062	320,476	303,422	229,936	200,276	2,470,440
LFPR, male	0.250	0.825	0.897	0.898	0.869	0.723	0.362	0.665
LFPR, female	0.131	0.396	0.229	0.187	0.167	0.130	0.099	0.206
Workers, male	145,612	378,122	321,521	246,576	194314	112257	38499	1,436,901
Workers, female	71,571	185,712	92,455	60,209	50,959	29,897	19,963	510,766
Average labor earnings, male, SEK	1501	2394	3618	4122	4136	3541	3207	3220
Average labor earnings, female, SEK	1172	1560	2023	2323	2549	2972	3015	1917
Per capita labor earnings, SEK	268	1289	1774	1944	1772	1263	599	1210
Normalized bill	0.222	1.064	1.464	1.605	1.463	1.042	0.495	1

Note: Data for Population before the pandemic are taken from Karlsson et al. (2014). The number of workers is calculated based on the LFPR taken from Census 1920 (Statistics Sweden, 1927). Average labor earnings are taken from Census 1920.

Table A2: Fertility rates

	Years									
	1918	1928	1938	1948	1958	1968	1978	1988	1998	2008
10-20	8.79	8.88	13.12	19	20.93	15.865	6.78	5.36	3.21	2.572
20-30	115.485	87.775	116.84	130.345	140.31	122.805	106.8	109.65	78.235	80.277
30-40	108.39	71.915	81.945	70.445	62.58	46.17	52.025	72.17	81.275	99.877
40-50	27.46	15.355	12.54	9.16	5.81	2.675	2.52	3.645	4.855	7.311

Note: Fertility rates per 1,000 women from official sources from (Statistics Sweden, 1927, 2009, 2018) aggregated into cohorts

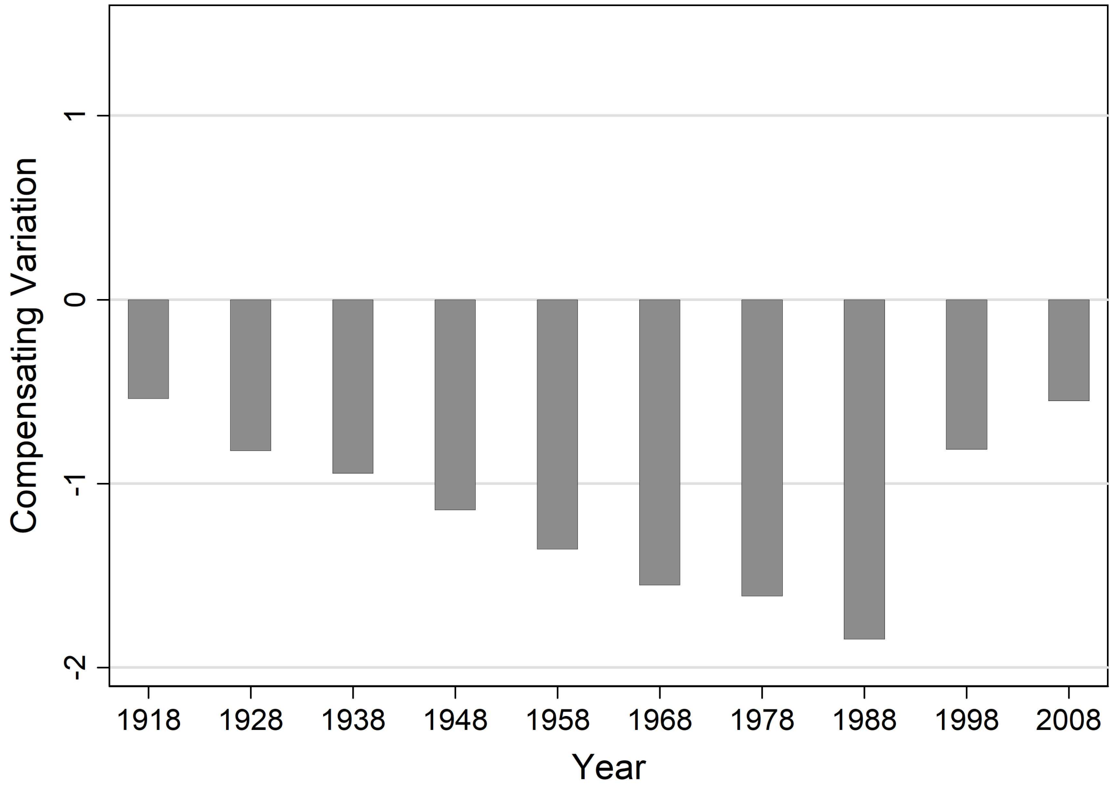


Fig. A1: Compensating Variation

Note: The horizontal axis corresponds to the last year of a generation. Compensating variation is expressed as a percent of weighted average income in the economy.

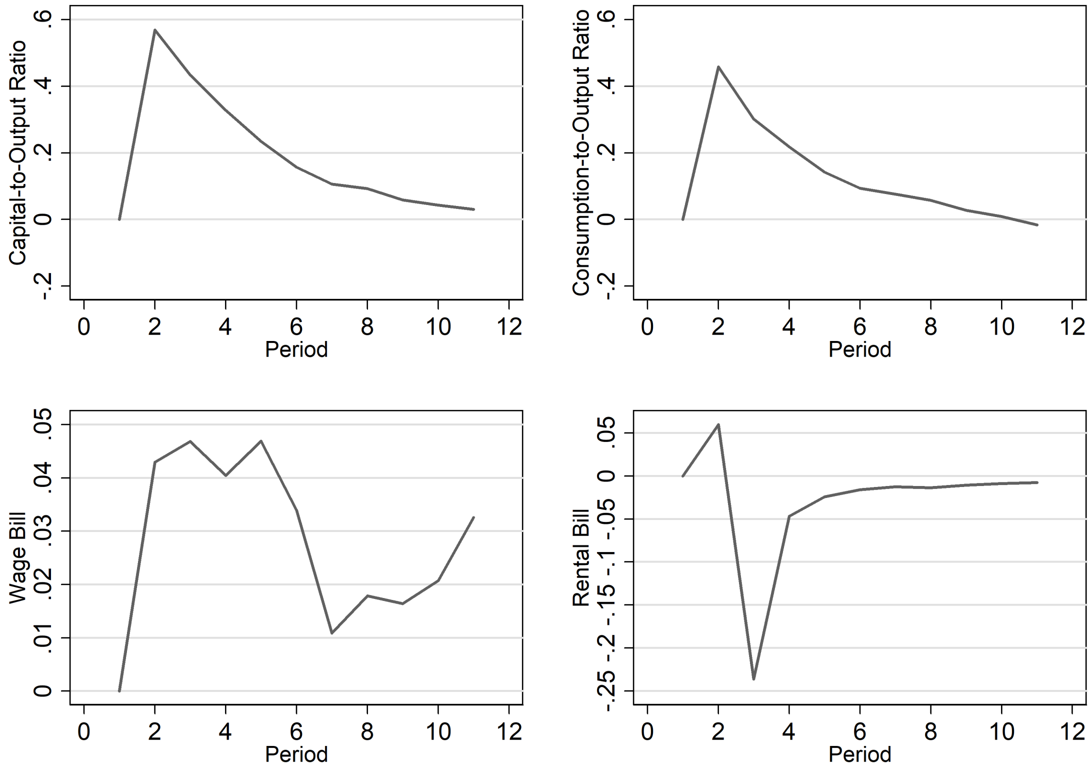


Fig. A2: Adjustment of capital-to-output, consumption-to-output ratios and factor payments after the flu.

Note: Plots depict percentage deviation from the corresponding convergence path to the new steady state value.