Longer-run economic consequences of pandemics*

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Abstract

How do major pandemics affect economic activity in the medium to longer term? Is it consistent with what economic theory prescribes? Since these are rare events, historical evidence over many centuries is required. We study rates of return on assets using a dataset stretching back to the 14th century, focusing on 15 major pandemics where more than 100,000 people died. In addition, we include major armed conflicts resulting in a similarly large death toll. Significant macroeconomic after-effects of the pandemics persist for about 40 years, with real rates of return substantially depressed. In contrast, we find that wars have no such effect, indeed the opposite. This is consistent with the destruction of capital that happens in wars, but not in pandemics. Using more sparse data, we find real wages somewhat elevated following pandemics. The findings are consistent with pandemics inducing labor scarcity and/or a shift to greater precautionary savings.

JEL classification codes: E43, F41, N10, N30, N40.

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1. Introduction

Little is known about the medium- to long-term macroeconomic effects of global pandemics. But the recent COVID-19 outbreak places more urgency on trying to gauge the likely economic fallout. In this paper we use the history of pandemics and rates of return since the 14th century to shed light on this problem.

Most attention has understandably focused on short-term impacts. Even then, direct measures based on data from past episodes are not generally available (e.g., in the U.S. Meltzer, Cox, and Fukuda, 1999). An alternative would be to look at realized microeconomic outcomes of a given population in countries and episodes for which high-quality administrative data are available (e.g., in Sweden Karlsson, Nilsson, and Pichler, 2014).

Absent such data, economic historians are forced to use more aggregated data at the regional or national level to study the relationship between pandemic incidence and economic outcomes (e.g., the 1918 flu epidemic across U.S. states Brainerd and Siegler, 2003). But again, most historical studies have typically focused on one event in one country or region and have traced local outcomes for up to a decade at most.

Of course, the most devastating pandemic of the last millennium, the Black Death, has attracted a great deal of attention. Economists and historians debate its pivotal role in economic, social, and political change, particularly in Europe. Events such as the Peasant Rebellion in England feature centrally in a narrative of rising worker power, and the data speak to a rise in labor scarcity seen in a positive deviation in the path of real wages. This shock left England with a 25% to 40% drop in labor supply, a roughly 100% increase in real wages, and a decline in rates of return on land from about 5% to 8% (Clark, 2007, 2010). But it is an open question how representative the macroeconomic responses in the case of the Black Death are of large pandemics in general.

Here we take a more global view of the macroeconomic consequences of pandemics, and we aim to study the average effect of pandemics across all major events since the Black Death, looking at outcomes up to 40 years out. In large scale pandemics, effects will be

Table 1: *Fifteen large pandemic events with at least 100,000 deaths*

Event	Start	End	Deaths
Black Death	1347	1352	75,000,000
Italian Plague	1623	1632	280,000
Great Plague of Sevilla	1647	1652	2,000,000
Great Plague of London	1665	1666	100,000
Great Plague of Marseille	1720	1722	100,000
First Asia Europe Cholera Pandemic	1816	1826	100,000
Second Asia Europe Cholera Pandemic	1829	1851	100,000
Russia Cholera Pandemic	1852	1860	1,000,000
Global Flu Pandemic	1889	1890	1,000,000
Sixth Cholera Pandemic	1899	1923	800,000
Encephalitis Lethargica Pandemic	1915	1926	1,500,000
Spanish Flu	1918	1920	100,000,000
Asian Flu	1957	1958	2,000,000
Hong Kong Flu	1968	1969	1,000,000
H1N1 Pandemic	2009	2009	203,000

Source: Alfani and Murphy (2017), Taleb and Cirillo (2020), `https://en.wikipedia.org/wiki/List_of_epidemics` and references therein.

felt across whole economies, or across wider regions, for two reasons: either because the infection itself is widespread, or because trade and market integration—in capital and/or labor markets—eventually propagates the economic shock across the map.

To that end, our focus will be mainly on European pandemics since macroeconomic data are only available in this region before modern times. We study rates of return on assets using a dataset stretching back to the 14th century, focusing on 15 major pandemic episodes where more than 100,000 people died. We also look at some more limited evidence on real wages. These events are listed in Table 1.

To put these historical pandemics in context, the scenarios contemplated by Ferguson et al (2020) place COVID-19 as the most serious episode since the 1918 pandemic. Absent non-pharmaceutical interventions, these researchers estimate the death toll at 510,000 in Britain and 2.2 million in the U.S. Aggressive and recurrent suppression strategies would reduce the death toll only by a factor of 10 approximately, according to these authors.[1] Worldwide, that could still leave COVID-19 as the second most devastating event of the

[1]However, the uncertainty around these estimates is quite large. Also, the ability and willingness of some countries to actually implement and sustain such suppression strategies properly is open to question.

past 100 years. At the time of this writing, global deaths already totaled over 20,000, with the infection peak still weeks away.

Our main interest will be in the response of the real natural rate of interest to a pandemic shock. Introduced by Wicksell, and central to modern macroeconomic theory and empirics (Laubach and Williams, 2003; Wicksell, 1898; Woodford, 2003), the natural rate of interest is the level of real returns on safe assets which equilibrates savings supply and investment demand—while keeping prices stable—in an economy. Such an ideal equilibrium variable can therefore serve as a useful barometer of medium-term fluctuations in economic dynamism.

In the very long run, from century to century, this variable may drift slowly for technological, political, or institutional reasons. But over a horizon of around 10–20 years, medium-term deviations will dominate. Economic theory presumptively indicates that pandemics could be felt in transitory downward shocks to the natural rate over such horizons: investment demand is likely to wane, as labor scarcity in the economy suppresses the need for high investment. At the same time, savers may react to the shock with increased saving, either behaviorally as new precautionary motives kick in, or simply to replace lost wealth used up during the peak of the calamity.[2]

2. Data

To study the macroeconomic responses to historic pandemic events, we use data collected over many years collectively by many economic historians and pulled together gradually to form continuous time series measuring economic performance at annual frequency in cities, regions, and countries from the 14th century to the present.

Historical interest rates from 1314 to 2018 compiled by Schmelzing (2020) are available at the Bank of England's data repository. We refer the reader to this source for further details on data sources. The dataset covers France (1387–2018), Germany (1326–2018), Italy (1314–

[2]Formally, in the canonical Ramsey (1928) model of neoclassical growth, it can be shown that population slowdown or greater preference to save can each depress the natural rate (Rachel and Smith, 2017).

2018), the Netherlands (1400–2018), Spain (1400–1729, 1800–2018), and the U.K. (1314–2018). European real interest rates are constructed by weighting real interest rates on long-term debt in these advanced economies by GDP shares (Maddison, 2010). The underlying assets are debt contracts "which are not contracted short-term, which are not paid in-kind, which are not clearly of an involuntary nature, which are not intra-governmental, and which are made to executive political bodies." More limited data on real wages for the U.K. from 1311 to 2016 come from the real consumption wage series of Clark (2007) extended by Thomas and Dimsdale (2017) and available at the Bank of England data repository. For France, Germany, Italy, Netherlands, and Spain, we obtain real wages from Allen (2001) available at the IISH List of Datafiles of Historical Prices and Wages.

3. Empirical design

Pandemics, like many other natural disasters, offer a unique opportunity to study how economies work. They have much in common with a randomized control trial, but at a much larger scale. Not surprisingly, our empirical approach shares similar features with such a trial. Specifically, we use history as a guide of how the future usually unfolds, then compare that prediction to how the future unfolded following pandemics. Microbiology turns out to be a natural random assignment mechanism.

Specifically, given what we observe, and using a historical sample, one can easily construct the expected value of a future outcome of interest. Similarly, one can compute the expectation of that same outcome with the added fact that a pandemic has also taken place. This is the key idea behind the local projections estimator that we use (Jordà, 2005).

In particular, we characterize the response of the natural rate to a pandemic as

$$\hat{\tau}(h) = E(r^*_{t+h} - r^*_t | P_t = 1\,;\,\Omega_t) - E(r^*_{t+h} - r^*_t | P_t = 0\,;\,\Omega_t)\,, \tag{1}$$

where $r^*_{t+h} - r^*_t$ refers to the change in the natural rate from the year the pandemic ends to a future time h years later. P_t is a dummy variable that is 1 if there is a pandemic ending in year t, and is 0 otherwise, and Ω_t refers to the information set available at time t.[3]

We estimate $\hat{\tau}(h)$ using local projections, specifically, using the set of regressions:

$$r^*_{t+h} - r^*_t = \alpha^h + \beta^h P_t + \sum_{l=1}^{L} \rho^h_l r^*_{t-l} + e^h_{t+h} \; ; \; h = 1, ..., H \,, \tag{2}$$

where clearly $\hat{\tau}(h) = \hat{\beta}_h$. We choose 10 lags ($L$ = 10) though the estimate $\hat{\beta}_h$ is unbiased whether we include these controls or not.[4]

Our estimate of the natural rate of interest, r^*_t, is based on the following simple model given the data that is available:

$$\begin{aligned} r_t &= r^*_t + u_t \,, \\ r^*_t &= r^*_{t-1} + v_t \,. \end{aligned} \tag{3}$$

Here, the natural rate is a latent unobserved variable that follows a random walk. Such a model is flexible enough to capture any secular trends without the need to specify them directly. The observed rate of interest r fluctuates around the natural rate r^*. The error terms are assumed to be Normal and Equation 3 can be estimated using the Kalman filter and maximum likelihood methods.

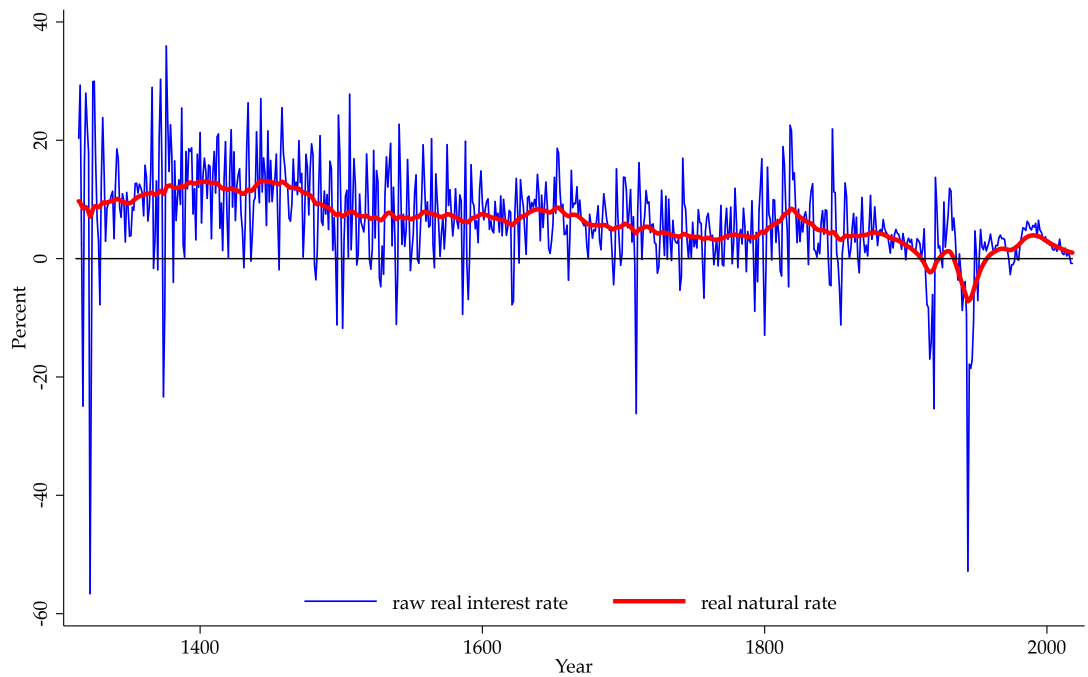
4. Results

These tools deliver the estimate of the natural rate shown in Figure 1, based on an aggregate using data from France, Germany, the Netherlands, Italy, Spain and the U.K. We simply call this aggregate "Europe." The figure displays the raw data on interest rates, along

[3] Pandemics sometimes last for more than one year. We adopt as a timing convention the year they end.

[4] Note that because pandemics are unpredictable and completely exogenous to the economy, we could omit Ω_t from the conditioning information set. $\hat{\tau}(h)$ would still be unbiased. Including right-hand side information improves the efficiency of the estimator. In other instances, when treatment is determined by observables, this will not be true. Thus $\hat{\tau}(h)$ is basically the cumulative Average Treatment Effect of the pandemic on interest rates, h periods later.

Figure 1: *The European real natural rate of interest, 1315–2018*

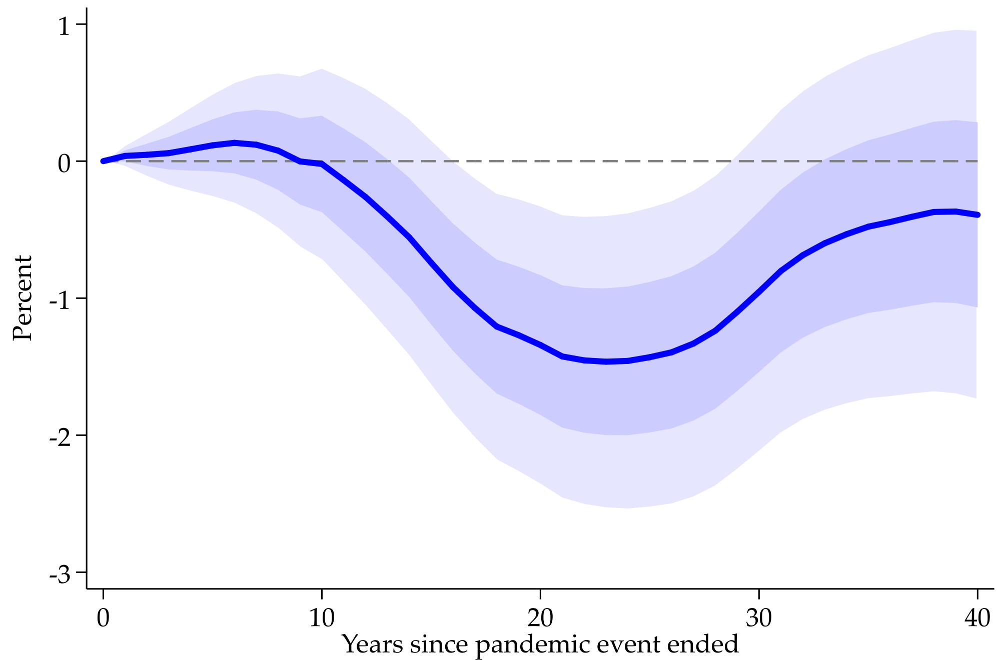


Notes: Raw interest data from Schmelzing (2020). The real rate is based on the model in Equation 3. See text.

with our estimate of the natural rate of interest. Our estimates of the natural rate show the now well documented pattern of a secular decline over the span of centuries, from about 10% in medieval times, to 5% at the start of the industrial revolution, and nowadays hovering near 0%. It is easy to see that our estimate of the natural rate goes a long way towards addressing the considerable annual noise that we observe in the raw data. In large part these reflect wild fluctuations in harvests, armed conflict, and other events to which pre-industrial societies were exposed to a much greater degree than today. With industrialization and modern finance, those fluctuations diminished considerably.

Figure 2 contains our main result, and displays $\hat{\tau}(h)$, the response of the natural rate to a pandemic, 1 to 40 years into the future. Pandemics have effects that last for decades. Following a pandemic, the natural rate of interest declines for decades thereafter, reaching its nadir about 20 years later, with the natural rate about 150 bps lower had the pandemic not taken place. At about four decades later, the natural rate returns to the level it would

Figure 2: *Response of the European real natural rate of interest following pandemics*



Notes: Response calculated using Equation 2. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

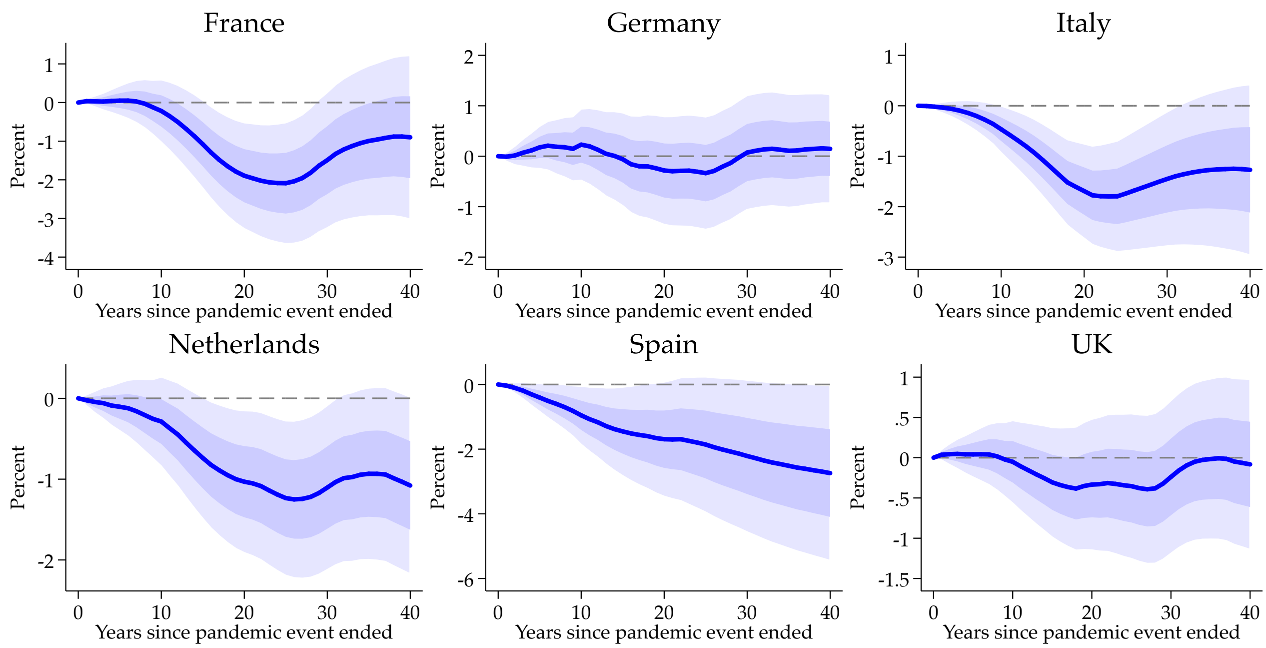
be expected to have had the pandemic not taken place.

These results are staggering and speak of the disproportionate effects on the labor force relative to land (and later capital) that pandemics had throughout centuries. It is well known that after major recessions cased by financial crises, history shows that real safe rates can be depressed for 5 to 10 years (Jordà, Schularick, and Taylor, 2013), but the responses here display even more pronounced persistence.

However, did all countries in the Europe aggregate experience pandemics in the same manner? To answer that question, we turn to Figure 3 where we present similar responses of the natural rate for each of the component economies: France, Germany, Italy, the Netherlands, Spain, and the U.K.

The heterogeneity of the responses turns out to be quite striking. At one end we have countries like France, Italy, and Spain where the effects of pandemic are much larger (3–4% for France, Italy and Spain) in contrast to the Anglo-Saxon bloc of the Germany, the Netherlands and the U.K., with far more modest effects on the natural rate.

Figure 3: *Country-specific response of the real natural rate of interest following pandemics*



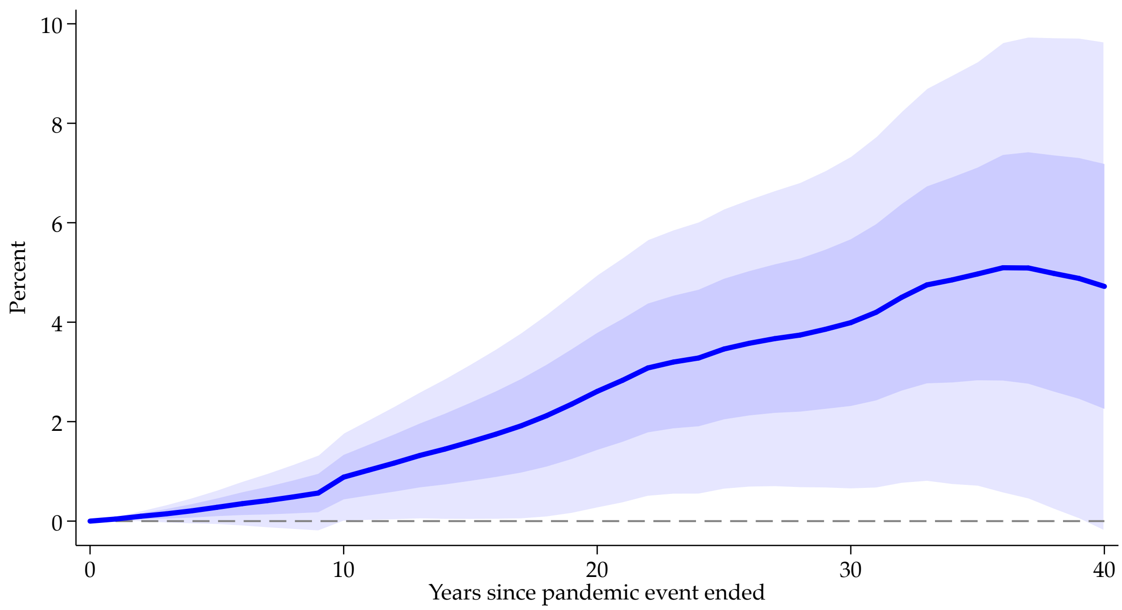
Notes: Responses calculated using Equation 2. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

This heterogeneity reflects, among other explanations, the timing of the pandemics across countries, the relative exposure of each country to the pandemic, the relative size of the working population, and how industrialized each economy was relative to one another.

By defining pandemics as events with 100,000 deaths or more, we identified episodes with large contractions in the labor force and, hence, the ratio of labor to capital. We see this as one explanation for the response of interest rates. If so, we should see a countervailing response in real wages. To explore whether this is indeed the case, we use a similar local projection estimator in Figure 4 where instead of the real interest rate, we use real wages in the left-hand side and in the control set.

The response of real wages is almost the mirror image of the response of the natural rate of interest, with its effects being felt over decades. The figure shows that real wages gradually increase until about three decades after the pandemic, where the cumulative deviation in the real wage peaks at about 5%. These results match the predictions of the

Figure 4: *The response of real wages in Europe following pandemics*



Notes: Response calculated using Equation 2. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

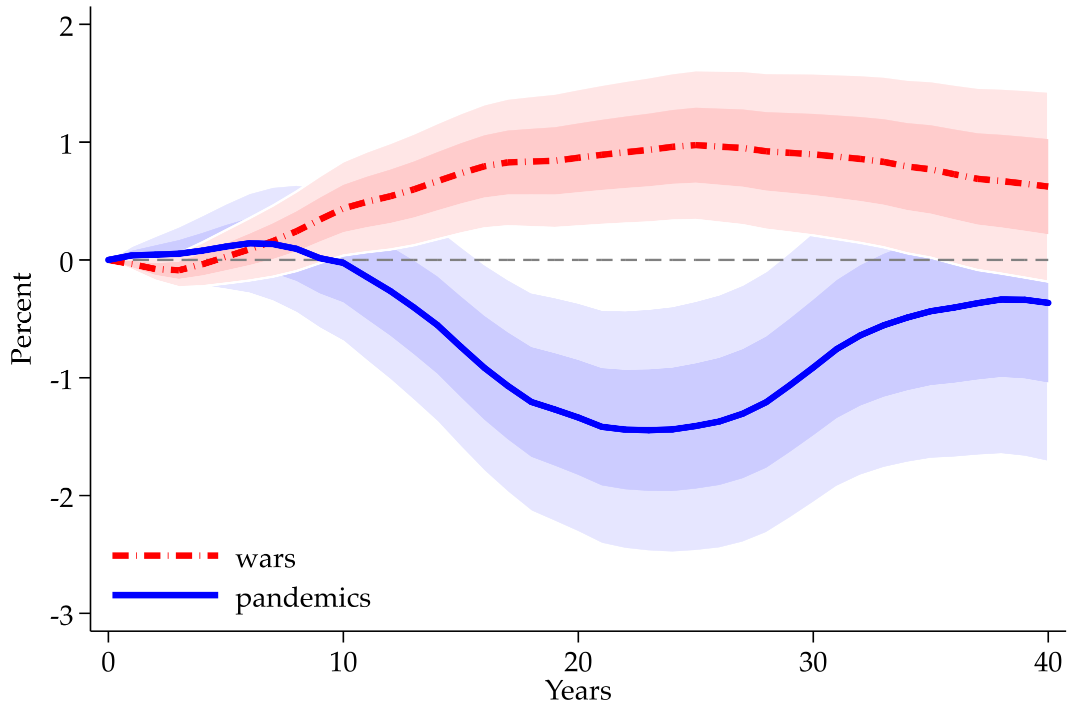
neoclassical model, and accord with historical narratives: the Black Death induced labor scarcity in the European economy, and pushed real wages up. In equilibrium, this went hand in hand with lower returns to capital.

5. Pandemics versus wars

A natural concern might be omitted variables, specifically the historical occurrence of other macro-salient events that could persistently disturb real interest rates. One obvious concern is war. A clear confounding potential stems from the privations of wartime conditions which make diseases more likely. For example, a plague, possibly the first recorded influenza outbreak, occurred among the Athenians during the Peloponnesian War (Thucydides, 2.47–54). However, the correlation of war and disease outbreaks is not exactly one.

On the other hand, for the economic indicator of interest in this study, the bias could easily go the other way. Sovereign bond markets were to a large degree an innovation whose mother was military necessity, and the fiscal state had perhaps its most important

Figure 5: *Response of the European real natural rate of interest following pandemics and wars*



Notes: Response calculated using Equation 4. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

role as an instrument of war (Brewer, 1990). Yet here the burden of raising large sums via debt finance could just as easily imply higher real interest rates via conventional crowding out arguments, or via risk-premium (e.g., default) channels, or simply due to capital scarcity created by wartime physical capital destruction (a feature absent in pandemics).

To address this concern here we control for wars, by using an indicator variable War_t which is set equal to one in any year in which war-time deaths in Europe exceed 20,000. We obtain the war-time military personnel casualties from Schmelzing (2020) dataset who draws data from Table 4.1 in Levy (1983).[5,6]

We then estimate an augmented local projection, now including the contemporaneous

[5]Total number of battle deaths are divided by duration of the battle (in years) to obtain an annual series of battle deaths. Since battles lasted more than a year, sometimes more than a decade, we think 20,000 deaths per year is comparable to the pandemic death toll threshold of 100,000 we employ.

[6]Readers interested in the debate on severity of pre 19th century epidemics may refer to Alfani and Murphy (2017), Roosen and Curtis (2018) and Biraben (1975) among others.

and lagged values of this indicator:

$$r^*_{t+h} - r^*_t = \alpha^h + \beta^h P_t + \gamma^h War_t + \sum_{l=1}^{L} \rho^h_l r^*_{t-l} + \sum_{l=1}^{L} \phi^h_l War_{t-l} + e^h_{t+h} \; ; \; h = 1, ..., H \,, \quad (4)$$

there the lags of the war variable are present as controls, and the coefficients γ^h are the impulse response of the real interest to a war event in year 0.

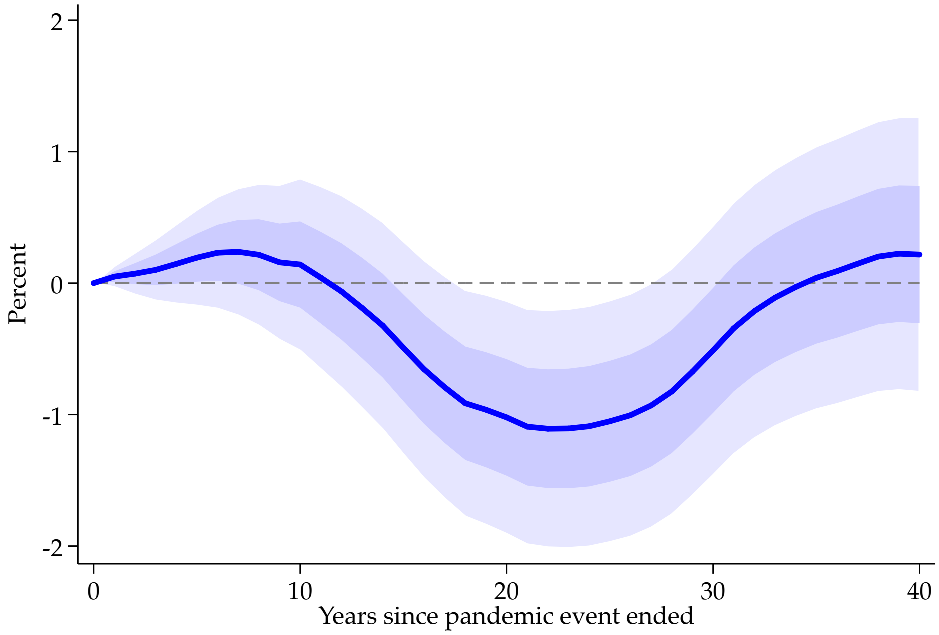
Figure 5 shows the result of this exercise. Our main finding is robust. The dynamic response of the real natural rates to pandemics is as before, and even slightly amplified: lowered for 30–40 years and in a statistically significant way. As we anticipated, the effect of war activity goes the other way: wars tend to leave real interest rates elevated for 30–40 years and in an economically (and statistically) significantly way.

6. Robustness

Robustness to possible major trend breaks Schmelzing (2020) notes three historical dates at which the trend for the real interest rate could have changed. These are associated with "post-Bullion famine" following the end of the global monetary contraction (1494), the "North-Weingast" institutional revolution that led to emergence of credible debt mechanisms in Britain (1694), and the "post-Napoleonic" trend due to the founding of the modern international state system (1820). Although the state-space model from Equation 3 is sufficiently flexible, to confirm that our results are not affected by such shifts, we now add controls for linear time trends starting at these historical dates. Figure 6 plots the new estimated impulse response of the European real natural interest rate following a pandemic event. As the figure shows, our baseline result is largely unchanged. The trough happens at about the same value (almost 2%) and at around the same time.

Robustness when excluding the Black Death and the Spanish Flu events Figure 7 contains two additional robustness checks. In Figure 7a, we verify that our results are not significantly affected by the Black Death by omitting this episode (i.e., setting the indicator

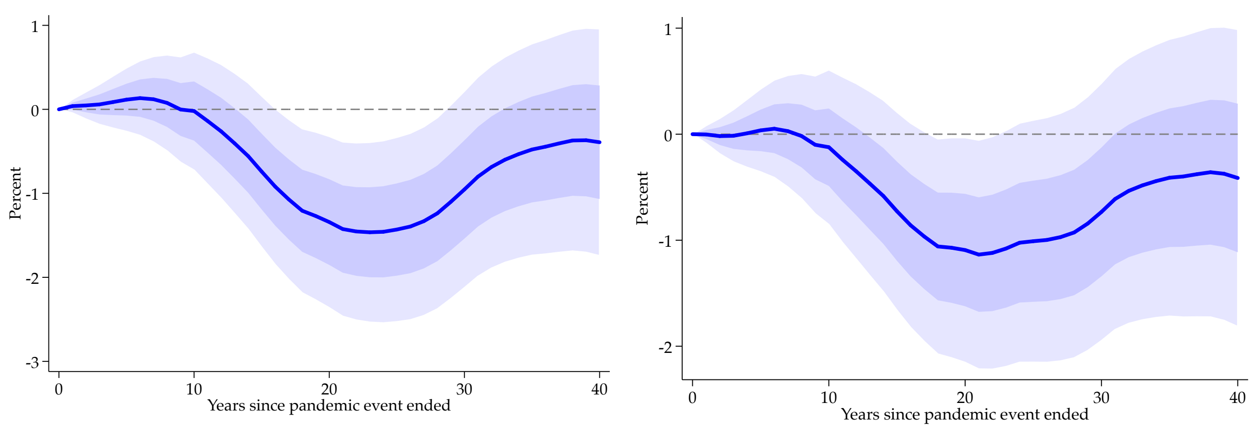
Figure 6: *Response of the European real natural rate of interest allowing for trend breaks*



Notes: Response calculated using Equation 2. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

Figure 7: *Response of the European real natural rate of interest following pandemics,*

(a) *excluding the Black Death* **(b)** *excluding the 1918 Spanish Flu*



Notes: Response calculated using Equation 2. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

to zero). Similarly, since the Great Depression followed the Spanish flu a decade later, one might be concerned that the decline in the natural interest rate was due to the Great Depression and not the Spanish flu. Thus, in Figure 7b, we omit this pandemic from the sample. The main results are largely unaffected by omitting either of these two events.[7]

7. Conclusions

Summing up our findings, the great historical pandemics of the last millennium have typically been associated with subsequent low returns to assets, as far as the limited data allow us to conclude. These responses are huge. Smaller responses are found in real wages, but still statistically significant, and consistent with the baseline neoclassical model.

Measured by deviations in a benchmark economic statistic, the real natural rate of interest, these responses indicate that pandemics are followed by sustained periods—over multiple decades—with depressed investment opportunities, possibly due to excess capital per unit of surviving labor, and/or heightened desires to save, possibly due to an increase in precautionary saving or a rebuilding of depleted wealth.

Either way, if the trends play out similarly in the wake of COVID-19—adjusted to the scale of this pandemic—the global economic trajectory will be very different than was expected only a few weeks ago. If low real interest rates are sustained for decades they will provide welcome fiscal space for governments to mitigate the consequences of the pandemic. The major caveat is that past pandemics occurred at time when virtually no members of society survived to old age. The Black Death and other plagues hit populations with the great mass of the age pyramid below 60, so this time may be different.

[7]Furthermore, three historical pandemic events (London, Seville and Marseille) presented in Table 1 are largely localized at city level than the wider European region. One may surmise that local shocks attenuate the effects on the aggregate Europe real natural interest rate. In additional robustness, we corroborate this intuition by omitting London, Seville and Marseille plagues (i.e., setting the indicator to zero). The peak decline in real natural interest rate is about 185 basis points with global events. Results available on request.

References

Alfani, Guido, and Tommy E. Murphy. 2017. Plague and Lethal Epidemics in the Pre-Industrial World. *The Journal of Economic History* 77(1): 314–343.

Allen, Robert C. 2001. Consumer price indices, nominal/real wages and welfare ratios of building craftsmen and labourers, 1260–1913. International Institute of Social History.

Biraben, Jean-Noël. 1975. *Les hommes et la peste en France et dans les pays européens et méditerranéens. Tome I: la peste dans l'histoire*. Mouton, Paris.

Brainerd, Elizabeth, and Mark Siegler. 2003. The Economic Effects of the 1918 Influenza Epidemic. CEPR Discussion Paper 3791.

Brewer, John. 1990. *The Sinews of Power: War, Money, and the English State, 1688–1783*. Cambridge, Mass.: Harvard University Press.

Clark, Gregory. 2007. The long march of history: Farm wages, population, and economic growth, England 1209–1869. *The Economic History Review* 60(1): 97–135.

Clark, Gregory. 2010. The macroeconomic aggregates for England, 1209–2008. *Research in Economic History* 27: 51–140.

Ferguson, Neil, et al. 2020. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf.

Jordà, Òscar. 2005. Estimation and inference of impulse responses by local projections. *American Economic Review* 95(1): 161–182.

Jordà, Òscar, Moritz Schularick, and Alan M. Taylor. 2013. When credit bites back. *Journal of Money, Credit and Banking* 45(s2): 3–28.

Karlsson, Martin, Therese Nilsson, and Stefan Pichler. 2014. The impact of the 1918 Spanish flu epidemic on economic performance in Sweden: An investigation into the consequences of an extraordinary mortality shock. *Journal of health economics* 36(C): 1–19.

Laubach, Thomas, and John C. Williams. 2003. Measuring the natural rate of interest. *Review of Economics and Statistics* 85(4): 1063–1070.

Levy, Jack S. 1983. *War in the Modern Great Power System: 1495–1975*. Lexington, Ky.: University Press of Kentucky.

Maddison, Angus. 2010. Historical statistics on world population, GDP and Per Capita GDP, 1–2008 AD. University of Groningen.

Meltzer, Martin I., Nancy J. Cox, and Keiji Fukuda. 1999. The economic impact of pandemic influenza in the United States: priorities for intervention. *Emerging Infectious Diseases* 5(5): 659–671.

Rachel, Łukasz, and Thomas D. Smith. 2017. Are low real interest rates here to stay? *International Journal of Central Banking* 13(3): 1–42.

Ramsey, Frank Plumpton. 1928. A mathematical theory of saving. *Economic Journal* 38(152): 543–559.

Roosen, Joris, and Daniel R Curtis. 2018. Dangers of noncritical use of historical plague data. *Emerging infectious diseases* 24(1): 103.

Schmelzing, Paul. 2020. Eight centuries of global real interest rates, RG, and the 'suprasecular'decline, 1311–2018. Bank of England Staff Working Paper 845.

Taleb, Nassim Nicholas, and Pasquale Cirillo. 2020. Tail Risk of Contagious Diseases. RESEARCHERS.ONE, https://www.researchers.one/article/2020-03-17.

Thomas, Ryland, and Nicholas Dimsdale. 2017. A Millennium of UK Data: Bank of England OBRA dataset.

Thucydides. 1881. *History of the Peloponnesian War*. Oxford: Clarendon Press. Edited and translated by Benjamin Jowett.

Wicksell, Knut. 1898. *Interest and Prices: A Study of the Causes Regulating the Value of Money*. Jena: Gustav Fischer.

Woodford, Michael. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton, N.J.: Princeton University Press.