EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Roberto A. De Santis, Wouter Van der Veken

Macroeconomic risks across the globe due to the Spanish Flu

No 2466 / September 2020

Abstract

We characterise the distribution of expected GDP growth during the Great Influenza Pandemic (known also as Spanish Flu) using a non-linear method in a country panel setting. We show that there are non-negligible risks of large GDP losses with the 5% left tail of the distribution suggesting a drop in the typical country's real per capita GDP equal to 29.1% in 1918, 10.9% in 1919 and 3.6% in 1920. Moreover, the fall in per capita GDP after the Spanish flu was on average particularly large in low-income countries. Particularly, the size of the GDP drop in the lower tail of the distributions is high for higher income countries and immense for lower income countries. As for the United States, the estimated size of the recession in the lower tail of the distribution following the Spanish flu is not negligible.

Keywords: Spanish flu, Pandemic disease, Macroeconomic risks, Non-linear models
JEL Classification: E3, I0

Non-technical summary

Assessing the economic consequences of the spread of the new coronavirus disease (Covid-19) in the world in 2020 is a challenge for the economic profession. The unprecedented nature and global scale of a pandemic renders traditional linear tools ill-suited for macroeconomic monitoring, including the monitoring of macroeconomic risk.

We try to gain insights from the 1918-1920 Great Influenza Pandemic (known also as Spanish flu); arguably the only precedent for a global pandemic that the world has seen in modern history. To address the question, we use a non-linear model in a country panel setting covering all major countries in the world, which are two key features characterizing pandemic diseases. Specifically, we estimate the macroeconomic risks of the pandemic using as exogeneous regressors the cross-country death rates due to the Spanish Flu, after controlling for the death rates due to the World War I.

Barro et al. (2020) show that the loss in terms of real per capita GDP for a typical country due to the Spanish flu amounts to 6.0% cumulated over the three year period 1918-1920. Using the non-linear panel model, we corroborate the cumulated drop in economic activity of about 7.2% for the typical country due to the pandemic disease, about 70% of the economic damage occurring in the first year. But, additionally, we can study the downside risks. We show that the economic costs associated to the pandemic can be very high, with the 5% left tail of the distribution suggesting a drop in the typical country's real per capita GDP amounting to 29.1% in 1918, 10.9% in 1919 and 3.6% in 1920, most of the real risk occurring in the first year.

The pandemic flu can have an adverse distributional impact across countries, because it has a disproportionate burden on low-skilled workers and because infection diseases and their associated death toll can spread more rapidly in lower income countries given the high healthcare costs and public spending needed to contain the virus. We estimate that the expected real income loss due to the pandemic is more than double for the typical lower income country compared to the typical higher income country every year between 1918 and

1920. The expected income loss cumulated over the three periods amounts to 10.9% for the typical lower income country and 4.7% for the typical higher income country; thereby causing an increase in income inequality.

The downside risks associated to the pandemic are also confirmed to be large for higher income countries and are immense for the lower income countries. The macroeconomic risks amount to the extraordinary fall of real per capita GDP in 1918 of 52.1% for the typical lower income country and 15.3% for the typical higher income country.

As for the United States, the literature has argued that the recession during the Spanish flu was mild in the US. Given the central tendency of our results, we would also agree. However, the estimated macroeconomic risks due to pandemic are non-negligible cumulated over the period 1918-1920.

These potential extreme economic losses, which a country could face, can explain the prompt and large fiscal and monetary policy interventions globally after the spread of the Covid-19 disease in 2020. Although the mortality rate due to the Covid-19 pandemic will be much lower, due to the health infrastructure, the stringent lockdown measures and the general knowledge about the disease, the insights from the Spanish flu should not be dismissed, as both periods share the countries' adoption of social distancing measures (in terms of restrictions on economic activity and travelling imposed or self-imposed). The Covid-19 pandemic is a disaster risk and the insights from the Spanish flu are telling: the risk of a sharp fall in economic activity in 2020 close to two digits due to the Covid-19 is real. Similarly, our results support the view of international economic organizations, such as the World Bank and the United Nation Development Programme (UNDP), which argue that the Covid-19 pandemic will leave deep scars in lower income countries, unless urgent policy action is taken with support from the international community.

I Introduction

Assessing the macroeconomic risks across countries associated to a pandemic disease is of paramount importance, because the associated welfare losses could be relevant. We estimate the macroeconomic risks in lower and higher income countries during the Great Influenza Pandemic (known also as Spanish Flu), which began in 1918 and persisted until 1920. Pandemic outbreaks are rare events generating non-normal economic effects in many countries of the world.[1] Therefore, we estimate the macroeconomic risks of the pandemic by employing a non-linear model in a country panel setting and by using as exogeneous regressors the cross-country death rates due to the Spanish Flu, after controlling for the death rates due World War I (see Barro et al., 2020).

Traditional linear macroeconomic tools are ill-suited to address the economic risks, because downside risk can be measured by the left-tail of the conditional distribution of economic growth (Giglio et al., 2016; Adrian et al., 2019; Chavleishvili and Manganelli, 2019; Plagborg-Møller et al., 2020; Figueres and Jarociński, 2020; De Santis and Van der Veken, 2020). Therefore, we estimate a non-linear model using quantile regressions and the flexible skewed-t distribution, which is indexed over four parameters that trace the mean, variance, skewness and kurtosis of the distribution. The non-linear approach can uncover and quantify the extent to which a reduction in the conditional expectation of economic activity due to a pandemic is associated with an increased potential of very negative growth outcomes. We show that the uncertainties associated with a pandemic are large. In addition to significantly reducing economic activity globally with more adverse effects in lower income countries, the Spanish flu also caused a strong increase in macroeconomic risks across the globe, which were massive in lower income countries.

Barro et al. (2020) show that the loss in terms of real per capita GDP for a typical country due to the Spanish flu amounts to 6.0% cumulated over the three year period 1918-

[1] Disaster risks are associated to non-normal shocks, whose implications for asset prices, consumption and welfare have been investigated by the literature (see, e.g., Barro, 2006, 2009; Barro and Jin, 2011; Berkman et al., 2011; Barro and Ursúa, 2012; Gabaix, 2012; Nakamura et al., 2013; Farhi and Gabaix, 2016).

1920. Using the non-linear panel model, we corroborate the cumulated drop in economic activity of about 7.2% for the typical country due to the pandemic disease, about 70% of the economic damage occurring in the first year. But additionally we can study the downside risks. The left tail of the conditional distribution of real per capita GDP growth indicates that macroeconomic risk due to the pandemic increases substantially, as real per capita GDP conditional to a contraction would plummet by 7.3% in 1918, 2.7% in 1919 and 0.9% in 1920. Even more, economic activity due to exposure to the pandemic as predicted by the 5% left-tail of the distribution drops by 29.1% in 1918, 10.9% in 1919 and 3.6% in 1920. Given that the left tail of the distribution better characterises economic contractions, the economic costs associated to the pandemic can be very high.

The pandemic flu can have an adverse distributional impact across countries, because it has a disproportionate burden on low-skilled workers and because infection diseases and their associated death toll can spread more rapidly in lower income countries given the high healthcare costs and public spending needed to contain the virus. Economists are concerned that pandemic diseases raise inequality (Furceri et al., 2020).[2] The amount of per capita income of a nation and public resources needed to monitor, prevent and mitigate the spread of the virus are highly correlated. We study the heterogeneous effect on real income in the context of the Spanish flu by investigating the differential impact of the Spanish flu among the higher and lower income countries in our sample and corroborate this hypothesis. We estimate that the expected real income loss due to the pandemic is more than double for the typical lower income country than for the typical higher income country every year between 1918 and 1920. The expected income loss cumulated over the three periods amounts to 10.9% for the lower income country group and 4.7% for the higher income country group; thereby causing an increase in income inequality. The macroeconomic risks, captured by the 5% expected shortfall, amount to the extraordinary fall of real per capita GDP in 1918 of 52.1% for the typical lower income country and 15.3% for the typical higher income country.

[2] A poll of economists found that the vast majority are concerned that COVID-19 will raise inequality (see http://www.igmchicago.org/surveys/inequality-and-the-covid-19-crisis/).

In the specific case of the US economy, Correia et al. (2020) estimate that the pandemic caused an 18% drop in US manufacturing output and a 23% decline in US manufacturing employment. The drop in US activity is also documented by Bodenhorn (2020). Using the specific death rates for the US and the pass-through coefficients of the higher income country group, our estimates suggest an expected decline in US real per capita GDP by 1.8% in 1918, 0.4% in 1919 and 0.3% in 1920, in line with Burns and Mitchell (1946)'s views that the US recession in 1918-1919 was brief and of moderate amplitude, a view corroborated by Velde (2020). However, the estimates of the macroeconomic risks due to the Spanish flu for the US amount to -5.5% in 1918, -0.8% in 1919 and -0.3% in 1920, a non negligible cumulated fall in real per capita GDP.

The literature on the macroeconomic impact of pandemic diseases is fast-growing, as a reaction to the Covid-19 disease and the needs to estimate its economic implications (e.g., Alvarez et al., 2020; Atkeson, 2020; Baqaee and Farhi, 2020; Bodenstein et al., 2020; Brodeur et al., 2020; Jones et al., 2020; Coibion et al., 2020; Correia et al., 2020; Eichenbaum et al., 2020a,b; Faria-e-Castro, 2020; Favero et al., 2020; Fornaro and Wolf, 2020; Glover et al., 2020; Gonzalez-Eiras and Niepelt, 2020; Guerrieri et al., 2020; Jordà et al., 2020; Kaplan et al., 2020; Krueger et al., 2020; Lenza and Primiceri, 2020; Primiceri and Tambalotti, 2020; Stock, 2020). A large variety of methods are used to assess the economic implications of the pandemic outbreak. We suggest a non-linear model in a country panel setting. Our insights from the Spanish flu are informative for the potential depth of contraction and income inequality implications across lower and higher income countries following the Covid-19 pandemic.

Section II describes the non-linear framework to evaluate macroeconomic risk. Section III discusses the empirical results, applying this framework to the episode of the Spanish flu. Section IV address the income inequality dimension. Section V concludes.

II Modelling Macroeconomic Risk

To quantify the macroeconomic risk posed by a pandemic, we rely on a two-step estimation procedure (see Adrian et al., 2019). First, a non-parametric quantile regression is used to estimate how country-level death rates heterogeneously affect real per capita GDP growth across the different percentiles of the conditional distribution of GDP growth; and second, the predicted growth rates for those various percentiles of the conditional distribution of GDP growth are smoothed, for each country, into a skewed-t distribution (see Azzalini and Capitanio, 2003) to facilitate interpretation and the computation of a number of informative statistics. The quantification of macroeconomic risk then follows from the behaviour of the left tail of the conditional distribution of GDP growth.

The quantile regression estimator used in the first step is developed by Koenker and Bassett (1978). Even though the economic profession has typically applied it to large, microeconomic datasets, quantile regressions are more recently also applied to macroeconomic data, and GDP growth in particular (see, e.g., Adrian et al., 2018, 2020; Chavleishvili and Manganelli, 2019; Figueres and Jarociński, 2020; Ghysels et al., 2018; Giglio et al., 2016; Brownlees and Souza, 2019; Plagborg-Møller et al., 2020; De Santis and Van der Veken, 2020). The coefficient vector β_τ, which collects the τ-th quantile regression coefficients, relates a vector x_{it} containing n explanatory variables (including an intercept) for country i in year t to the τ-th percentile ($\tau \in [0,1]$) of the conditional distribution of the endogenous variable y_{it}. An estimator $\hat{\beta}_\tau$ is obtained by minimizing the sum of the absolute values of the weighted residuals with positive residuals receiving a weight τ and negative residuals a weight $1-\tau$:

$$\hat{\beta}_\tau = \underset{\beta_\tau}{argmin} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\tau \cdot \mathbb{1}_{(y_{it} \geq x_{it}\beta_\tau)} \mid y_{it} - x_{it}\beta_\tau \mid + (1-\tau) \cdot \mathbb{1}_{(y_{it} < x_{it}\beta_\tau)} \mid y_{it} - x_{it}\beta_\tau \mid \right),$$

where $\mathbb{1}_{(\cdot)}$ is the indicator function, N the number of cross-sectional units in the panel and T the number of time periods. Following Adrian et al. (2019), this estimation is executed for $\tau = 5, 25, 75, 95$. From this first step, the predicted values for those different quantiles of the conditional distribution are obtained as $\hat{Q}_{y_{it}|x_{it}}(\tau \mid x_{it}) = x_{it}\hat{\beta}_\tau$.

In the second step, these predicted values are used to estimate the four parameters of the skewed-t distribution developed by Azzalini and Capitanio (2003). This distribution is governed by four parameters (μ, σ, α, and ν) that relate, respectively, to the location, scale, shape and degrees of freedom of the probability density. Despite the small number of parameters that need to be estimated, the skewed-t distribution provides ample flexibility to model GDP growth rates which may be skewed and/or fat tailed. In addition, symmetric and mesokurtic distributions are encompassed as special cases of the skewed-t distribution. To get estimates of these parameters, we minimize, at the four percentiles under consideration, the squared distance between $\hat{Q}_{y_{it}|x_{it}}(\tau \mid x_{it})$ obtained in the first step and the growth rates corresponding to the same four percentiles of the inverse cumulative skewed-t density $F^{-1}_{y|x}(\tau; \mu, \sigma, \alpha, \nu)$:

$$\{\hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu}\} = \underset{\mu,\sigma,\alpha,\nu}{argmin} \sum_{\tau} \left(\hat{Q}_{y_{it}|x_{it}}(\tau \mid x_{it}) - F^{-1}_{y|x}(\tau; \mu, \sigma, \alpha, \nu) \right)^2 .$$

This procedure delivers a closed-form expression for the conditional distribution of the growth rate of real per capita GDP conditioning on the explanatory variables x_{it}. In addition to the median, which is recovered from the cumulative skewed-t distribution, this approach facilitates the computation of summary statistics requiring the integration of a probability density. Integrals are derived from a numerical integration, in contrast to the approximate sum used in Adrian et al. (2019).

In particular, we focus on the expected value (or mean), the expected value conditional on an economic contraction, and the 5% expected shortfall. The expected value of the conditional distribution is an alternative measure for the conditional expectation of $y_{it}|x_{it}$ obtained from an OLS regression (as, for example, reported in Barro et al., 2020). It is obtained by weighting and integrating the entire probability density:

$$EV(\hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu}) = \int_{-\infty}^{\infty} st(y; \hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu}) dy,$$

where st represents the probability density function of the skewed-t distribution. Therefore, compared to the predicted value for real per capita GDP growth from an OLS regression, $EV(\hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu})$ is a better-suited metric in the case of substantial skewness of the conditional distribution. Next, the 5% expected shortfall is the expected value of the GDP growth rate evaluated in the left tail of the conditional distribution that covers 5% of the probability density. For a generic percentile π the expected shortfall is given by:

$$SF(\pi; \hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu}) = \frac{1}{\pi} \int_{0}^{\pi} \hat{F}_{y|x}^{-1} (\tau; \hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu}) \, d\tau.$$

In contrast to the median and the expected value, this metric evaluated at $\pi = 5\%$ captures macroeconomic risk by evaluating the expected real per capita GDP growth in the 5% most adverse cases. An increase in macroeconomic risk is reflected by more negative values of the 5% expected shortfall. Finally, we also report the expected value conditional on a contraction, $SF(\pi_0)$, where $\pi_0 = \hat{F}_{y|x}(0; \hat{\mu}, \hat{\sigma}, \hat{\alpha}, \hat{\nu})$ is the probability of a contraction in economic activity.

III Macroeconomic Risk and the Spanish Flu

III.A Data

We quantify macroeconomic risk during the Spanish flu period by applying the methodology described in the previous section to the dataset of Barro et al. (2020). This dataset comprises annual real per capita GDP, total population and deaths caused by the Spanish flu and the Great War for 42 countries, covering about 90% of the world population in 1918. The historical data on real per capita GDP is compiled by Barro and Ursua (2008) and collected in Barro and Ursua (2010). For population data, Barro et al. (2020) rely on McEvedy and

Jones (1978) and death rates related to the Spanish flu and the Great War are detailed in Weng (2016) and Ursua (2009) and briefly described in Barro et al. (2020).

Panels A and B of Figure I show the unconditional distribution of real per capita GDP growth on an annual basis. The probability density that overlays the histogram in Panel A is obtained using the model described in Section II with the constant as the only regressor. Consequently, this distribution can be interpreted as the unconditional distribution of real per capita GDP growth in a panel setting. The distribution is fat-tailed and slightly skewed to the left. Panel B gives an indication of the cross-sectional variation in the real per capita GDP growth over time: the bold line and the dashed line report the real per capita GDP growth for the median country and the US, respectively; the shaded areas and dotted lines represent the 16th to 84th percentiles and the lower and upper values realized in each year, respectively. Many countries including the US suffered a contraction during the Spanish flu, a period highlighted in grey. Also the time series dimension reported in Panel B shows the skewed nature of real per capita GDP growth, highlighting the advantage of the non-linear approach taken in this paper to study macroeconomic risk.

Panels C and D tentatively illustrate a negative relationship between the number of deaths caused by the Spanish flu (as a share of total country population) and real per capita GDP growth. Both panels span the period during which the flu spread, i.e., 1918 until 1920, and observations with zero deaths are dropped. In order to reveal cross-country heterogeneity related to the level of development, two groups of countries are created by ordering countries according to their level of real per capita GDP relative to the median country in 1917, the year preceding the outbreak of the Spanish flu. The first group, shown in Panel C, collects the 50% lower income countries; while the second group, shown in Panel D, focuses on the 50% higher income countries. The negative relationship between death rates due to the Spanish flu and real per capita GDP growth is apparent in both sets of countries. In addition, it is also clear that the lower income countries suffered more deaths per citizen than the higher income countries. Cumulated over the entire Spanish flu period, lower and higher income countries each lost about 2,5% and 1% of their total populations, respectively. Overall, about 2% of the world population was killed due to the Spanish flu (Barro et al., 2020).

III.B Average Impact of the Spanish Flu on Per Capita GDP

We revisit the analysis carried out by Barro et al. (2020) using the same cross-sectional database with 42 countries over the sample period 1901-1929 through the lenses of the non-linear model, applying the two-step semi-parametric approach discussed in Section II, in a panel setting. The non-linear model allows to trace the impact of a pandemic on different quantiles of the GDP growth distribution and, in addition, by fitting a skewed-t distribution, it facilitates the computation of the associated macroeconomic risk, which requires the integration of a predictive density. The key regressors included in x_{it}, in addition to the intercept, are the death rates due to the Spanish flu and the death rates due to the Great War, because it is important to control for the possibly correlated contemporaneous effects of labour supply shortages due to World War I. We report two central tendency measures, the median and the mean, and two macroeconomic risk measures, the expected value of each country's real per capita GDP growth conditional on an economic contraction and the 5% expected shortfall. The partial effect of the Spanish flu on either of these metrics is evaluated by calculating the difference $\mathcal{S}\left(\hat{f}_{y_{it}|x_{it}}\right) - \mathcal{S}\left(\hat{f}_{y_{it}|x^*_{it}}\right)$, where $\mathcal{S}$ is the metric of interest, $\hat{f}_{y_{it}|x_{it}}$ is the estimated conditional distribution and $\hat{f}_{y_t|x^*_{it}}$ is $\hat{f}_{y_{it}|x_{it}}$ evaluated putting to zero the death rates due to the Spanish flu.

Figure II shows in each panel three distributions of the real per capita GDP growth of the typical country. The density shown in a full line ("War and Flu Deaths") uses the observed data on war deaths and flu deaths (e.g. $\hat{f}_{y_{it}|x_{it}}$); the dashed density ("War, no Flu Deaths") uses the war deaths, but puts each country's flu deaths at zero (e.g. $\hat{f}_{y_t|x^*_{it}}$); and the dashed-dotted density ("No Deaths") shows the distribution of GDP growth setting both flu and war deaths to zero. In the absence of both military casualties and flu-related deaths (dashed-dotted line), the conditional distribution of the GDP growth rate is, in line with conventional wisdom, fairly symmetric and centered around a moderately positive growth rate. Including the military death rate in the conditioning set both shifts and skews the distribution to the left (dashed line). The impact of the Spanish flu, however, introduces a much stronger skew to the left. This is clear evidence of considerable macroeconomic risk due to the pandemic disease. A full set of results for all countries in the sample is provided in Table I, where the partial effect of the Spanish flu is evaluated with respect to a counterfactual, constructed by putting to zero the deaths due to the Spanish flu: $\mathcal{S}\left(\hat{f}_{y_{it}|x_{it}}\right) - \mathcal{S}\left(\hat{f}_{y_{it}|x^*_{it}}\right)$.

Using the same dataset, Barro et al. (2020) finds that the typical country's real per capita GDP dropped by 6% cumulated over the period 1918-1920 as a consequence of the Spanish flu. Our estimated cumulated drop in economic activity of 7.2% based on the expected value (see Table I) confirms this result, with about 70% of the economic damage occurring in 1918 (-4.9%). The adverse impact is slightly larger due to the skewness of the conditional distribution. Most importantly, we can show that macroeconomic risks increase substantially. The expected loss due to the pandemic in real per capita GDP of the typical country conditional on an economic contraction is estimated at 7.3% in 1918, 2.7% in 1919 and 0.9% in 1920 and the 5% expected shortfall implies a drop in real per capita income by 29.1% in 1918, 10.9% in 1919 and 3.6% in 1920. All in all, there is clear evidence that a pandemic disease increases enormously the macroeconomic risks.

IV Inequality and the Spanish Flu

Pandemic diseases can have adverse distributional consequences across countries. We address this issue by investigating the differential impact of the Spanish flu among the higher and lower income countries in our sample. We make use of a dummy variable d_i interacted with all regressors, which is set to one for the group of countries with real per capita GDP higher than the median country in 1917, the year before the start of the pandemic outbreak. Therefore, the predicted values of the conditional distribution are obtained as $\hat{Q}_{y_{it}|x_{it}}(\tau \mid x_{it}) = x_{it}(\hat{\beta}_{1\tau} + \hat{\beta}_{2\tau}d_i)$, where the vector $\hat{\beta}_{2\tau}$ estimates the differential impact of the variables in x_{it} (i.e., intercept and war and flu death rates) in lower versus higher income countries.

Table II shows the estimated differential effect of the flu death rates on real per capita GDP and the associated macroeconomic risk across the lower and higher income countries. The partial effect of the Spanish flu is again evaluated with respect to a hypothetical counterfactual, constructed by putting to zero the deaths due to the Spanish flu: $\mathcal{S}\left(\hat{f}_{y_{it}|x_{it}}\right) - \mathcal{S}\left(\hat{f}_{y_{it}|x^*_{it}}\right)$. On average, the real income loss for the typical lower income country is more than double every year between 1918 and 1920. The expected income loss cumulated over this three-year period is equal to 10.9% for the lower income country group and 4.4% for the higher income country group, thereby raising income inequality across countries. Moreover, the macroeconomic risks computed using the 5% expected shortfall are equal to -52.1% for the typical lower income country and -15.4% for the typical higher income country in 1918 and remain very high during the two subsequent years in the lower income country group, thereby generating additional uncertainty in the typical lower income country. The risks associated to the pandemic are confirmed to be large for the higher income countries and are immense for the lower income countries. Panels C and D of Figure III illustrate that this finding is mostly related to a very heavy left tail for the typical lower income country. Also notice that the stronger skew for the higher income economies partly reflects their higher military engagement in the Great War, resulting in more military casualties. The military death rate in 1918 (the only year of overlap between the Great War and the Spanish flu) is 0.2% in the higher income country group and 0.01% in the lower income country group.

The case of the US is interesting because the US recession in 1918-1919 was brief and of moderate amplitude (Burns and Mitchell, 1946; Velde, 2020). Using the specific death rates for the US and the quantile regression coefficients for the higher income country group, our estimates suggest an average decline in the US real per capita GDP by 1.8% in 1918, 0.4% in 1919 and 0.3% in 1920. The Spanish flu did not have a large negative impact on the US economic activity and this is in line with the view that the US recession in 1918-1919 was mild. However, the estimates of the macroeconomic risks for the US amount to -5.5% in 1918, -0.8% in 1919 and -0.3% in 1920, a non-negligible risk in real per capita GDP, which confirms that the economic costs associated to the pandemic can be very high in an adverse scenario.

The heterogeneous results among lower and higher income countries are driven by both the country group-specific parameters (i.e. pass-through coefficients) and the country-specific death count due to the pandemic flu. We separate those effects along both steps of the two-step estimation procedure.

First, we focus on the heterogeneity captured by the quantile regression in the first step. Figure IV shows the estimated quantile regression coefficients and the associated 90% error bands for percentiles $\tau = 5, 10, \ldots, 95$. More precisely, Panel A shows $\hat{\beta}_{1\tau}$, the impact of a 1 percentage point increase in the Spanish flu death rate on real per capita GDP growth. Panel B shows $\hat{\beta}_{2\tau}$, the extent to which the transmission of the flu death rate to GDP growth differs for higher relative to lower income countries. Even though the higher percentiles of the conditional distribution of GDP growth may not be responsive to the Spanish flu, the distribution below the 50th percentile, which represents the downside macroeconomic risk, is substantially adversely affected by the pandemic. As such, it is mostly the lower percentiles of the GDP growth distribution that shift to the left when the flu death rate increases. Moreover, although the estimated uncertainty is high, Panel B indicates that real per capita GDP growth below the 50th percentile of the conditional distribution is more sensitive to flu death rates in higher income countries than in lower income countries. Since the death rates are exogenous labour supply shifters, the pass-through coefficients from the Spanish flu death rates to economic growth measure the effect of the labour force contraction on economic activity. Labour force is expected to be more productive in higher income countries. This explains why $\hat{\beta}_{2\tau}$ is negative, particularly in the left tail of the distribution.

The second step of the estimation procedure corresponds to a highly non-linear mapping of the quantile regression coefficients into our metrics of interest, such as the expected value and the 5% expected shortfall. To assess whether the higher sensitivity of lower-income countries' macroeconomic risk to the pandemic is primarily driven by their higher death rates rather than by the pass-through coefficients, which shape the density functions, we perform a counterfactual exercise. Specifically, we substitute the pass-through coefficients of the pandemic death rate estimated for the higher income country group into the estimation of the conditional distribution of real per capita GDP growth of the lower income country group. If the pass-through were the key drivers of such difference, then $\mathcal{S}\left(\hat{f}_{y_{it}|x_{it}}\right) - \mathcal{S}\left(\hat{f}_{y_{it}|x^*_{it}}\right)$ would be the same across country groups and, for example, the impact of the flu on the 5% expected shortfall would amount to about -15.3% in 1918 in the lower income country group as well as in the higher income country group (see Table II). In a typical lower income country, the 5% expected shortfall implies a drop in real per capita GDP by 52.1% in the baseline and by 37.1% in the counterfactual exercise. Similarly, the 10% expected shortfall implies a drop in real per capita GDP in the lower income country by 37.1% in the baseline and by 32.2% in the counterfactual exercise. The same holds for the effect of the flu on the expected value of real per capita GDP conditioning on a contraction in economic activity. This metric is at 11.7% in the baseline (reported in Table II) and at 13.3% in the counterfactual exercise. Given that the impact in the baseline is close to the impact obtained with the counterfactual, we can conclude that the higher death rates in lower income countries explain the emergence of the extraordinarily large macroeconomic risks in the typical lower income country.

V Conclusions

Assessing the economic consequences of the spread of the new coronavirus disease (Covid-19) in the world in 2020 is a challenge for the economic profession. The unprecedented nature and global scale of a pandemic renders traditional tools for macroeconomic monitoring, including the monitoring of macroeconomic risk, ill-suited, as they are typically linear models or log-linearized models around the steady state.

We try to gain insights from the 1918-1920 Great Influenza Pandemic (known also as Spanish flu); arguably the only precedent for a global pandemic that the world has seen in modern history. To address the question, we use a non-linear model in a country panel setting covering all major countries in the world, which are two key features characterizing pandemic diseases.

We show that the economic costs associated to the pandemic can be very high, with the 5% left tail of the distribution suggesting a drop in the typical country's real per capita GDP amounting to 29.1% in 1918, 10.9% in 1919 and 3.6% in 1920, most of the real risk occurring in the first year. The results are highly heterogeneous across lower and higher income countries; thereby causing an increase in income inequality. Moreover, the risk associated to the pandemic are confirmed to be large for higher income countries and are immense for the lower income countries, potential source of additional uncertainty in these countries. As for the United States, the literature has argued that the recession during the Spanish flu was mild in the US (Burns and Mitchell, 1946; Velde, 2020). Given the central tendency of our results, we would also agree. However, the estimated macroeconomic risks due to pandemic are non-negligible cumulated over the period 1918-1920.

These potential extreme economic losses, which a country could face, can explain the prompt and large fiscal and monetary policy interventions globally after the spread of the Covid-19 disease in 2020. Although the mortality rate due to the Covid-19 pandemic will be much lower, due to the health infrastructure, the stringent lockdown measures and the general knowledge about the disease, the insights from the Spanish flu should not be dismissed, as both periods share the countries' adoption of social distancing measures (in terms of restrictions on economic activity and travelling imposed or self-imposed), well documented in the case of United States (e.g. Bootsma and Ferguson, 2007; Markel et al., 2007; Bodenhorn, 2020; Wheelock, 2020) and Italy (e.g. Carillo and Jappelli, 2020).[3] The Covid-19 pandemic is a disaster risk and the insights from the Spanish flu are telling: the risk of a sharp fall in economic activity in 2020 close to two digits due to the Covid-19 is real. Similarly, our results support the view of international economic organizations, such as the World Bank and the United Nation Development Programme (UNDP), which argue that the Covid-19 pandemic will leave deep scars in lower income countries, unless urgent policy action is taken with support from the international community.

[3] An example of social distancing policy put in place in Europe in 1918 is detailed in these articles about Liverpool (https://www.liverpoolecho.co.uk/news/liverpool-news/social-distancing-liverpool-during-spanish-18139281) and Milan (https://www.fondazionecorriere.corriere.it/ai-tempi-dellinfluenza-spagnola/).

References

Adrian, Tobias, Nina Boyarchenko, and Domenico Giannone (2019) "Vulnerable Growth," *American Economic Review*, Vol. 109, pp. 1263–1289.

Adrian, Tobias, Fernando Duarte, Nellie Liang, and Pawel Zabczyk (2020) "Monetary and Macroprudential Policy with Endogenous Risk," Working Paper DP14435, CEPR.

Adrian, Tobias, Federico Grinberg, Nellie Liang, and Sheheryar Malik (2018) "The Term Structure of Growth-at-Risk," IMF Working Papers 18/180, International Monetary Fund.

Alvarez, Fernando E., David Argente, and Francesco Lippi (2020) "A Simple Planning Problem for COVID-19 Lockdown," NBER Working Papers 26981, National Bureau of Economic Research, Inc.

Atkeson, Andrew (2020) "What Will Be the Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios," Working Paper 26867, National Bureau of Economic Research.

Azzalini, Adelchi and Antonella Capitanio (2003) "Distributions Generated by a Perturbation of Symmetry with Emphasis on a Multivariate Skew t-Distribution," *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, Vol. 65, pp. 367–389.

Baqaee, David and Emmanuel Farhi (2020) "Supply and Demand in Disaggregated Keynesian Economies with an Application to the Covid-19 Crisis," Working Paper 27152, National Bureau of Economic Research.

Barro, Robert (2006) "Rare Disasters and Asset Markets in the Twentieth Century," *The Quarterly Journal of Economics*, Vol. 121, pp. 823–866.

——— (2009) "Rare Disasters, Asset Prices, and Welfare Costs," *American Economic Review*, Vol. 99, pp. 243–64.

Barro, Robert J., José F. Ursúa, and Joanna Weng (2020) "The Coronavirus and the Great Influenza Pandemic: Lessons from the "Spanish Flu" for the Coronavirus's Potential Effects on Mortality and Economic Activity," nber working papers, National Bureau of Economic Research, Inc.

Barro, Robert and Tao Jin (2011) "On the Size Distribution of Macroeconomic Disasters," *Econometrica*, Vol. 79, pp. 1567–1589.

Barro, Robert and J.F. Ursua (2008) "Macroeconomic Crises since 1870," *Brookings Papers on Economic Activity*, Vol. Spring.

Barro, Robert and José F. Ursua (2010) "Barro-Ursua Macroeconomic Data."

Barro, Robert and José F. Ursúa (2012) "Rare Macroeconomic Disasters," *Annual Review of Economics*, Vol. 4, pp. 83–109.

Berkman, Henk, Ben Jacobsen, and John B. Lee (2011) "Time-Varying Rare Disaster Risk and Stock Returns," *Journal of Financial Economics*, Vol. 101, pp. 313–332.

Bodenhorn, Howard (2020) "Business in a Time of Spanish Influenza," Working Paper 27495, National Bureau of Economic Research.

Bodenstein, Martin, Giancarlo Corsetti, and Luca Guerrieri (2020) "Social Distancing and Supply Disruptions in a Pandemic," Finance and Economics Discussion Series 2020-031, Board of Governors of the Federal Reserve System (U.S.).

Bootsma, Martin C. J. and Neil M. Ferguson (2007) "The Effect of Public Health Measures on the 1918 Influenza Pandemic in U.S. cities," *Proceedings of the National Academy of Sciences*, Vol. 104, pp. 7588–7593.

Brodeur, Abel, David M. Gray, Anik Islam, and Suraiya Jabeen Bhuiyan (2020) "A Literature Review of the Economics of COVID-19," IZA Discussion Papers 13411, Institute of Labor Economics (IZA).

Brownlees, Christian T. and Andre Souza (2019) “Backtesting Global Growth-at-Risk,” working paper, Universitat Pomepu Fabra.

Burns, Arthur F. and Wesley C. Mitchell (1946) *Measuring Business Cycles*: NBER.

Carillo, Msario F. and Tullio Jappelli (2020) “Pandemics and Local Economic Growth: Evidence from the Great Influenza in Italy,” Working Paper DP14849, CEPR.

Chavleishvili, Sulkhan and Simone Manganelli (2019) “Forecasting and Stress Testing with Quantile Vector Autoregression,” Working Paper Series 2330, European Central Bank.

Coibion, Olivier, Yuriy Gorodnichenko, and Michael Weber (2020) “The Cost of the Covid-19 Crisis: Lockdowns, Macroeconomic Expectations, and Consumer Spending,” Working Paper 27141, National Bureau of Economic Research.

Correia, Sergio, Stephan Luck, and Emil Verner (2020) “Fight the Pandemic, Save the Economy: Lessons from the 1918 Flu,” Liberty Street Economics 20200327, Federal Reserve Bank of New York.

De Santis, Roberto and Wouter Van der Veken (2020) “Forecasting macroeconomic risk in real time: Great and Covid-19 Recessions,” Working Paper 2436, European Central Bank.

Eichenbaum, Martin, Sergio Rebelo, and Mathias Trabandt (2020a) “The Macroeconomics of Epidemics,” NBER Working Papers 26882, National Bureau of Economic Research, Inc.

Eichenbaum, Martin S, Sergio Rebelo, and Mathias Trabandt (2020b) “The Macroeconomics of Testing and Quarantining,” Working Paper 27104, National Bureau of Economic Research.

Farhi, Emmanuel and Xavier Gabaix (2016) “Rare Disasters and Exchange Rates,” *Quarterly Journal of Economics*, Vol. 131, pp. 1–52, Lead Article.

Faria-e-Castro, Miguel (2020) “Fiscal Policy during a Pandemic,” Working Papers 2020-006, Federal Reserve Bank of St. Louis.

Favero, Carlo A., Andrea Ichino, and Aldo Rustichini (2020) "Restarting the Economy While Saving Lives Under COVID-19," Working Paper DP14664, CEPR.

Figueres, Juan Manuel and Marek Jarociński (2020) "Vulnerable Growth in the Euro Area: Measuring the Financial Conditions," *Economics Letters*, Vol. 191, p. 109126.

Fornaro, Luca and Martin Wolf (2020) "Covid-19 Coronavirus and Macroeconomic Policy," Working Papers 1168, Barcelona Graduate School of Economics.

Furceri, Davide, Prakash Loungani, Jonathan D. Ostry, and Pietro Pizzuto (2020) "Will Covid-19 affect inequality? Evidence from past pandemics," *Covid Economics*, Vol. 12, pp. 138–157.

Gabaix, Xavier (2012) "Variable Rare Disasters: An Exactly Solved Framework for Ten Puzzles in Macro-Finance," *The Quarterly Journal of Economics*, Vol. 127, pp. 645–700.

Ghysels, Eric, Leonardo Iania, and Jonas Striaukas (2018) "Quantile-based Inflation Risk Models," Working Paper Research 349, National Bank of Belgium.

Giglio, Stefano, Bryan Kelly, and Seth Pruitt (2016) "Systemic Risk And the Macroeconomy: An Empirical Evaluation," *Journal of Financial Economics*, Vol. 119, pp. 457–471.

Glover, Andrew, Jonathan Heathcote, Dirk Krueger, and José-Víctor Ríos-Rull (2020) "Health versus Wealth: On the Distributional Effects of Controlling a Pandemic," Working Paper 27046, National Bureau of Economic Research.

Gonzalez-Eiras, Martín and Dirk Niepelt (2020) "On the Optimal Lockdown During an Epidemic," Working Papers 20.01, Swiss National Bank, Study Center Gerzensee.

Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Iván Werning (2020) "Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?" NBER Working Papers 26918, National Bureau of Economic Research, Inc.

Jones, Callum, Thomas Philippon, and Venky Venkateswaran (2020) "Optimal Mitigation Policies in a Pandemic: Social Distancing and Working from Home," NBER Working Papers 26984, National Bureau of Economic Research, Inc.

Òscar Jordà, Sanjay R. Singh, and Alan M. Taylor (2020) "Longer-Run Economic Consequences of Pandemics," Working Paper Series 2020-09, Federal Reserve Bank of San Francisco.

Kaplan, Greg, Ben Moll, and Gianluca Violante (2020) "Pandemics According to HANK," mimeo, University of Chicago.

Koenker, Roger W and Jr Bassett, Gilbert (1978) "Regression Quantiles," *Econometrica*, Vol. 46, pp. 33–50.

Krueger, Dirk, Harald Uhlig, and Taojun Xie (2020) "Macroeconomic Dynamics and Reallocation in an Epidemic," working paper, Penn Institute for Economic Research, Department of Economics, University of Pennsylvania.

Lenza, Michele and Giorgio E. Primiceri (2020) "How to Estimate A VAR after March 2020," manuscript, Northwestern University.

Markel, Howard, Harvey B. Lipman, J. Alexander Navarro, Alexandra Sloan, Joseph R. Michalsen, Alexandra Minna Stern, and Martin S. Cetron (2007) "Nonpharmaceutical Interventions Implemented by US Cities During the 1918-1919 Influenza Pandemic," *JAMA*, Vol. 298, pp. 644–654.

McEvedy, Colin and Richard Jones (1978) *Atlas of World Population History*, New York: Penguin.

Nakamura, Emi, Jon Steinsson, Robert Barro, and José Ursúa (2013) "Crises and Recoveries in an Empirical Model of Consumption Disasters," *American Economic Journal: Macroeconomics*, Vol. 5, pp. 35–74.

Plagborg-Møller, Mikkel, Lucrezia Reichlin, Giovanni Ricco, and Thomas Hasenzagl (2020) "When is Growth at Risk?" Brookings Papers on Economic Activity, Spring 2020, Conference draft.

Primiceri, Giorgio E. and Andrea Tambalotti (2020) "Macroeconomic Forecasting in the Time of COVID-19," working paper, Northwestern University.

Stock, James H (2020) "Data Gaps and the Policy Response to the Novel Coronavirus," Working Paper 26902, National Bureau of Economic Research.

Ursua, José F. (2009) "Flu, War, and Economic Recessions," Unpublished, Harvard University, November.

Velde, Francois R. (2020) "What Happened to the US Economy During the 1918 Influenza Pandemic? A View Through High-Frequency Data," Working Paper Series WP 2020-11, Federal Reserve Bank of Chicago.

Weng, Joanna (2016) "Blue from the Flu? A Cross-Country Panel Analysis of the 1918-1920 Great Influenza on Macroeconomic Growth," Unpublished senior thesis, Harvard University, March.

Wheelock, David C. (2020) "What Can We Learn from the Spanish Flu Pandemic of 1918-19 for COVID-19?," *Economic Synopses*.

Table I: Spanish Flu's Partial Effect on Real Per Capita GDP in 1918-1920 (%)

	Median			Mean			Exp. Value / Contract.			5% Shortfall		
	1918	1919	1920	1918	1919	1920	1918	1919	1920	1918	1919	1920
Typical country	-2.03	-0.74	-0.24	-4.86	-1.74	-0.57	-7.27	-2.75	-0.92	-29.12	-10.86	-3.55
Argentina	-0.24	-0.26	0.00	-0.57	-0.61	0.00	-0.91	-0.98	0.00	-3.53	-3.79	0.00
Australia	0.00	-0.37	-0.06	0.00	-0.87	-0.13	0.00	-1.41	-0.21	0.00	-5.55	-0.78
Austria	-1.17	-0.31	0.00	-2.69	-0.74	0.00	-3.73	-1.20	0.00	-17.23	-4.74	0.00
Belgium	-1.06	-0.17	-0.02	-2.50	-0.40	-0.04	-3.91	-0.65	-0.06	-15.46	-2.50	-0.21
Brazil	-0.73	-0.31	0.00	-1.71	-0.73	0.00	-2.70	-1.19	0.00	-10.64	-4.72	0.00
Canada	-0.62	-0.23	-0.11	-1.46	-0.54	-0.25	-2.03	-0.87	-0.40	-9.97	-3.38	-1.52
Chile	-0.09	-0.81	-0.05	-0.22	-1.90	-0.12	-0.36	-2.99	-0.19	-1.36	-11.79	-0.72
China	-0.85	-0.98	-0.33	-2.00	-2.31	-0.77	-3.15	-3.62	-1.25	-12.42	-14.29	-4.93
Colombia	-0.66	0.00	-0.04	-1.56	0.00	-0.08	-2.47	0.00	-0.12	-9.71	0.00	-0.45
Denmark	-0.25	-0.12	-0.09	-0.60	-0.28	-0.21	-0.95	-0.46	-0.34	-3.70	-1.76	-1.29
Egypt	-1.19	-0.28	-0.15	-2.80	-0.65	-0.36	-4.37	-1.06	-0.57	-17.34	-4.18	-2.21
Finland	n.a.	-0.23	-0.04	n.a.	-0.53	-0.09	n.a.	-0.85	-0.13	n.a.	-3.29	-0.49
France	-0.79	-0.34	0.00	-1.89	-0.79	0.00	-2.52	-1.28	0.00	-12.30	-5.07	0.00
Germany	-1.00	-0.03	-0.16	-2.31	-0.07	-0.37	-3.14	-0.10	-0.59	-15.20	-0.35	-2.30
Greece	-0.64	-0.03	0.00	-1.52	-0.07	0.00	-2.31	-0.11	0.00	-9.33	-0.38	0.00
Iceland	-0.66	-0.31	-0.23	-1.55	-0.73	-0.55	-2.46	-1.19	-0.88	-9.67	-4.72	-3.42
India	-6.48	-1.28	-0.40	-15.63	-3.03	-0.93	-19.96	-4.72	-1.50	-93.70	-18.69	-5.90
Indonesia	-3.40	-1.14	0.00	-8.04	-2.70	0.00	-12.14	-4.22	0.00	-48.24	-16.76	0.00
Italy	-1.71	-0.09	0.00	-4.10	-0.22	0.00	-6.12	-0.35	0.00	-24.58	-1.34	0.00
Japan	-0.61	-0.28	-0.56	-1.43	-0.65	-1.32	-2.27	-1.05	-2.11	-9.00	-4.13	-8.32
Malaysia	-1.83	-0.10	0.00	-4.33	-0.23	0.00	-6.63	-0.37	0.00	-26.10	-1.42	0.00
Mexico	-2.30	0.00	-0.78	-5.46	0.00	-1.83	-8.33	0.00	-2.89	-33.06	0.00	-11.40
Netherlands	-0.83	-0.21	-0.03	-1.95	-0.48	-0.08	-3.06	-0.78	-0.12	-12.07	-3.02	-0.44
New Zealand	-0.80	-0.04	-0.13	-1.95	-0.09	-0.31	-2.94	-0.14	-0.50	-11.04	-0.52	-1.94
Norway	-0.67	-0.17	-0.02	-1.58	-0.39	-0.04	-2.50	-0.63	-0.05	-9.86	-2.45	-0.18
Peru	-0.15	-0.15	-0.29	-0.34	-0.34	-0.69	-0.56	-0.56	-1.12	-2.15	-2.15	-4.43
Philippines	-1.59	-1.22	0.00	-3.77	-2.89	0.00	-5.80	-4.50	0.00	-22.86	-17.86	0.00
Portugal	-2.55	-0.14	0.00	-6.07	-0.32	0.00	-9.17	-0.52	0.00	-36.50	-2.01	0.00
Russia	-2.10	-0.59	-0.09	-5.04	-1.39	-0.21	-7.24	-2.21	-0.34	-31.05	-8.72	-1.31
Singapore	-1.48	-0.22	-0.24	-3.50	-0.51	-0.56	-5.40	-0.82	-0.90	-21.34	-3.17	-3.51
South Africa	-3.14	-1.85	0.00	-7.45	-4.39	0.00	-11.24	-6.72	0.00	-44.68	-26.47	0.00
South Korea	-1.16	-0.37	-0.56	-2.74	-0.86	-1.31	-4.28	-1.39	-2.08	-17.00	-5.47	-8.23
Spain	-1.57	-0.21	-0.26	-3.71	-0.49	-0.62	-5.71	-0.79	-0.99	-22.50	-3.08	-3.85
Sri Lanka	-0.86	-1.49	-0.26	-2.03	-3.53	-0.60	-3.19	-5.44	-0.96	-12.57	-21.46	-3.74
Sweden	-0.70	-0.21	-0.04	-1.66	-0.49	-0.08	-2.62	-0.78	-0.13	-10.33	-3.04	-0.46
Switzerland	-0.80	-0.16	-0.19	-1.89	-0.38	-0.44	-2.98	-0.61	-0.70	-11.74	-2.36	-2.73
Taiwan	-0.80	-0.03	-0.78	-1.88	-0.06	-1.84	-2.97	-0.09	-2.90	-11.74	-0.34	-11.46
Turkey	-1.59	-0.08	0.00	-3.77	-0.18	0.00	-4.80	-0.28	0.00	-24.79	-1.08	0.00
United Kingdom	-0.50	-0.18	0.00	-1.20	-0.43	0.00	-1.62	-0.69	0.00	-7.66	-2.69	0.00
United States	-0.59	-0.11	-0.08	-1.40	-0.26	-0.19	-2.18	-0.42	-0.31	-8.69	-1.62	-1.17
Uruguay	-0.19	-0.08	-0.06	-0.45	-0.19	-0.13	-0.73	-0.30	-0.21	-2.82	-1.13	-0.79
Venezuela	-1.48	-0.40	0.00	-3.50	-0.94	0.00	-5.39	-1.51	0.00	-21.29	-5.92	0.00

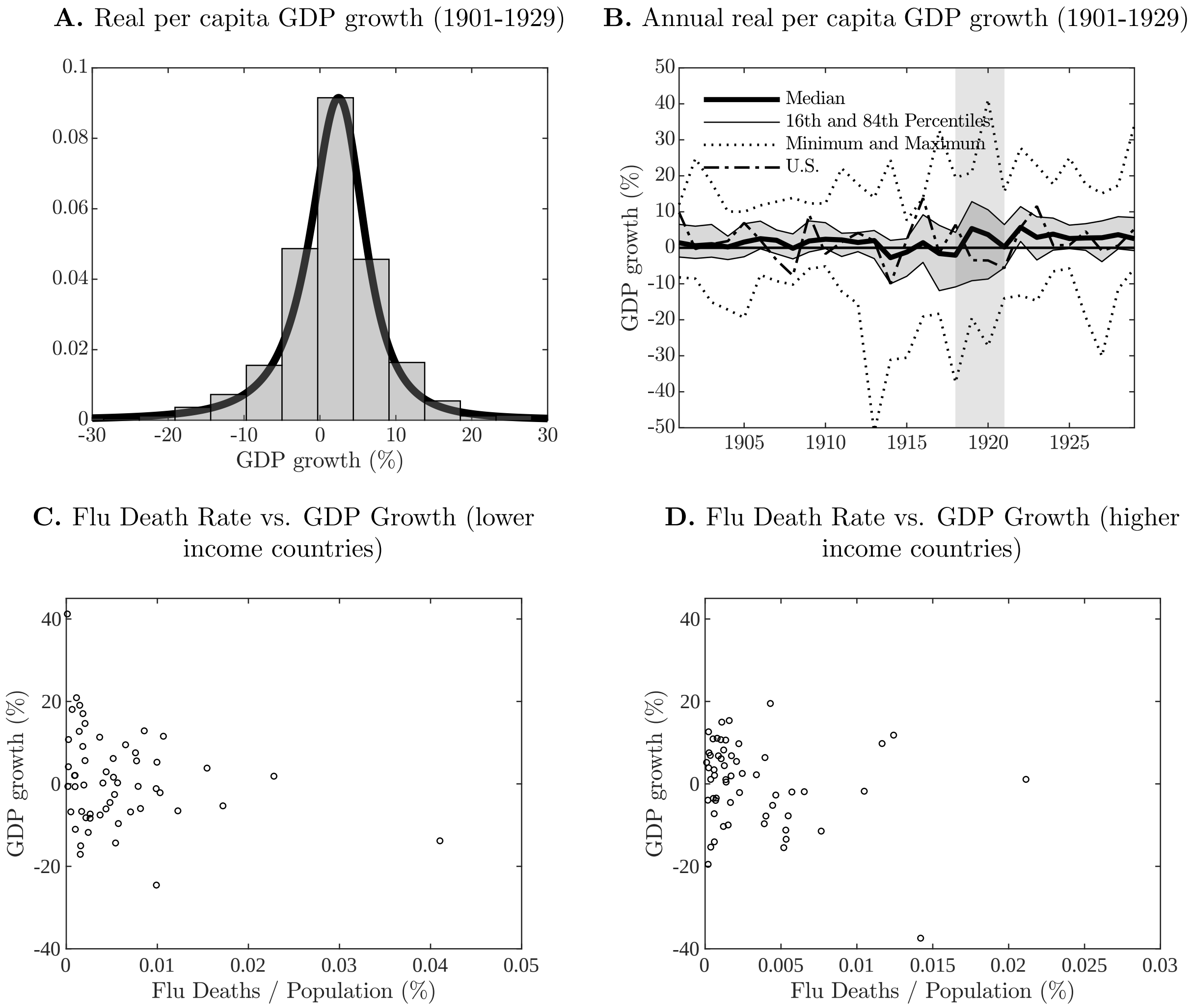
Notes: This table shows the partial effect of the Spanish flu on (i) the median of real per-capita GDP growth, (ii) the expected value of real per-capita GDP growth, (iii) the expected value of real per-capita GDP growth conditional on a contraction, and (iv) the expected value of real per-capita GDP growth in the lower 5% tail of the conditional probability density. The partial effect is computed as $\mathcal{S}\left(\hat{f}_{y_{it}|x_{it}}\right) - \mathcal{S}\left(\hat{f}_{y_{it}|x^*_{it}}\right)$, where $\mathcal{S}$ is one of the four described metrics, $\hat{f}_{y_{it}|x_{it}}$ is the estimated conditional distribution, and x^*_{it} is the same distribution function derived by putting the number of deaths due to the Spanish flu to zero.

Table II: Spanish Flu's Partial Effect on Real Per Capita GDP in Lower and Higher Income Countries in 1918-1920 (%)

	Median			Mean			Exp. Value / Contract.			5% Shortfall		
	1918	1919	1920	1918	1919	1920	1918	1919	1920	1918	1919	1920
Typical Lower Income	-0.92	-0.32	-0.09	-7.27	-2.75	-0.86	-11.65	-5.03	-1.97	-52.13	-22.14	-8.98
Typical Higher Income	-1.50	-0.55	-0.17	-3.50	-0.89	-0.26	-6.61	-1.06	-0.30	-15.35	-1.07	-1.30
Lower Income												
Belgium	-0.36	-0.04	0.00	-3.04	-0.43	-0.05	-5.49	-1.26	-0.09	-24.08	-6.09	-0.34
Brazil	-0.24	-0.09	0.00	-2.05	-0.84	0.00	-3.92	-1.94	0.00	-17.34	-8.87	0.00
China	-0.28	-0.33	-0.09	-2.42	-2.80	-0.88	-4.44	-5.11	-2.01	-19.85	-22.46	-9.17
Colombia	-0.21	0.00	-0.01	-1.86	0.00	-0.09	-3.62	0.00	-0.19	-16.06	0.00	-0.67
Egypt	-0.40	-0.08	-0.03	-3.41	-0.74	-0.37	-6.05	-1.77	-1.17	-26.49	-8.19	-5.72
Finland	n.a	-0.06	-0.01	n.a.	-0.58	-0.10	n.a.	-1.52	-0.20	n.a.	-7.13	-0.71
Iceland	-0.21	-0.09	-0.06	-1.86	-0.84	-0.61	-3.61	-1.94	-1.56	-15.99	-8.87	-7.31
India	-5.40	-0.43	-0.12	-18.58	-3.70	-1.09	-24.93	-6.51	-2.36	-112.90	-28.48	-10.66
Indonesia	-1.44	-0.38	0.00	-9.94	-3.28	0.00	-15.66	-5.85	0.00	-68.55	-25.67	0.00
Japan	-0.20	-0.07	-0.18	-1.73	-0.73	-1.57	-3.23	-1.76	-3.15	-15.02	-8.15	-14.04
Malaysia	-0.63	-0.01	0.00	-5.31	-0.21	0.00	-9.03	-0.89	0.00	-39.70	-4.52	0.00
Mexico	-0.82	0.00	-0.26	-6.70	0.00	-2.20	-11.09	0.00	-4.17	-48.55	0.00	-18.41
Peru	-0.03	-0.03	-0.08	-0.36	-0.36	-0.78	-1.15	-1.15	-1.85	-5.62	-5.62	-8.51
Philippines	-0.54	-0.41	0.00	-4.62	-3.52	0.00	-8.04	-6.23	0.00	-35.62	-27.26	0.00
Portugal	-0.98	-0.02	0.00	-7.54	-0.33	0.00	-11.50	-1.10	0.00	-53.19	-5.44	0.00
Singapore	-0.50	-0.05	-0.06	-4.28	-0.56	-0.63	-7.46	-1.48	-1.59	-32.88	-6.97	-7.43
South Korea	-0.39	-0.11	-0.18	-3.33	-1.00	-1.55	-5.93	-2.21	-3.12	-26.01	-10.01	-13.90
Sri Lanka	-0.29	-0.51	-0.07	-2.45	-4.31	-0.68	-4.56	-7.51	-1.67	-20.07	-33.11	-7.75
Taiwan	-0.27	-0.01	-0.26	-2.28	-0.07	-2.22	-4.21	-0.14	-4.19	-18.84	-0.51	-18.50
Turkey	-0.98	0.00	0.00	-5.44	-0.15	0.00	-3.46	-0.76	0.00	-34.98	-3.98	0.00
Venezuela	-0.50	-0.12	0.00	-4.27	-1.09	0.00	-7.44	-2.37	0.00	-32.79	-10.69	0.00
Higher Income												
Argentina	-0.45	-0.48	0.00	-0.72	-0.77	0.00	-0.78	-0.86	0.00	-0.50	-0.50	0.00
Australia	0.00	-0.67	-0.13	0.00	-1.11	-0.19	0.00	-1.43	-0.23	0.00	-2.17	-0.96
Austria	-2.03	-0.58	0.00	-3.53	-0.94	0.00	-5.95	-1.14	0.00	-12.57	-1.30	0.00
Canada	-1.09	-0.44	-0.22	-1.84	-0.69	-0.33	-3.16	-0.73	-0.31	-5.20	-0.49	-0.72
Chile	-0.20	-1.06	-0.12	-0.29	-2.32	-0.18	-0.26	-3.81	-0.21	-0.53	-9.08	-0.90
Denmark	-0.47	-0.25	-0.19	-0.75	-0.38	-0.28	-0.83	-0.38	-0.24	-0.49	-0.99	-0.46
France	-1.36	-0.62	0.00	-2.37	-1.01	0.00	-4.16	-1.25	0.00	-7.68	-1.65	0.00
Germany	-1.85	-0.06	-0.31	-3.04	-0.09	-0.48	-5.13	-0.11	-0.44	-9.75	-0.48	-0.40
Greece	-1.12	-0.07	0.00	-1.96	-0.10	0.00	-3.30	-0.12	0.00	-6.06	-0.52	0.00
Italy	-2.49	-0.19	0.00	-5.17	-0.29	0.00	-9.28	-0.25	0.00	-23.67	-0.51	0.00
Netherlands	-1.07	-0.40	-0.08	-2.37	-0.62	-0.12	-3.93	-0.63	-0.14	-9.41	-0.49	-0.59
New Zealand	-1.53	-0.09	-0.27	-2.63	-0.13	-0.41	-4.60	-0.16	-0.36	-8.51	-0.67	-0.47
Norway	-1.01	-0.34	-0.03	-1.98	-0.51	-0.05	-3.05	-0.48	-0.06	-6.91	-0.56	-0.26
Russia	-3.24	-0.95	-0.19	-6.38	-1.75	-0.28	-11.30	-2.59	-0.25	-29.21	-5.58	-0.48
South Africa	-6.21	-3.12	0.00	-10.05	-5.69	0.00	-15.81	-9.25	0.00	-44.59	-25.44	0.00
Spain	-2.42	-0.41	-0.48	-4.71	-0.63	-0.78	-7.83	-0.65	-0.88	-21.16	-0.55	-0.54
Sweden	-1.02	-0.40	-0.08	-2.06	-0.62	-0.12	-3.23	-0.63	-0.14	-7.41	-0.51	-0.61
Switzerland	-1.06	-0.32	-0.37	-2.31	-0.49	-0.56	-3.79	-0.45	-0.55	-9.03	-0.46	-0.56
United Kingdom	-0.99	-0.36	0.00	-1.56	-0.55	0.00	-2.88	-0.54	0.00	-3.05	-0.51	0.00
United States	-1.00	-0.23	-0.17	-1.79	-0.35	-0.25	-2.82	-0.34	-0.21	-5.47	-0.83	-0.32
Uruguay	-0.38	-0.16	-0.13	-0.58	-0.24	-0.19	-0.57	-0.19	-0.23	-0.44	-0.28	-0.97

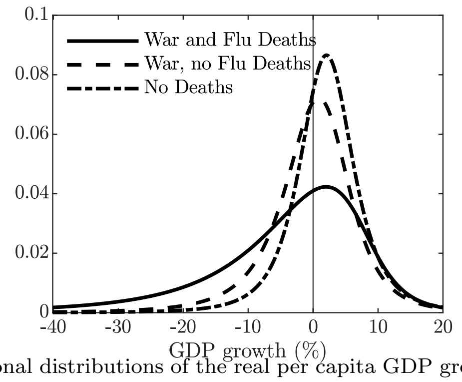
Notes: This table shows the heterogeneous effect of the Spanish flu among lower and higher income countries using four metrics derived from the conditional distribution of real per-capita GDP growth. The higher (lower) income country group comprises countries with a real per capita GDP above (below) the median in 1917. The first two lines show the summary statistics for the typical lower and higher income groups, respectively. The summary statistics are (i) the median of real per-capita GDP growth, (ii) the expected value of real per-capita GDP growth, (iii) the expected value of real per-capita GDP growth conditional on a contraction, and (iv) the expected value of real per-capita GDP growth in the lower 5% tail of the conditional probability density. The partial effect is computed as $\mathcal{S}\left(\hat{f}_{y_{it}|x_{it}}\right) - \mathcal{S}\left(\hat{f}_{y_{it}|x^*_{it}}\right)$, where $\mathcal{S}$ is one of the four described metrics, $\hat{f}_{y_{it}|x_{it}}$ is the estimated conditional distribution, and x^*_{it} is the same distribution function derived by putting the number of deaths due to the Spanish flu to zero.

Figure I: Data



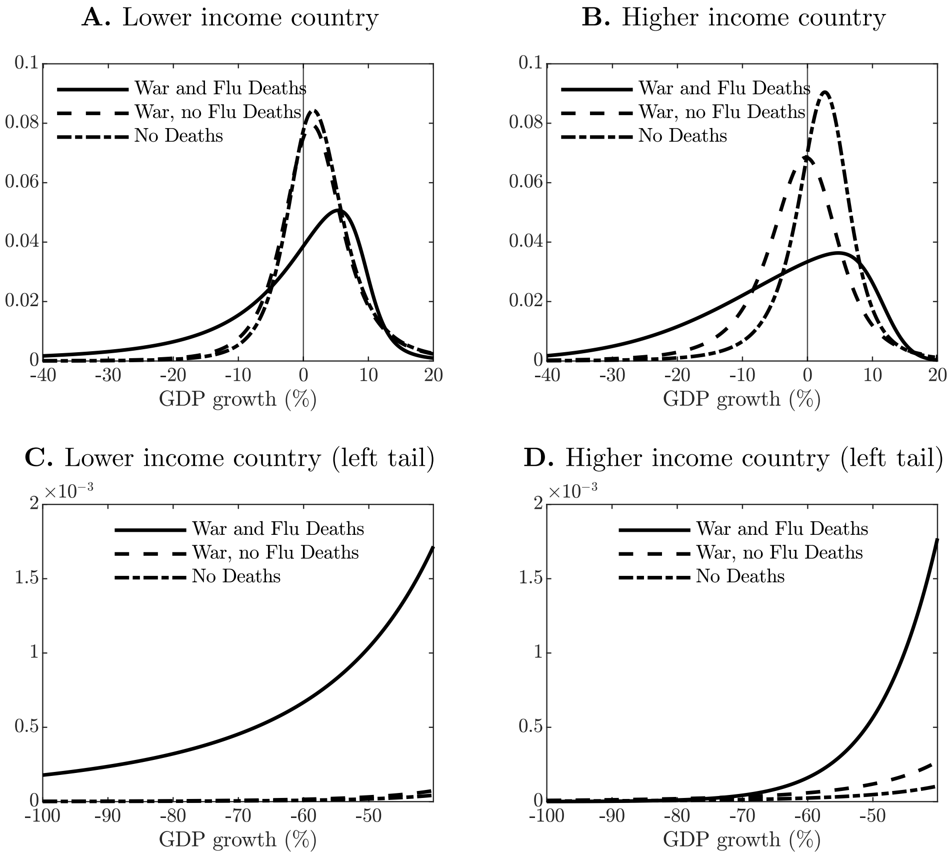
Notes: Panels A and B show the annual real per capita real GDP growth in percent computed for 42 countries over the period from 1901 until 1929. In Panel A, the fitted distribution corresponds to the unconditional distribution of real per capita GDP growth, which is obtained using the methodology described in section II with a constant as the only regressor. In Panel B, the full line shows the median real per capita GDP growth across countries over time, the shaded area covers the respective 16th to 84th percentiles, the dotted lines show the minimum and maximum values over time and the dashed-dotted line shows the US real per capita GDP growth. The shaded bar highlights the period of the Spanish Flu. Panels C and D show the relation between the annual real per capita GDP growth and the number of deaths caused by the Spanish flu, expressed as percentage of each country's population, in the lower and higher income countries, respectively. The lower and higher income country classification is relative to the across-countries' median of the real per capita GDP in 1917. Only observations with a non-zero death count are included.

Figure II: Conditional Probability Density of Real Per Capita GDP Growth (1918)



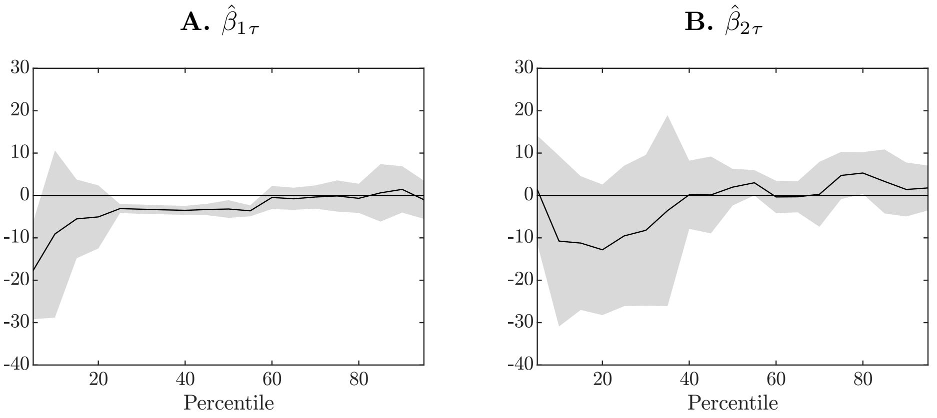
Notes: This figure shows three conditional distributions of the real per capita GDP growth rate for a typical country generated by the model described in Section II. The density shown in a full line ("War and Flu Deaths") uses the observed data on war deaths and flu deaths; the dashed density ("War, no Flu Deaths") uses the war deaths, but puts the flu deaths at zero; and the dashed-dotted density ("No Deaths") shows the distribution when both flu and war deaths are put to zero.

Figure III: Conditional Probability Densities of Real Per Capita GDP Growth in the Typical Lower and Higher Income Countries (1918)



Notes: Each panel shows three conditional distributions of the real per capita GDP growth rate generated by the model described in Section II, where the estimated parameters are allowed to differ according to whether or not the country's 1917 level of GDP is below or above the across countries' median level of real per capita GDP in 1917. The density shown in a full line ("War and Flu Deaths") uses the observed data on war and flu deaths aggregated either over the below-median countries (Panels A and C), or over above-median countries (Panels B and D); the dashed density ("War, no Flu Deaths") uses the (per category aggregation of) war deaths, but puts the flu deaths at zero; and the dashed-dotted density ("No Deaths") shows the distribution when both flu and war deaths are put to zero. Panels C and D focus on the extreme left-tails of the distribution.

Figure IV: Pass-Through Coefficients from Spanish Flu to Real Per-Capita GDP growth in Typical Lower and Higher Income Countries



Notes: This figure shows estimated quantile regression coefficients and the associated 90% error bands for percentiles $\tau = 5, 10, \ldots, 95$. Panel A shows $\hat{\beta}_{1\tau}$, the impact of a 1 percentage point increase in the Spanish flu death rate on real per capita GDP growth in percent as a function of τ. Panel B shows $\hat{\beta}_{2\tau}$, the extent to which the transmission of the flu death rate to GDP growth differs for higher relative to lower income countries.

Acknowledgements

We are very grateful to Robert Barro for having shared with us his historical database covering the Spanish Flu. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank or the Eurosystem.

Roberto A. De Santis (corresponding author)
European Central Bank, Frankfurt am Main, Germany; email: roberto.de_santis@ecb.europa.eu

Wouter Van der Veken
European Central Bank, Frankfurt am Main, Germany; Ghent University, Ghent, Belgium; email: wouvdrve.vanderveken@ugent.be

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

PDF ISBN 978-92-899-4383-3 ISSN 1725-2806 doi:10.2866/32021 QB-AR-20-118-EN-N