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ORIGINAL PAPER

Pandemics and Economic Growth: Evidence from the 1968 H3N2 Influenza

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Abstract
We evaluate the 1968 H3N2 Flu pandemic's economic cost in a cross-section of 52 countries. Using excess mortality rates as a proxy for the country-specific severity of the pandemic, we find that the average mortality rate (0.0062% per pandemic wave) was associated with a decline in output of 2.4% over the two pandemic waves. Our estimates also suggest the losses in consumption (-1.9%), investment (-1.2%), and productivity (-1.9%) over the two pandemic waves. The results are robust across regressions using alternative measures of mortality and output loss. The study adds to the current literature new empirical evidence on the economic consequences of the past pandemics in light of the potential impacts of the Covid-19 pandemic on productivity.

Keywords Output loss · Productivity · Pandemics · Hong Kong flu · H3N2

JEL Classifications E65 · I15 · Q54

Introduction

The spread of a new coronavirus (Covid-19) in early 2020 has caught the world by surprise and led to a dramatic contraction in the global economy. Our understanding of pandemics' macroeconomic impact was limited, based only a handful of studies on previous pandemic outbreaks. There were three significant global influenza pandemics since the early twentieth century: 1918, 1957, and 1968.[1] The first one, in 1918–1920, was by far the most catastrophic and has received the most research attention (e.g., Beach et al. 2020).

[1] The more recent 2009 'Swine flu' H1N1 pandemic turned out to be significantly less costly that feared at its onset. There is also research evaluating the economic impacts of the 2009 Swine Flu (e.g. Rassy and Smith 2013). Another recent coronavirus pandemic, SARS, has been researched more, but its spatial spread was limited to a few countries (Noy and Shields 2019).

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Why are there so few empirical studies evaluating the impact of past pandemics on economic growth more generally? Apart from the fact that those events are thankfully rare, data constraint is an important factor explaining this gap in our current knowledge, especially for events before the twenty-first century. Only a few empirical studies estimate the adverse impacts of the 1918 Influenza at the aggregate level (e.g., Karlsson et al. 2014; Barro et al. 2020; Bodenhorn 2020; Dahl et al. 2020). Yet, even for the 1918 pandemic, the difficulties in separating the pandemic's impact from the war and the paucity of reliable data have prevented much quantification of its economic impact (Noy et al. 2020). Here, in contrast, we focus on the 1968 influenza pandemic, an event that is closer in time, documented with a lot more economic data and probably more reliable mortality data, and can better serve as a useful comparator to the current global predicament. Surprisingly, though, the 1968 pandemic's consequence on economic growth has yet to be studied. This is what we undertake herein.

For the current Covid-19 pandemic, recent works attempt to identify the pandemic's adverse effects on economic growth separately through demand and supply channels. Demand-side channels capture the consequential effects on consumption, investment, trade, and travel, while supply channels reflect workforce and supply-chain disruptions and the rising costs of doing business (Guerrieri et al. 2020; World Bank 2020).

Besides the useful distinction between demand and supply effects, another important puzzle is whether epidemics can affect longer-term productivity and growth. In principle, pandemics could affect labor productivity through their direct impact on human health and indirectly by affecting skill acquisition and capital investment. In principle, an influenza epidemic can have permanent consequences on the productivity of an economy. Even if the productivity growth rate returns to its pre-pandemic value, it might be that the productivity level will always lie below the path it would have followed in the absence of the epidemic. The objective of our study is to assess how large these effects are empirical. To the best of our knowledge, only Guimbeau et al. (2020) studied and found negative effects of the 1918 influenza on agricultural productivity using district-level data in the Brazilian city of Sao Paulo.

Here, we investigate the impact of the 1968 H3N2 influenza pandemic on output and productivity in a cross-section of 52 countries. The H3N2 was the first pandemic spreading rapidly through international air travel (Viboud et al. 2005). According to recent estimates, it affected 30–57 percent of the global population, with the mortality rates estimated in the range of 0.02–0.03 percent. It was a less lethal pandemic than the H1N1 influenza pandemic of 1918 (World Bank 2020).

We contribute to the 'economics of pandemics' literature by analysing the economic cost of the H3N2 pandemic using historical data on mortality rates (two waves) obtained from the World Health Organization database on the International Classification of Diseases. We find that the pandemic reduced output growth rate by 2.4% cumulatively over the two seasons (mortality rate was 0.0062% per season) and productivity by 1.9%. The evidence also shows that the pandemic shock led to a reduction in private consumption and investment by 1.9% and 1.2%, respectively. Our study cannot incorporate the efficacy of non-pharmaceutical interventions due to the lack of data.

The rest of the paper is organized as follows. Pandemics and Development presents the background of the pandemic, and Data Description shows the data available. Empirical Specification describes the empirical specification, followed by the estimation results in Estimation Results. Conclusion concludes.

Table 1 Estimated mortality and infection rates of the Influenza pandemics since the past century

Event	1918–1920	1957–1958	1968–1970	2009–2010
Deaths (% of global population)	1.0—5.7	0.03 – 0.05	0.02 – 0.03	0.001 – 0.004
Infections (% of global population)	28	42—55	30 – 57	24
Reproduction number	1.80	1.65	1.80	1.46

Source: World Bank (2020); Biggerstaff et al. (2014).

Pandemics and Development

Background of the H3N2 Flu Pandemic

Three worldwide (pandemic) influenza outbreaks occurred in the last century, including the H1N1 pandemic in 1918–1920, the H2N2 pandemic in 1957–1958, and the H3N2 pandemic in 1968–1969; the three are also colloquially known as the Spanish, Asian, and Hong Kong flu pandemics.[2] Each event differed from the others concerning the aetiological agent, its epidemiological characteristics, and the associated disease severity. These influenza pandemics did not occur at regular intervals. In the two that occurred with modern virology tools available (1957 and 1968), the causative viruses' antigen showed major changes from the corresponding antigens of immediately antecedent strains. Among the past events, the 1918 pandemic was the most severe, with the mortality rate ranging from 1 to 5 percent of the global population. However, the 1957 Influenza spread most widely, with more than 40% of the global population likely got infected (Table 1).

The influenza A (H3N2) virus combines two genes from an avian influenza A virus: the new H3 hemagglutinin and the N2 neuraminidase (from the 1957 H2N2 virus). Although the new disease-causing virus identified in 1968 was extremely transmissible (its reproduction number[3] was similar to the H1N1 strain from 1918), the disease severity was milder than both previous flu pandemics. It emerged in Hong Kong on the 13$^{\text{th}}$ of July 1968, and reached its maximum intensity in two weeks, lasting some six weeks in all with 500,000 cases in Hong Kong in July. The outbreak was the largest in Hong Kong since the 1957 pandemic (Jester et al., 2020). About 15% of the population across all age groups was affected, but the mortality rate was low, and the clinical symptoms were typically mild (Chang 1969).

That year, the World Health Organization warned of its possible worldwide spread on 16 August 1968 and identified it as the cause for epidemic outbreaks in other parts of the world. Viboud et al. (2020) show that the H3N2 epidemic started in the last quarter of 1968 in the northern hemisphere countries, while the southern-hemisphere countries started to experience the epidemic in 1969. Air travel (an estimated 160 million persons during the pandemic) facilitated rapid transmission worldwide (Jester et al., 2020). Jackson et al. (2010) use various published data to estimate that the first-wave reproduction number

[2] Since the current accepted standard, adopted by the WHO, is not to name a pandemic after the first publicized location of its emergence, we continue to refer to these events by the official influenza virus strain name.

[3] Reproduction or basic reproduction number is defined as the average number of secondary cases associated with a typical infectious case. It is an important parameter of transmissibility.

was between 1.1 and 2.1, and the second-wave reproduction number was possibly higher, between 1.2 and 3.6.

The 1968 H3N2 flu caused between 500,000 and two million deaths in two waves (1968–1969 and 1969–1970). As the epidemic progressed (initially in Asia; Singapore, Taiwan, the Philippines, Vietnam, and Malaysia), geographic patterns of mortality emerged. In North America, most deaths occurred during the first pandemic season. In Europe and Asia, 70% of the deaths happened during the second pandemic season.[4]

Economic Growth before the 1968 H3N2 Pandemic

The 1960s saw a rapid expansion in real economic activity associating with high employment and investment, price stability, productivity improvement, and freer trade (FED 1967; United Nations 1969). For OECD countries, the rapid growth was due to a high capital formation rate ranging from 14% in the United Kingdom to 30% in Japan, coupled with significant human-capital accumulation. For the first half of the 1960s, a shift of labor out of agriculture increased productivity by 10%—15% in France, Germany, Italy, and Japan (FED 1967). Many developing countries were also recording high growth, thanks to capital inflows and their demographic dividends.

Pandemics and Economic Growth

A now growing body of literature has examined the economic costs of pandemics over the short-to-medium-term horizon. Pandemics' macroeconomic impacts could stem from effects on aggregate demand and aggregate supply adjustments. The expected loss in disposable income associated with the epidemic would reduce private consumption for the demand side. Lockdown and travel ban measures to slow the spread of the disease, for instance, can affect aggregate demand as well. Fear and uncertainty, and the disruptions associated with them, cause more precautionary behavior and a further drop in demand.

Social-distancing requirements reduce productivity and investment. The decline in international trade and the rising cost of doing business disrupt the global value chains, further compounding the supply side issues from workers' exposure to lockdown, infection, and mortality. Thus, the pandemics' supply-side effects are likely through lower productivity, adverse impact on investment, labor supply, and total factor productivity (Dieppe 2020; World Bank 2020).[5]

For the 1918 pandemic, Barro et al. (2020) find that it lowered real GDP and consumption by 6% and 8%, respectively, in cross-country data. Dahl et al. (2020) find that

[4] Viboud et al. (2020)'s findings suggest that the 1-year delay in mortality might be the most common experience in continents other than North America. They hypothesize that this phenomenon may be explained by the higher pre-existing neuraminidase immunity (from the A/H2N2 era) in other places rather than North America, combined with a subsequent drift in the neuraminidase antigen during 1969/1970.

[5] Pandemics can also lead to permanent changes in productivity through other channels. For example, higher unemployment, especially among young workers, can lead to de-skilling or permanent loss of opportunities to acquire new skills, which can lead to persistent reductions in the accumulation of human capital. Besides, pandemics affect mental health in ways that may imperil labor productivity. While there are multiple channels through which productivity could be adversely affected, there might be other indirect effects on productivity. For example, a shift to work-from-home could, in principle, be productivity-improving for some sectors and occupations.

it resulted in a V-shaped recession using municipality-level data from Denmark. Using regional data from Sweden, Karlsson et al. (2014) find that the 1918 pandemic led to a persistent increase in poverty rates and reduced capital return. Bodenhorn (2020), focusing on the Southern United States, find that the 1918 Influenza reduced retail sales and manufacturing activity. Garrett (2009) finds that geographic areas with higher influenza mortality saw a relative increase in wages from 1914 to 1919 census years, consistent with the effect of labor shortages. Guimbeau et al. (2020) find robust evidence of contemporary and persistent effects on health, educational attainment, and agricultural productivity using district-level data in the Brazilian city of Sao Paulo. Noy et al. (2020) examined the Japanese textile industry, and find that a prefecture with the mean excess mortality experienced a 28.3 percent reduction in annual textile output. There is so far no study on the H2N2 and H3N2 pandemics that can offer comparable lessons.[6]

The recent literature with regards to the ongoing Covid-19 pandemic has provided some useful insights. Martin et al. (2020) introduce a household-level model to assess the socio-economic impacts of Covid-19 on per capita consumption losses and depletion of savings. Using an agent-based model of out-of-equilibrium economic dynamics to estimate the cost of the Covid-19 lockdowns, accounting both for direct impacts of the lockdowns and its propagation through the global supply chain, Mandel and Veetil (2020) estimate the total impact amounting to 9% of global GDP. Considering the demand perspective, Nakamura and Managi (2020) calculate the overall relative risk of the importation and exportation of Covid-19 from every airport in local municipalities around the world, based on global spatial and mapping information under three scenarios of air travel restriction. The relative risk of importation and exportation of Covid-19 clearly shows that not only China, Europe, Middle East, and East Asia, but also the U.S., Australia, and countries in Northeast Asia and Latin America are subject to such risk.

Likewise, in a two-step Vector Auto-Regressive (VAR) model to forecast the effect of the virus outbreak on the economic output of the New York state, Gharehgozli et al. (2020) predict annualized quarterly growth rate of real GDP to be between -4% to -4.3% for the first quarter and between -19.8% to -21.7% for the second quarter of 2020. Considering an artificial neural network model to forecast GDP loss in eight major countries, the findings show that the April to June quarters of 2020 saw a significant decline in economic growth in all countries while the annualized GDP growth is expected to reach double-digit negative growth rates in most countries (Jena et al. 2021).

NPIs might play a role in mitigating the economic decline from a pandemic by reducing the spread of the virus and thus retaining more confidence in business activity and investment. For instance, Kurita and Managi (2020) and Katafuchi et al. (2020) point out that social stigma can effectively prevent people from going out and possibly spreading Covid-19 infection. These studies show both theoretical analysis and empirical evidence that non-legally binding Covid-19 policies, i.e., a declared state of emergency reduce the share of people going out through self-restraint behaviour.

[6] There is some research estimating the economic consequences of other biological disasters since the 1980s (including AIDS, SARS, Ebola, and Zika, e.g., Lee and McKibbin 2004; Siu and Wong 2004; Keogh-Brown and Smith 2008; Joo et al. 2019; and Noy and Shields 2019), and some evaluating the impacts of the current Covid-19 pandemic (e.g., Andersen et al. 2020; Baker et al. 2020; Banco de Espana 2020; Chen et al. 2020; Coibion et al. 2020; and Guerrieri et al. 2020). The former is not directly relevant, given the differences in the epidemioloigical characteristics of the diseases involved.

Table 2 Excess mortality and economic outcomes during the H3N2 pandemic

		Obs	Mean	S.D	Min	Max
excess_a (baseline, in %)	All	52	0.0076	0.0062	0	0.0233
	Northern hemisphere	43	0.0068	0.0068	0	0.0233
	Southern hemisphere	9	0.0115	0.0115	0.003	0.0217
excess_b (in %)	All	52	0.0085	0.0069	0	0.025
	Northern hemisphere	43	0.0079	0.0071	0	0.025
	Southern hemisphere	9	0.0115	0.0115	0.003	0.0217
excess_c (in %)	All	52	0.0066	0.0059	0	0.0224
	Northern hemisphere	43	0.0061	0.0058	0	0.0224
	Southern hemisphere	9	0.0090	0.0060	0	0.0189
Output	Output1 (baseline)	52	1.30	2.74	-8.35	6.61
	Output2	52	1.54	3.79	-12.32	10.48
	Output3	52	1.12	2.74	-8.71	6.89
Productivity (baseline)	Labor productivity	46	1.61	2.92	-9.35	7.24
	TFP	45	2.74	2.81	-7.14	8.58
Consumption (baseline)		52	1.43	4.29	-8.39	13.13
Investment (baseline)		52	0.91	1.79	-2.83	6.54

Source: WHO, PWT 9.1, and authors' calculation.

Baseline: Averaged 1968–70 deviation (for the Northern hemisphere) and averaged 1969–70 deviation (for the Southern hemisphere) from pre-pandemic (1965–67).

Output 2; excess_b: Averaged 1969–70 deviations from pre-pandemic (1965–67).

Output3; excess_c: Averaged 1968–70 deviation (for the Northern hemisphere) and averaged 1969–70 deviation (for the Southern hemisphere) from pre-pandemic (1963–67).

Data Description

Defining Excess Mortality

Most influenza victims die of pneumonia or pneumonia-like complications that develop due to the immune system's response to the viral infection (Viboud et al., 2016; Bodenhorn 2020). Regarding the severity of a pandemic across countries, excess mortality rate—the number of deaths in the pandemic years over the population relative to the average pre-pandemic mortality rate, is considered a better measure than measured infection rate. The heterogeneous mortality patterns from a pandemic indeed reflect differences in how effectively countries have managed the associated outbreaks, the resilience of the economy, and the preparedness of their healthcare system. Thus, the baseline index for pandemic intensity (*"excess_a"* variable in Table 2) is the average annual excess mortality rate (i.e., excess deaths as a percent of the population) caused by Influenza and pneumonia during the two pandemic seasons of 1968/69 and 1969/70. Data on mortality rates are from the International Classification of Diseases of WHO (versions ICD-7 and ICD-8): the main disease codes 470–517 and 480–493. A caveat is the mortality data is available only on annual basis from WHO. Subject to the data availability, we have 52 countries in the sample including mostly high-income countries and some upper-middle-income countries.

Excess deaths are the number of deaths in the pandemic years relative to the average pre-pandemic mortality rate for 1965–1967. Also, as mortality data is available from the past pandemics in the twentieth century, related works in the literature use excess mortality rates to examine their impacts on the economic dependent variables (e.g., Viboud et al., 2016; Correia et al. 2020; Barro et al. 2020; Bodenhorn 2020; Dahl et al. 2020, and Noy et al. 2020). In particular, our excess mortality estimates for country i are as follows:

$$\mathrm{Excess_i} = \text{Mortality rate}_{i,\ \text{pandemic period}} - \text{Mortality rate}_{i,\ 1965-1967} \tag{1}$$

The pandemic period is from 1968 to 1970 for the Northern hemisphere and 1969 to 1970 for the Southern countries; Appendix Table 9 provides the climatic region list. Our analysis thus considers the seasonality of the virus trans-mission among the Northern and the Southern hemispheres. Specifically, the baseline measure uses an average excess mortality rate from 1968 to 1970 for 43 countries in the Northern hemisphere and the 1969–1970 period for 9 countries in the Southern hemisphere. After accounting for the two pandemic seasons' duration, the total excess mortality rate is around 0.023%, consistent with the literature's estimated mortality rates (Table 1).

Many countries might not be significantly affected by the pandemic in 1968, and most countries had much higher mortality rates in the second wave 1969/1970. We use an alternative measure of the pandemic for robustness, defining the 1969–1970 period as the pandemic period (*"excess_b"* variable in Table 2). On average "excess_b" is 11% higher than "excess_a," the baseline measure for the northern hemisphere. The correlation between the two measures of excess mortality is 0.95. Also, we construct another alternative measure of excess mortality (excess_c) using the period 1963–1967 as the comparison period. On average "excess_c" is 13% lower than the baseline measure "excess_a".

Output Measures

$$\Delta Y_i = \mathrm{Y}_{\mathrm{i,\ pandemic\ period}} - \mathrm{Y}_{\mathrm{i,1965-1967}} \tag{2}$$

Equation (2) defines the deviation of the average real GDP growth rate during the two pandemic waves from that in the preceding period 1965–1967 (Output1 as the outcome variable $\Delta \mathrm{Y}_i$). The mean of this variable "Output1" is 1.30%. For robustness, we use other measures of output. The variable "Output2" in Table 2 is from Eq. (2) applied to the pandemic period 1969–1970. The variable "Output3" uses the pre-pandemic period from 1963 to 1967. The correlation coefficients of these output measures are about 0.9 (Appendix Table 8).

Productivity Measures

We apply Eq. (2) to define "labor productivity" and "TFP" as the outcome variables, further shown in Table 2, measuring the deviations of the productivity growth rates during the pandemic from those in the preceding period (as the outcome variables). Labor productivity is the real output per worker. Total factor productivity TFP is the real output divided by the weighted productive capital input and the weighted labor input from the Penn World

Tables 9.1[7] We have 46 countries with data on labor productivity and 45 countries with TFP[8]. The average labor-productivity deviation is 1.61%, and the TFP deviation is 2.74%.

Consumption and Investment

Using Eq. (2) to define the consumption and investment as the outcome variables Y, Table 2 shows, respectively, the deviations of real consumption and investment growth rates during the pandemic from those in the preceding period. The average deviation in consumption is 1.43%, and the investment deviation is 0.91%.

Control Variables

We use a set of control variables in our estimation following the literature, including inflation, government spending, trade openness, years of secondary schooling, population growth, and political right index all in the pre-pandemic period. Our selection of these controls follows Brainerd and Siegler (2003), Guimbeau et al. (2020), and Correia et al. (2020). Demographic, geographic, and initial economic factors control for differences in the pre-pandemic conditions. The demographic and geographic characteristics may also influence the mortality patterns of affected countries at the onset of an influenza outbreak; thus, we do not control these factors. Also, Correia et al. (2020) suggest that places with better institutions may have a lower cost of intervening and relatively better economic prospects during influenza outbreaks. Hence, we control for quality institutions using as a proxy the political right index.

Our controls are consistent with the literature; for example, a study by Guimbeau et al. (2020) on the consequential effect of the 1918 Influenza on agricultural productivity in Brazil.[9] Data on output, productivity, and control variables are from Penn World Tables 9.1 and World Development Indicators; more details are in Appendix Tables 6, 7, 8 and 9.

Empirical Specification

To estimate the association between the H3N2 pandemic and output growth and TFP, we use a cross-section of 52 countries with available data to examine the pandemic as a common shock that affected all countries in the two pandemic waves 1968/69 and 1969/70. The dependent variables are the deviations of growth and productivity during the pandemic seasons from the preceding period (1965–1967). The estimating equation is as follows:

[7] In the PWT 9.1, the 'productive capital input' measures firstly introduced are more appropriate for comparing productivity across countries and over time than the capital stock measures previously in the PWT 9.0. Specifically, measures of physical and human capital and estimates of productivity are based on the translog production function which allows for substitution elasticities to differ across countries and over time. In addition, the authors improve the measure of physical capital by estimating the user cost of capital and comparing the implicit rental price of capital and the level of capital services rather than capital stock.

[8] The TFP level is in current PPPs with the United States as the base country, thus, we drop the US in the specification of TFP. Six countries in the sample do not have data on productivity include: Honduras, Mauritius, Nicaragua, Panama, Paraguay, and El Salvador.

[9] See also Engelbrecht (1997); Dowrick and Nguyen (1989); Madsen (2007); Bonfiglioli (2008); Ayhan Kose et al. (2009); Ang and Madsen (2013); Oulton and Sebastiá-Barriel (2013); Dua and Garg (2019).

$$\Delta Y_i = \alpha \text{ Excess}_i + \beta X_{\mathrm{i,o}} + u_i \tag{3}$$

where ΔY_i is the outcome variable of country i (output growth, TFP, consumption growth, investment growth). $Excess_i$ is the intensity of the pandemic, measured as the excess death rate from Influenza and pneumonia. $X_{i,o}$ is the set of lagged control variables including inflation, government spending, trade openness, years of secondary schooling, population growth, and political right index (all in the period 1965–1967; annual averages). u_i is the error terms. There are no significant correlations between the control variables and the pandemic measures (see Appendix Table 8).

Estimation Results

Impact of the Pandemic on Output

We rescale the excess mortality variables by its standard deviation to interpret its economic significance.[10] The first two columns of Table 3 present the estimates of Eq. (3) without control variables using the baseline measure (Output1). Column 3.1 suggests that the pandemic (a standard deviation excess mortality rate of 0.0062%) reduced real output growth by 1.2% per pandemic season. Using excess_b (a standard deviation of 0.0069%) and excess_c (a standard deviation of 0.0059%) provides consistent estimates. All pandemic measures explain about 19 percent of the variation in output during the pandemic outbreak if there no control variables.

The next two columns add control variables. Overall, the excess_a estimate in column 3.2 suggests an annual output loss of 1.2%; similarly, for column 3.3 using excess_b and column 3.4 using excess_c. Thus, the two-year outbreak is associated with a cumulative output loss of 2.4%. Using the Output2 (1969–70 deviation from pre-pandemic) gives higher estimates (columns 3.5 to 3.7 of Table 3) relative to the baseline estimates, suggesting that the adverse impact was larger in the second pandemic wave (1969/1970). The estimates for Output3 (1963–1967 as the pre-pandemic period) are also consistent with Output1 and Output2, shown in columns 3.8 to 3.10.

Table 4 provides estimates of real consumption and investment growth. The main results are supportive of the output estimates, though smaller. For consumption, the findings are consistent; the pandemic shock reduced consumption growth by 1.92% (column 4.3) and investment by 1.16% (column 4.8) over the two pandemic waves in the baseline.

Given the fact that we have few countries with data on productivity, we further examine the sensitivity of the estimates based on a sample of those 46 countries with productivity data. The results are provided in Appendix Tables 10 and 11, in which the estimates appear to be close to the baseline while the explanatory power generally increases.

Impact of the Pandemic on Productivity

The first two column of Table 5 report the pandemic's estimated impacts on labor productivity in the regressions without any additional controls. The pandemic reduced labor

[10] In particular, the variable "excess_a" is weighted by its standard deviation which is 0.0062 (dividing the original excess mortality rate by this number). Thus, the coefficient is interpreted as the impact of a one standard-deviation pandemic shock (a rise in mortality rate by 0.0062%) on the outcome variable. Likewise, the variable "excess_b) is weighted by its standard deviation which is 0.0069.

Table 3 Impact of the pandemic mortality on output

Dependent variable	Output1 (baseline)				Output2			Output3		
	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)	(3.7)	(3.8)	(3.9)	(3.10)
excess_a *(baseline)*	-1.157*** (0.290)	-1.151*** (0.324)			-1.464*** (0.418)			-0.995*** (0.333)		
excess_b			-1.263*** (0.327)			-1.600*** (0.455)			-1.011*** (0.353)	
excess_c				-1.230*** (0.333)			-1.556*** (0.481)			-1.045*** (0.368)
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	52	52	52	52	52	52	52	52	52	52
R-squared	0.18	0.31	0.34	0.32	0.24	0.27	0.25	0.23	0.24	0.24

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors are in parenthesis.

excess_a/ Output1 (baseline): Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate or real GDP growth rate from pre-pandemic level (1965–67).

excess_b/ Output2: Averaged 1969–70 deviation in excess mortality rate or real GDP growth rate from pre-pandemic level (1965–67).

excess_c/ Output3: Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate or real GDP growth rate from pre-pandemic level (1963–67).

Control variables: the underlying economic conditions, including inflation, government consumption, trade openness, years of secondary schooling, population growth, and political right index in the pre-pandemic period 1965–67.

Table 4 Impact of the pandemic mortality on consumption and investment

Dependent variable	Consumption					Investment				
	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)	(4.7)	(4.8)	(4.9)	(4.10)
excess_a *(baseline)*	-1.139** (0.459)		-0.964** (0.470)			-0.614** (0.250)		-0.579*** (0.224)		
excess_b		-1.219*** (0.450)		-1.222** (0.413)			-0.569** (0.248)		-0.595*** (0.225)	
excess_c					-1.161** (0.455)					-0.613*** (0.221)
Controls	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Obs	52	52	52	52	52	52	52	52	52	52
R-squared	0.07	0.08	0.23	0.26	0.25	0.12	0.10	0.25	0.25	0.26

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors are in parenthesis.

excess_a (baseline): Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate from pre-pandemic level (1965–67).

excess_b: Averaged 1969–70 deviation in excess mortality rate from pre-pandemic level (1965–67).

excess_c: Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate from pre-pandemic level (1963–67).

Control variables: the underlying economic conditions, including inflation, government consumption, trade openness, years of secondary schooling, population growth, and political right index in the pre-pandemic period 1965–67.

Table 5 Impact of the pandemic mortality on productivity

Dependent variable	Labor productivity					TFP				
	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)	(5.6)	(5.7)	(5.8)	(5.9)	(5.10)
excess_a *(baseline)*	-1.006*** (0.335)		-0.949*** (0.322)			-0.923*** (0.326)		-0.880*** (0.265)		
excess_b		-1.027*** (0.359)		-0.959*** (0.355)			-1.009*** (0.341)		-0.950*** (0.311)	
excess_c					-0.927** (0.382)					-0.929*** (0.312)
Controls	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Obs	46	46	46	46	52	45	45	45	45	52
R-squared	0.13	0.14	0.37	0.36	0.25	0.12	0.15	0.41	0.42	0.41

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors are in parenthesis.

excess_a (baseline): Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate from pre-pandemic level (1965–67).

excess_b: Averaged 1969–70 deviation in excess mortality rate from pre-pandemic level (1965–67).

excess_c: Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate from pre-pandemic level (1963–67).

Control variables: the underlying economic conditions, including inflation, government consumption, trade openness, years of secondary schooling, population growth, and political right index in the pre-pandemic period 1965–67. A few countries are missing data for TFP, so the sample size is smaller (see Appendix Table 9).

productivity by 1% per pandemic wave; the explanatory power (R^2) is 13%. Adding all the regression controls, columns from 5.3 to 5.5 suggest that the loss in labor productivity is just below 1%; the explanatory power (R^2) is up to 37%. Over the two pandemic waves, the H3N2 Flu thus reduced the labor productivity by roughly 1.9%. The estimates for TFP in Table 5 give a similar pattern.

Overall, we find that the pandemic's impact on consumption (-1.9%), investment (-1.2%), output (-2.4%), and productivity (-1.9%) is very substantial. The main findings support negative economic impacts on output and its components as well as the productivity, in the aftermath of the H3N2 Flu pandemic of 1968.

Conclusion

We find the excess mortality due to the 1968 H3N2 Influenza is associated with a decline in output, productivity, consumption, and investment in a sample of 52 countries. Due to data constraints, we are unable to account for non-pharmaceutical interventions (NPIs) in determining these outcomes. NPIs measures are designed to help reduce the mortality rate but the associated economic costs are uncertain. On the one hand, NPIs could have increased the economic costs of the pandemic, by imposing interruptions to the flows of goods and services. On the other hand, NPIs could have decreased these economic costs by preventing the spread of the virus, thereby enabling consumption, investment, and production activities, or even by establishing better practices that increase the confidence of individuals and firms in the economy (e.g., Noy et al. 2020). As a result, the lack of NPIs data may bias our findings downward if those preventive measures could have reduced the economic decline associated with Influenza.

Appendix

Table 6 Data sources

Variable	Description	Source
mortality	The number of deaths from Influenza and pneumonia (WHO disease codes are 470–517 and 480–493)	WHO
gdp	real GDP at chained PPPs (in mil. 2011US$)	PWT 9.1
tfp	Total factor productivity, at current PPPs (USA = 1)	
consumption	Real private consumption in mil. 2011US$ (PPPs)	
investment	Real private investment in mil. 2011US$ (PPPs)	
govt spending	Share of government consumption to GDP (%)	
pop	Population (in millions)	
working population	Number of workers (in millions)	
cpi	Inflation (difference in the CPI in logs)	
open	Trade openness: a dummy variable	Wacziarg and Welch (2003)
school	Years of secondary schooling	WDI
pol	Political right index	www.freedomhouse.org

Table 7 Variable statistics

Variable	Description/Construction	Obs	Mean	St.Dev
"baseline"	*Pre-pandemic period:* 1965–1967 *Pandemic period:* 1968–1970 for the Northern hemisphere and 1969–1970 for the Southern hemisphere			
excess_a	Difference in mean mortality rate during the pandemic period relative to the pre-pandemic period (baseline, %)	52	.0076364	.0062479
excess_b	Similar measure to "excess_a", except the pandemic period is 1969–1970 for all countries (%)	52	.0085065	.0069851
excess_c	Similar measure to "excess_a", except the pre-pandemic period is 1963–1967	52	.0065971	.0058643
Output1	Difference in gdp growth between the pandemic and pre-pandemic periods (baseline, %)	52	1.296932	2.74062
Output2	Similar measure to "Output2", where the pandemic period is 1969–1970 for all countries (%)	52	1.541994	3.791761
Output3	Difference in gdp growth between crisis and pre-pandemic periods (where pre-pandemic period is 1963–1967)	52	1.116796	2.735895
lapro (labor productivity)	Difference in labor productivity growth between the pandemic and pre-pandemic periods (%) [labor productivity is measured by real output per worker]	46	1.607972	2.923586
TFP	Difference in total factor productivity growth between the pandemic and pre-pandemic periods (%)	45	2.738219	2.812022
con (consumption)	Difference in real per capita consumption growth between the pandemic and pre-pandemic periods (baseline, %)	52	1.429617	4.291726
inv (investment)	Difference in investment growth between the pandemic and pre-pandemic periods (baseline, %)	52	.9103743	1.7928
cpi_0	Inflation in the pre-pandemic period 1965–1967	52	2.326184	2.557353
$govt_0$	Government spending (as % of GDP) in the pre-pandemic period 1965–1967	52	.1469494	.0699663
pop_0	Population growth in the pre-pandemic period 1965–1967	52	.0179479	.0101987
$open_0$	Trade openness in the pre-pandemic period 1965–1967 (dummy)	52	.5384615	.5033822
pol_0	Political right index in the pre-pandemic period 1965–1967	52	79.03846	22.09513
$school_0$	Years of secondary schooling in the pre-pandemic period 1965–1967	52	1.080893	.8060666

Table 8 Pairwise correlations

Variables	(excess_a)	(excess_b)	(Ouput1)	(Output2)	(TFP)	(lapro)	(con)	(inv)	(cpi_0)	($govt_0$)	($school_0$)	($open_0$)	(pol_0)	(pop_0)
excess_a	1.000													
excess_b	0.946***	1.000												
Output1	-0.425***	-0.442***	1.000											
Output2	-0.418***	-0.438***	0.935***	1.000										
TFP	-0.352**	-0.383***	0.852***	0.790***	1.000									
lapro	-0.365**	-0.371**	0.898***	0.815***	0.922***	1.000								
con	-0.267*	-0.286**	0.712***	0.729***	0.583***	0.575***	1.000							
inv	-0.345**	-0.320**	0.527***	0.503***	0.179	0.403***	0.409***	1.000						
cpi_0	0.097	0.048	-0.184	-0.117	-0.190	-0.278*	-0.251*	-0.301**	1.000					
$govt_0$	-0.001	0.026	0.229*	0.153	0.194	0.113	0.217	0.161	-0.054	1.000				
$school_0$	-0.062	-0.099	-0.059	-0.040	-0.021	-0.058	-0.112	-0.079	0.212	0.050	1.000			
$open_0$	-0.112	-0.092	-0.017	0.048	-0.339**	-0.299**	0.115	0.055	0.343**	-0.182	0.273*	1.000		
pol_0	0.078	0.091	-0.236*	-0.208	-0.473***	-0.439***	-0.054	-0.035	0.255*	-0.104	0.457***	0.425***	1.000	
pop_0	-0.150	-0.185	0.079	0.125	0.343**	0.303**	-0.002	-0.015	-0.204	0.070	-0.344**	-0.519***	-0.701***	1.000

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9 Country list and the key variables

Number	WDI code	Country name	excess_a	excess_b	excess_c	Output1	Output2	Output3	TFP	lapro
1	ARG	Argentina*	0.0194	0.0194	0.016001	0.128274	0.128274	2.267981	0.523028	0.462145
2	AUS	Australia*	0.002997	0.002997	0	1.55368	1.553681	0.834257	1.68706	1.44252
3	AUT	Austria	0.016691	0.025036	0.01503	0.845932	1.168121	0.793232	2.28132	0.809935
4	BEL	Belgium	0.012974	0.012399	0.011047	1.03904	1.533407	0.659436	2.07387	1.55378
5	BRB	Barbados	0.003619	0.005429	0	1.78369	4.172643	5.078858	1.84303	2.25328
6	CAN	Canada	0.00152	0.001115	0	-0.8366	-1.39376	-1.14203	1.83668	1.34186
7	CHE	Switzerland	0.006608	0.007781	0.004712	2.50297	3.278331	1.566297	1.2526	1.00248
8	CHL	Chile*	0.00938	0.00938	0.00616	-1.39764	-1.39764	-0.7269	1.16935	-0.30902
9	COL	Colombia	0	0	0	3.64212	3.833719	2.827781	4.49707	3.37623
10	CRI	Costa Rica	0.003876	0.005814	0.003612	-0.49362	-0.42808	0.295504	2.6458	-0.21905
11	DEU	Germany	0.005552	0.005653	0.00588	3.75463	3.900309	2.82413	3.53208	2.47277
12	DNK	Denmark	0.003794	0.002296	0.003136	0.354156	-0.31092	0.022856	2.05829	0.214092
13	DOM	Dominican Republic	0.00394	0.005	0.003646	6.33862	10.48484	6.372761	7.06898	6.73732
14	ECU	Ecuador*	0.009074	0.009074	0.004686	0.287493	0.287493	0.235386	1.47324	0.286633
15	EGY	Egypt	0.005963	0.005963	0.005652	6.60564	6.765234	4.226338	7.86588	3.65426
16	ESP	Spain	0.000992	0.001435	0	0.844121	0.678874	0.844121	2.17792	0.55412
17	FIN	Finland	0.008399	0.011813	0.007821	2.90037	4.029218	3.128274	3.87904	2.54464
18	FRA	France	0.008763	0.009686	0.006089	0.742081	1.472078	0.304613	1.81413	0.353109
19	GBR	United Kingdom	0.023091	0.024506	0.02239	-0.61634	-1.32602	-0.49869	1.33249	0.899999
20	GRC	Greece	0.012639	0.010412	0.008535	1.23964	2.431382	0.504834	1.94308	0.758205
21	GTM	Guatemala	0.010756	0.016133	0.011948	1.71097	0.89209	1.587084	0.916493	2.06443
22	HKG	Hong Kong SAR	0.000551	0.000827	0.000689	1.35258	2.82535	0.004117	3.75032	1.30827
23	HND	Honduras	0.008715	0.01307	0.00923	-2.15408	-4.10721	-1.57079	-	-
24	IRL	Ireland	0.01316	0.01974	0.015693	1.23728	-0.3205	1.220421	1.39067	1.49735
25	ISL	Iceland	0.00401	0.006015	0.004741	-0.4354	4.16083	-1.7564	0.529997	-2.27697
26	ISR	Israel	0.000848	0.001272	0	6.21865	9.052931	3.936749	8.5827	7.0534
27	ITA	Italy	0.008878	0.009242	0.008271	1.87623	2.85529	3.925663	2.85485	2.47001
28	JAM	Jamaica	0.006785	0.003691	0.005114	3.9655	6.322402	2.288332	4.8919	4.39023
29	JPN	Japan	0.002338	0.002913	0.002108	2.54397	2.18041	2.402717	2.75064	3.2693

Table 9 (continued)

Number	WDI code	Country name	excess_a	excess_b	excess_c	Output1	Output2	Output3	TFP	lapro
30	LKA	Sri Lanka	0.000365	0.000365	0.000319	3.02621	1.688944	3.889429	3.77739	3.38706
31	LUX	Luxembourg	0	0	0	3.13969	3.498503	2.60419	4.45571	2.96738
32	MEX	Mexico	0.0233	0.0184	0.01641	0.600024	-0.62376	-1.41432	2.4565	0.511329
33	MUS	Mauritius*	0.008252	0.008252	0.006292	3.70709	3.707087	3.707067	-	-
34	NIC	Nicaragua	0.01128	0.0114	0.009345	-3.93698	-3.4006	-5.31303	-	-
35	NLD	Netherlands	0.009673	0.013022	0.00892	1.03223	1.076975	1.903189	1.58852	0.486268
36	NOR	Norway	0.013505	0.016427	0.013867	-8.34751	-12.3221	-8.71446	-7.14789	-9.35894
37	NZL	New Zealand*	0.010265	0.010265	0.006977	0.942385	0.942386	0.107959	5.27322	3.08953
38	PAN	Panama	0.007529	0.010733	0.009	2.32337	4.234654	3.563689	-	-
39	PER	Peru*	0.021722	0.021722	0.0189	-1.68591	-1.68591	-1.41094	0.68236	-2.30402
40	PHL	Philippines	0.001313	0.000414	0.00495	2.2127	1.96137	2.209811	5.8383	5.71161
41	PRT	Portugal	0.004542	0.006813	0.000198	1.90852	-0.67973	2.393728	2.63412	1.00641
42	PRY	Paraguay*	0.012898	0.012898	0.013454	0.967892	0.967892	1.47375	-	-
43	ROU	Romania	0.01957	0.02336	0.018646	-2.06861	-2.26171	-1.21273	-0.58402	-1.78401
44	SGP	Singapore	0.000991	0.000823	0	5.05916	6.369545	3.10734	0.515397	2.59992
45	SLV	El Salvador	0.008101	0.012151	0.009258	-3.03759	-3.71759	-2.3639	-	-
46	SWE	Sweden	0.005211	0.003512	0.00362	1.83501	2.542208	0.730281	1.5766	0.323947
47	THA	Thailand	0	0	0	5.74728	10.03623	6.886227	7.98812	5.92483
48	TTO	Trinidad and Tobago	0	0	0	1.17572	-0.34109	-1.18039	3.07708	1.52179
49	TWN	Taiwan	0	0	0	-0.56859	-0.58509	-0.43422	-1.88176	-2.34514
50	URY	Uruguay*	0.00906	0.00906	0.008405	3.98227	3.982271	3.981951	6.97354	6.47432
51	USA	United States	0.00736	0.005908	0.004372	-2.41953	-3.47084	-2.34782	-	-1.45226
52	VEN	Venezuela	0.006844	0.00872	0.007922	4.31167	3.54123	3.44966	7.37415	7.24138

Sources are WHO, PTW 9.1 and author’s calculation. An asterisk * marks the Southern Hemisphere countries

Table 10 Impact of the pandemic mortality on output (smaller sample)

Dependent variable	Output1 (baseline)				Output2			Output3		
	(10.1)	(10.2)	(10.3)	(10.4)	10.5)	(10.6)	(10.7)	(10.8)	(10.9)	(10.10)
excess_a *(baseline)*	-1.104*** (.289)	-1.041*** (.277)			-1.326*** (.394)			-0.890*** (0.309)		
excess_b			-1.083*** (.303)			-1.368*** (0.432)			-0.859** (0.335)	
excess_c				-1.101*** (.316)			-1.399*** (0.474)			-0.956** (0.360)
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	46	46	46	46	46	46	46	46	46	46
R-squared	0.19	0.41	0.41	0.41	0.31	0.31	0.32	0.31	0.30	0.32

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parenthesis

excess_a/ Output1 (baseline): Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate or real GDP growth rate from pre-pandemic level (1965–67)

excess_b/ Output2: Averaged 1969–70 deviation in excess mortality rate or real GDP growth rate from pre-pandemic level (1965–67)

excess_c/ Output3: Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate or real GDP growth rate from pre-pandemic level (1963–67)

Control variables: the underlying economic conditions, including inflation, government consumption, trade openness, years of secondary schooling, population growth, and political right index in the pre-pandemic period 1965–67

The estimation sample includes 46 countries with available data on labor productivity (the exact sample used in Table 5)

Table 11 Impact of the pandemic mortality on consumption and investment (smaller sample)

Dependent variable	Consumption					Investment				
	(11.1)	(11.2)	(11.3)	(11.4)	(11.5)	(11.6)	(11.7)	(11.8)	(11.9)	(11.10)
excess_a *(baseline)*	-1.003** (.445)		-0.782* (.390)			-0.559** (.254)		-0.478** (.236)		
excess_b		-1.041** (.436)		-0.962** (.363)			-0.525** (.250)		-0.519*** (.244)	
excess_c					-0.926** (.420)					-0.531** (.238)
Controls	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Obs	46	46	46	46	46	46	46	46	46	46
R-squared	0.07	0.07	0.24	0.26	0.25	0.11	0.10	0.30	0.31	0.31

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parenthesis

excess_a (baseline): Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate from pre-pandemic level (1965–67)

excess_b: Averaged 1969–70 deviation in excess mortality rate from pre-pandemic level (1965–67)

excess_c: Averaged 1968–70 deviation (for the Northern hemisphere) or averaged 1969–70 deviation (for the Southern hemisphere) in excess mortality rate from pre-pandemic level (1963–67)

Control variables: the underlying economic conditions, including inflation, government consumption, trade openness, years of secondary schooling, population growth, and political right index in the pre-pandemic period 1965–67

The estimation sample includes 46 countries with available data on labor productivity (the exact sample used in Table 5)

Data Availability The full dataset used in this study will be available from the corresponding upon request.

Declarations

Ethics Statement No ethical approval was required to conduct this study.

Conflict of Interest All authors have no conflicts of interest to declare.

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