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Using past epidemics to estimate the macroeconomic implications of COVID-19: A bad idea!

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ABSTRACT

This work is intended to show that past epidemic scenarios are not suitable to estimate the macroeconomic impact of the new 2019 coronavirus. Using five centuries of macroeconomic data for England and a unique dataset on epidemics and other significant events (i.e., wars and natural disasters), we show that the macroeconomic effect of epidemics reflects the socio-economic features characterizing different eras. A mapping between past epidemic scenarios and the COVID-19-induced environment can thus lead to misleading outcomes. We believe our evidence to be of general interest and key for policymakers forced to implement rapid and effective policies.

1. Introduction

The rapid and growing spread of COVID-19 around the world made it necessary for governments to implement policies (e.g., school closures, workplace closures and travel bans) to slow down the onset of new cases. A direct consequence of these policies has been an unprecedented global macroeconomic recession.

The study of the potential macroeconomic effects of COVID-19 has attracted a lot of attention. A predominant approach relies on past epidemics/pandemics (hereinafter epidemics) to estimate the potential effects of the novel coronavirus on macroeconomic dynamics (see, among others, Barro et al., 2020; Beach et al., 2020; Correia et al., 2020; Jordà et al., 2020).

Jordà et al. (2020) focus on the macro effects of epidemics that occurred in past centuries in a group of European countries and conclude that COVID-19 will generate a significant drop in the real natural interest rate over the next decades. Barro et al. (2020) rely instead on the 1918 Spanish flu. They point out that a "rule of three" can be applied to estimate the potential output loss induced by COVID-19.[2] Correia et al. (2020) investigate the effects of implementing non-pharmaceutical interventions (NPI) in US cities during the 1918 Spanish flu. They suggest that NPIs represent a key instrument to reduce the risk of contagion as well as the adverse economic effects of COVID-19. Beach et al. (2020) examine the literature on the health and economic effects of the 1918 pandemic flu in order to gain useful lessons for estimating the macroeconomic impact of COVID-19.

However, it should be noticed that the socio-economic characteristic of major economies exhibited significant differences over the last centuries, and in particular over the latest one. As a consequence, the economic dynamics induced by an epidemic that occurred, say, in the 18th century cannot be compared to those implied by an epidemic in the 20th century.

By relying on the historical evolution of socio-economic characteristics, one can identify the following three eras: *(i) pre-*

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[2] According to the "rule of three", an epidemic death rate of 2% is associated to a 6% drop in GDP per capita growth rate.

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0954-349X/

capitalism (1500-1749), *(ii) industrial-capitalism* (1750-1899) and *(iii) financial-capitalism* (1900-2020).[3]

In the *pre-capitalism* era the business in England was driven by farms, husbandry and *"cottage industry"*. Ownership was in the hands of a few individuals, usually landlords or merchant-capitalists (Heller, 2011; Mendels, 1972; Overton, 1996). Labor – employed in fixed proportion relative to capital - was the main productive factor (Wilde, 2017). A central role within the society was played by the family (composed by a large number of children and elderly). Family earnings from labor activity were allocated only for subsistence purposes (Allen, 2009). Therefore, income was entirely spent and savings were absent.

The *industrial-capitalism* era – which started in the second half of the eighteenth century – has been characterized by the rise of manufacturing industry. Firm ownership moved from single individuals to "capitalist-entrepreneurs", whose goal was to maximize profits and to accumulate physical capital. Technology was rather rigid, allowing for limited re-allocation between labour and capital (Allen, 2009). Profits were re-invested in the production process in order to sustain an increasing domestic demand and accumulate further capital. Moreover, in this period a high rate of population growth deteriorated the standard of living of families in Europe, though not in North America (Mokyr, 2010, ch. 18).

During the *financial-capitalism* period the economic environment developed at a pace never seen before. A massive development of the financial system contributed substantially to economic growth, while it also made the economy more volatile and unstable. The rising importance of financial markets allowed firms to become bigger and to exploit economies of scale. The ownership of enterprises became fragmented among many shareholders. The evolution of the business environment made it necessary to adopt "forward-looking" management practices and strategies (Coluccia, 2012). Technology became more flexible, allowing for easier substitution between capital and labor, with the latter requiring both manual and intellectual skills. Thanks to a stronger bargaining power by workers, wages started to be set above the subsistence level (De Zwart et al., 2014). The rise of wages and the development of financial markets induced then households to save or invest part of their income (Chwieroth and Walter, 2019). The beginning of the 20th century marks also the end of "laissez faire" governments. As a consequence of global financial crises and rising geopolitical risks, governments became more active implementing policies aimed at improving welfare and living standards. The last thirty years are associated to a further evolution of financial capitalism. Information and communication technology, the acceleration of financial and economic integration, and new lifestyles and habits have significantly changed the structure of both developed and emerging societies. Therefore, we may expect that epidemic shocks occurring today will bring unprecedented macroeconomic consequences.

The analysis of the effects of pandemics on the macroeconomy represents thus a complex challenge not only due to changes in the socio-economic structure, but also because some of the past epidemics occurred in the proximity of wars or natural disasters.[4] This is clear from Figure 1, which depicts recessions – as measured by negative GDP growth – and major epidemics – as measured by epidemic death rates – that occurred in England in the three different eras i.e., *(i) pre-capitalism* (Panel A), *(ii) industrial-capitalism* (Panel B) and *(iii) financial-capitalism* (Panel C). It is easy to check that there is not a clear link between economic crisis and epidemics. Actually, their joint behaviour is rather complex, in particular if one focuses on the first two eras.

During the *pre-capitalism* era there have been severe recessions. However, in this period numerous wars and natural disasters also occurred, contributing to economic downturns. Establishing a clear link between growths and epidemics represents in the end a hard task. Nevertheless, several recessions occurred in correspondence of epidemics but not wars, such as the Epidemics in London (1500), the 2nd and 4th English sweat (1507), and the London Plague (1563). In the *industrial-capitalism* era the number of recessions still exceeds those of epidemics. One can observe a decrease in the GDP per capita only in the aftermath of important epidemics such as Smallpox of 1847–1849 and 1871-1872. Once again, in the same period wars and natural disasters complicate the picture.

During the *financial-capitalism* era, epidemics have not been followed by adverse economic effects (e.g., Scandinavian, Asian and Hong Kong flu). An exception is the Spanish flu (1918). However, and most importantly, this flu occurred during the first World War (Figure 1, Panel C). No other important epidemic episodes hit England in the post-war period.[5] Thus, epidemics per sè have never generated drops in output growth similar in magnitude to those induced (today) by the novel coronavirus. In this respect, the projected relationship between COVID-19 and economic performance in England appears to be an outlier with respect to past epidemic-induced macroeconomic events.[6] Motivated by these observations, we attempt to show that past epidemics do not necessarily shape the ongoing and future COVID-19-implied macro environment.

We estimate the response of a set of macroeconomic variables to an epidemic shock in England in the three eras using the Jordà (2005) local projection methodology controlling for wars and natural disaster shocks. Estimated impulse responses indicate that the effect of epidemics on the economy across eras changes in sign, magnitude and timing. In particular, we observe the following: (i) an immediate and positive impact on GDP per capita growth following an epidemic shock in the *pre-capitalism* era; (ii) a significant negative impact on GDP per capital growth one year after an epidemic shock in the *industrial-capitalism* era; and (iii) a negative impact on GDP per capita growth five years after an epidemic shock in the *financial-capitalism* era. It is therefore unlikely that the use of past epidemic scenarios to estimate the potential economic impact of COVID-19 will yield realistic and reliable estimates.

The rest of the paper paper is organized as follows. Section 2 describes the data and the methodology. Section 3 is devoted to the discussion of the empirical results for the three different eras. Section 4 concludes.

2. Data and methodology

2.1. Data

Our analysis of the macroeconomic implications of epidemics focuses on English data spanning the period 1500–2019. In line with existing empirical works, the death rate is used as a proxy for epidemic intensity. We first retrieve an estimate of the crude number of deaths from different sources and then divide it by population taken from Ryland and Dimsdale (2017). Full details on data are provided in Appendix A and Appendix B.

For the sake of robustness, we control for other factors correlated to our macroeconomic variables. In particular, we control for the effect of wars. To do so, we build a novel war death rate using

[3] A similar classification can be found in Reid (1989, p. 3–13).

[4] To this end, our paper builds an innovative dataset – collected manually from various sources (see section Appendix A and Appendix B) – for England over a period of five centuries.

[5] The swine flu of 2009 led to a number of deaths close to 300 in the UK (see http://en.wikipedia.org/wiki/2009_swine_flu_pandemic_in_the_United_Kingdom).

[6] Statistically, the average epidemic death rates in the three eras correspond to 2.9, 2.2, and 1.4 per 1,000 people, respectively.

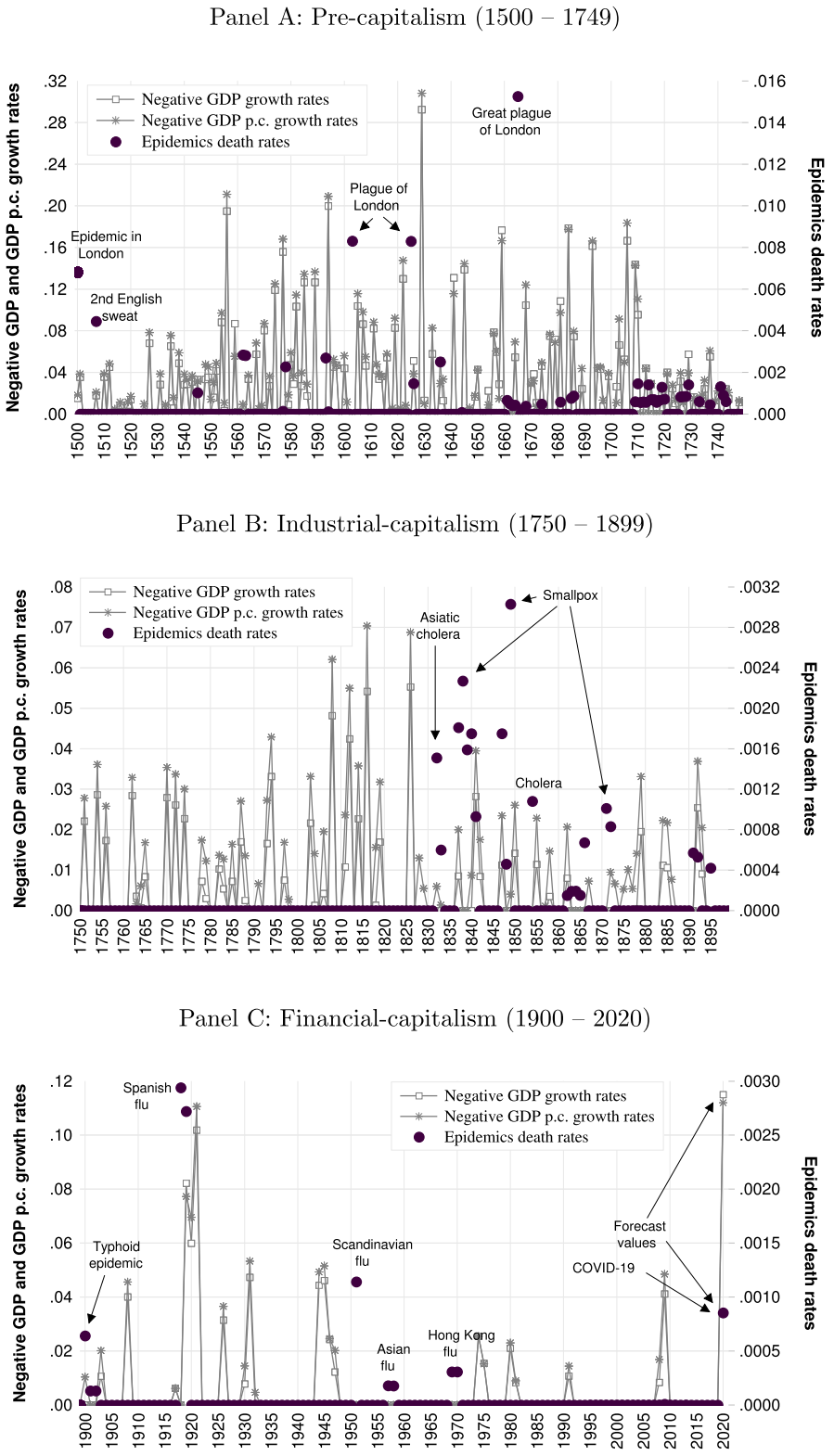

Fig. 1. Epidemics vs. Economic Recessions in England *Notes*: This figure reports the main recessions (captured by negative GDP and GDP per capita growth rates) and the major epidemic death rates (calculated as epidemic-induced deaths divided by population) over the last five centuries in England. Data details are reported in Appendix A and Appendix B.

war dates from Sorokin (1937), Clodfelter (2017) and BritishBattles.com (http://britishbattles.com/). We further include a dummy taking value 1 if an extreme climate event occurred in a specific year t and 0 otherwise.[7]

As main macroeconomic variables, we employ real GDP per capita and the real wage. Both variables have been collected from Ryland and Dimsdale (2017) and run from 1500 to 2019. As previously discussed, the economic environment evolved significantly over the centuries. Consistently with the different socio-economic characteristics characterizing the three eras, we study the responses to epidemic shocks of other variables. For the most basic economy, i.e., pre-capitalism, we only account for real wages and real GDP per capita. In the industrial-capitalism period, inflation is included as well. Finally, for the financial-capitalism era, we compute responses also for real investment growth, labour-to-capital-ratio, real consumption growth and real share price return.

2.2. Methodology

We estimate impulse response functions using the local projections method developed by Jordà (2005), controlling for wars and extreme weather events. Formally, we estimate the following equation:

$$y_{t+H} = \alpha^H + \sum_{j=1}^{n} \beta_j^H y_{t-j} + \sum_{j=0}^{m} \gamma_j^H P_{t-j} + \sum_{j=0}^{m} \delta_j^H W_{t-j} + \sum_{j=0}^{m} \phi_j^H C_{t-j} + \epsilon_t \text{ with } H = \{0, ..., 5\} \quad (1)$$

where y_t represents the dependent or response variable. Lagged values of the dependent variable are also included in order to control for autocorrelation.[8] The number of lags, n and m, are selected according to BIC criteria and equal to two. P_t, W_t and C_t are shock variables indicating epidemics, wars, and adverse climate events, respectively. P_t and W_t are expressed as crude death rates and C_t is the dummy indicating years in which an extreme climate event occurred. The inclusion of W_t and C_t in Eq. (1) allows us to identify the response to a epidemic shock, controlling for wars and adverse climate events.

3. Empirical results

In what follows we present local projections impulse responses of our main macroeconomic aggregates to epidemic shocks estimated in the three different eras, i.e., *pre-capitalism*, *industrial-capitalism*, and *financial-capitalism*.

While discussing the impact of epidemics on the GDP per capita (Y/Pop) we will refer to two distinct components: (i) labor productivity (Y/L, where L indicates the number of people employed) and (ii) share of employed workers over population (L/Pop).[9]

3.1. Pre-capitalism (1500–1749)

Figure 2 depicts the responses of real wages (Panel A) and real GDP per capita (Panel B) to an epidemic shock. The contemporaneous effect of a rise in the death rate from epidemics on real wages is negative, although not significant, but becomes positive after one year. The intuition behind this results is straightforward and comes as a direct implication of the socio-economic environment characterizing the pre-capitalism period. The epidemic-induced deaths in this era gives rise to a shortage of work (i.e., L decreases). Since reallocating labor with capital is not possible, the excess demand for labor causes a rise in wage levels. This effect jointly with the drop in the number of family members due to the epidemic, induces an increase in the wealth level of survivors and probably an rise in the labor-productivity ($Y/L \uparrow$).

It is also most likely that the epidemic generated more deaths among young and old people leading to an increase in the worker-population ratio ($L/Pop \uparrow$). If both Y/L and L/Pop go up, we expect the GDP per capita to increase, as shown in Figure 2 (Panel B). In fact, our analysis confirms a significant and immediate rise in GDP per capita growth (of around 5%) following a shock to the epidemic death rate.

3.2. Industrial-capitalism (1750–1899)

During the *industrial-capitalism* period the rise of manufacturing enterprises has remarkably changed society and in particular industrial organization. Yet, the technology level was not sufficient to efficiently substitute capital with labor, so the labor share was still high. However, the response of real wages to an epidemic shock is different than the one estimated for the preceding era (Figure 3, Panel A). This may be induced by the presence of "profit-seeking" entrepreneurs. The sudden sizeable number of deaths due to an epidemic generates an immediate shortage of work. In such a scenario, entrepreneurs try to keep their profit constant by increasing prices in the short-term (Figure 3, Panel C). As a result, we observe a drop in real wages (Figure 3, Panel A). The decrease in real wages in turn leads to a drop in the level of health of survivors and therefore a reduction in the labour-productivity ($Y/L \downarrow$). The fall in productivity forces firms to raise real wages in the medium run, with the ultimate goal of stimulating domestic demand. By doing so, firms avoid further reduction of profits (Figure 3, Panel B). The overall impact on output per capita is uncertain. On one hand, Y/L drops immediately. On the other hand, it is most likely that the ratio L/Pop increases due to a larger fraction of deaths among children and elderly population. Empirical findings indicate that the effect on wage reduction dominates, causing recessionary effects (Figure 3, Panel B). In particular, an epidemic shock should generate a drop (of around 9%) in GDP per capita growth rate after one year.

3.3. Financial-capitalism (1900–2019)

Examining the implications of epidemics for the real economy during the financial era of capitalism becomes more complex. In this period technology evolved significantly allowing for capital-labor reallocation. Demand and financial market shocks represent key drivers of the business cycles and entrepreneurs adopt more "forward-looking" investment strategies in a Keynesian sense.[10]

The impact of epidemic-induced shocks on real wages is not clear. We only observe a significant drop after one year from the shock (Figure 4, Panel A). The reason can be related to a "forward-looking" attitude of entrepreneurs who find it more convenient to make new investments and replace workers with machines, as indicated by the responses of real investment and the labour-to-capital ratio (Figure 4, Panel C and D). The risk of losing the job and the general uncertainty implied by the epidemic forces

[7] Due to data availability it has not been possible to build a proper climate event death rates. Therefore, we use a dummy to separate the effect of adverse climate events from epidemics.

[8] Confidence bands are based on Newey-West corrected standard errors (Newey and West, 1987; 1994) that control for serial correlation in the error terms induced by the successive leading of the dependent variable and heteroskedasticity.

[9] It is immediate to note that GDP per capita can be rewritten as $Y/Pop = (Y/L)(L/Pop)$.

[10] According to the Keynesian view, investment decisions about the purchase of different assets are necessarily forward-looking as they depend on the expected future returns of each asset in a given period.

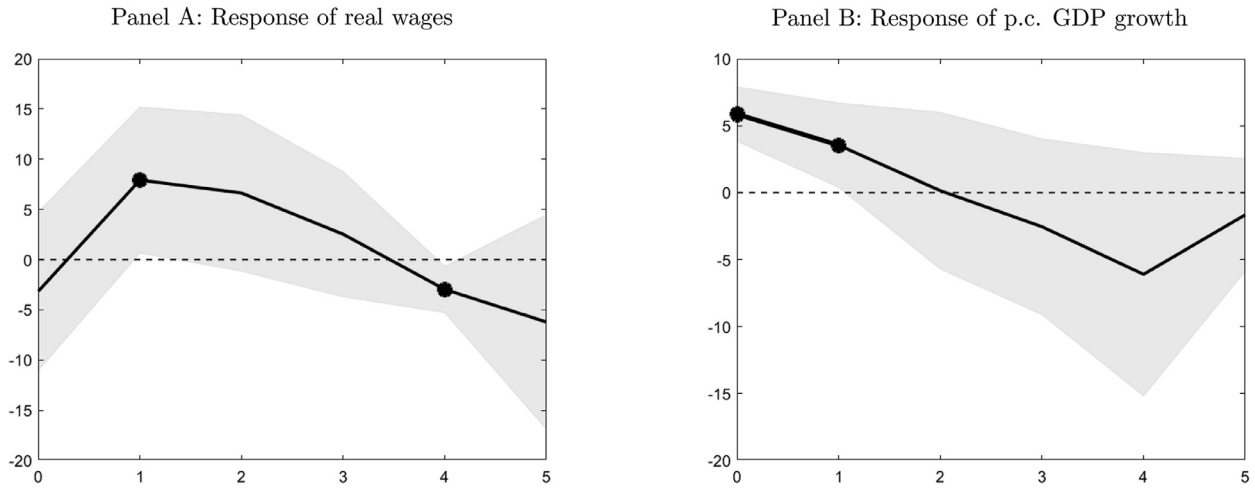

Fig. 2. Responses to an epidemic shock in the pre-capitalist period (1500–1749) *Notes*: This figure depicts the impulse responses – estimated by Jordà (2005)'s local projections – of real wages (Panel A) and GDP per capita growth (Panel B) to a shock in the epidemics death rate. A wars death rate and a dummy taking value one if an adverse climate event occurs and zero otherwise are included. To control for autocorrelation we include two lags of the dependent and control variables. Significant point estimates are denoted by dots. Grey bands indicate 90% confidence bands. Standard errors are corrected for heteroskedasticity and autocorrelation (Newey and West, 1987; 1994).

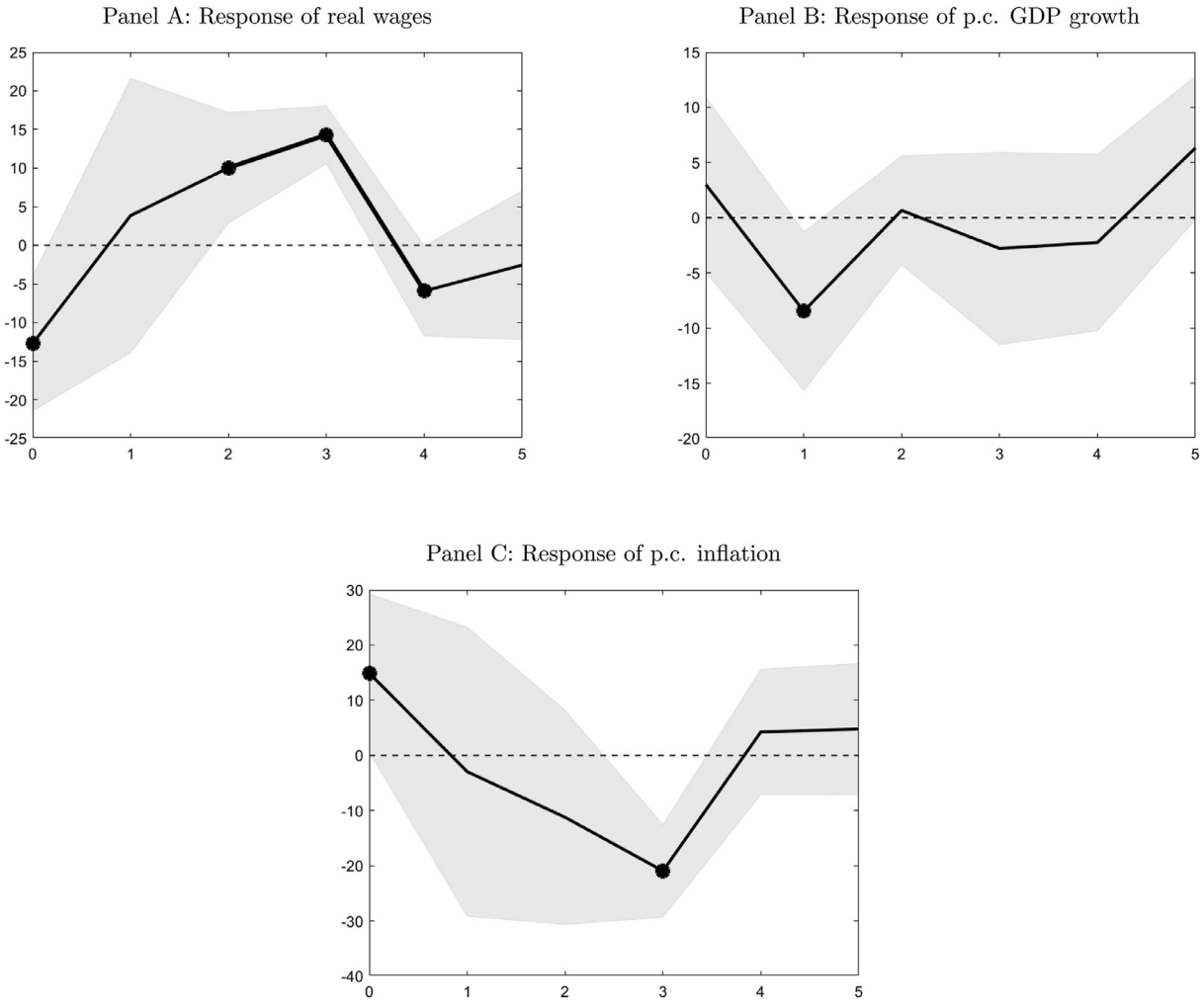

Fig. 3. Responses to an epidemic shock in the industrial capitalist period (1750–1899) *Notes*: This figure depicts the impulse responses – estimated by Jordà (2005)'s local projections – of real wages (Panel A), GDP per capita growth (Panel B) and inflation (Panel C) to a shock in the epidemic death rate. A wars death rate and a dummy taking value one if an adverse climate event occurs and zero otherwise are included. To control for autocorrelation we include two lags of the dependent and control variables. Significant point estimates are denoted by dots. Grey bands indicate 90% confidence bands. Standard errors are corrected for heteroskedasticity and autocorrelation (Newey and West, 1987; 1994).

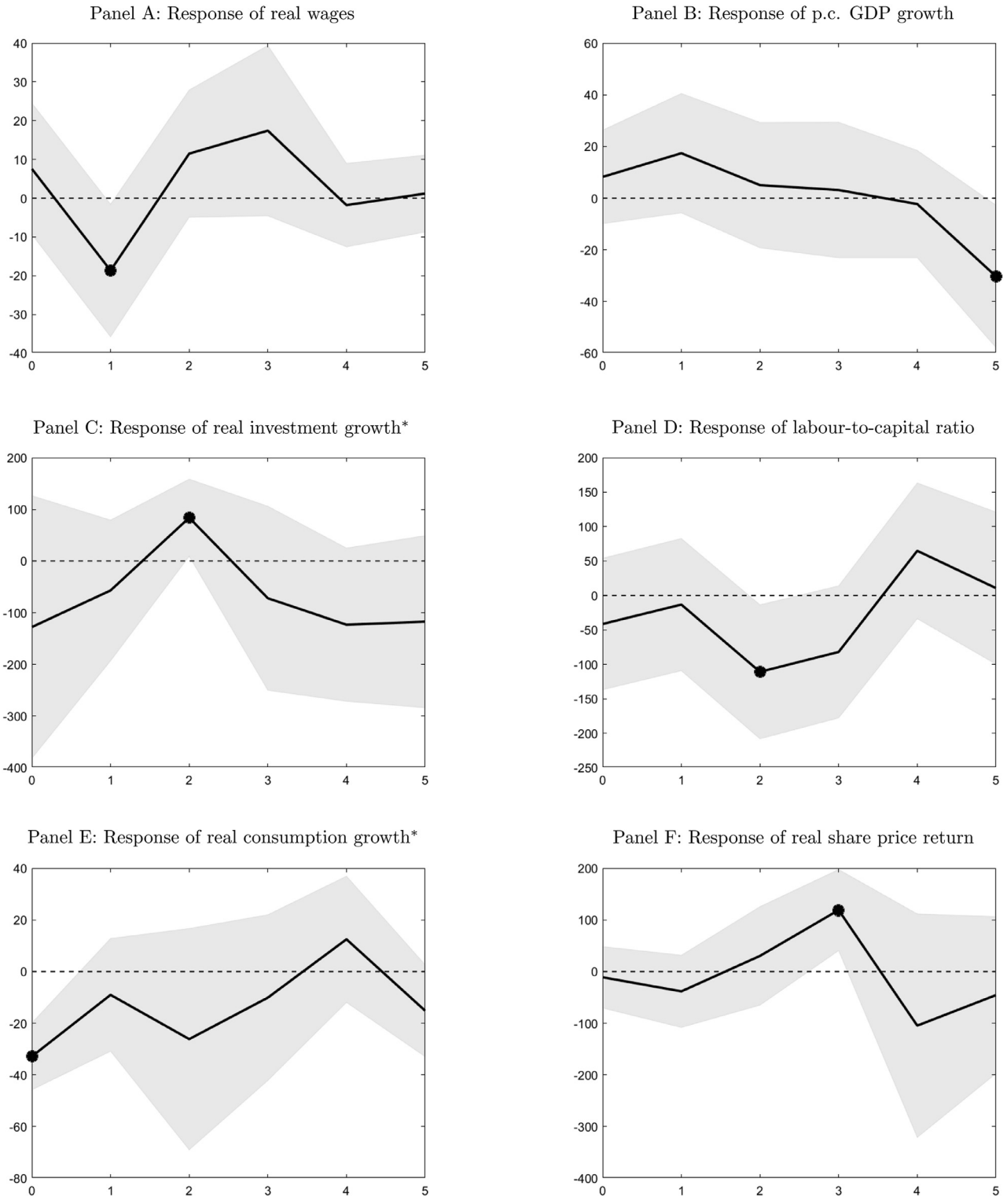

Fig. 4. Responses to an epidemic shock in the finance capitalist period (1900–2019) *Notes*: The figure depicts impulse responses – estimated by Jordà (2005)'s local projections – of real wages (Panel A), GDP per capita growth (Panel B), real investment growth (Panel C), labour-to-capital ratio (Panel D), real consumption growth (Panel E) and real share price return (Panel F) to a shock in the epidemic death rate. We include death rate from wars and a dummy taking value one if an adverse climate event occurred and zero otherwise. To control for autocorrelation we include two lags of the dependent and control variables. Significant estimates are denoted by dots. Grey bands indicate 90% confidence bands. Standard errors are corrected for heteroskedasticity and autocorrelation (Newey and West, 1987; 1994). * IRF refers to period 1900–2016.

economic agents to save more and to postpone consumption. Indeed, we observe an immediate drop in real consumption growth (Figure 4, Panel E). Epidemic shocks do not have an immediate effect on financial markets. We only observe a significant increase in stock prices after three years (Figure 4, Panel F).

The 20th century also brought the end of laissez-faire economics. Whereas in the 18th century government interventions in business affairs were seen as an obstacle to economic prosperity, the last decades have been characterized by a large government involvement in the economy. In general during the latest crisis, governments have employed public resources to compensate severe demand drops (see, among others, Chwieroth and Walter, 2019; Dingeldey, 2007; Lewis et al., 2008). This is clear from Figure C.5, which reports the response of the primary budget surplus to an epidemic shock. In the presence of a non-laissez-faire government the primary surplus drops after the shock. Thanks to the government intervention, GDP per capita does not fall initially. Actually, we observe a significant negative impact on the standard of living only from five years after the shock (Figure 4, Panel F). Epidemic shocks generate also a drop (of around 30%) in GDP per capita growth rate after five years.

Let us finally stress that our results for the *financial-capitalism* period are subject to at least a couple of major drawbacks. First, they do not fully account for the steep and rapid increase in (*i*) the degree of goods and financial markets integration of the last 30 years (Figure C.6, Panels A-D), (*ii*) the degree of population mobility (Figure C.6, Panel E) and (*iii*) the level of news-induced uncertainty (Figure C.6, Panel F). Taken together, these phenomena change completely the response of macro and financial aggregates to any kind of shock (including infectious diseases). Second, in England as well as in other advanced economies over the last fifty years, very few epidemic episodes occurred.[11] In this respect, our estimates for the period 1900-2019 cannot really capture the COVID-19-induced real economic effects. This because major epidemics occurred in times where technology and capital stock levels were rather low, global goods and financial markets were still segmented, and the diffusion of both good and bad news on epidemics was not global and instantaneous as it is today.

4. Concluding remarks

The COVID-19 has already generated severe output losses. There is no doubt that further drops in consumption, investment and output will follow. Needless to say, this will lead to adverse economic effects also in the medium- and long-run. There have been many attempts to estimate the macroeconomic effects of this new epidemic. In the absence of a proper information set, very recent empirical works relied on past epidemic events to capture the implications for macro and financial aggregates of the COVID-19. However, this approach may lead to misleading results due to the different socio-economic features characterizing economies during epidemics that occurred in different eras.

In this paper we first build a novel dataset of macroeconomic aggregates and epidemics for England spanning the period 1500–2019. We then compute the effect of epidemic events on major macroeconomic variables in three distinct eras classified by their different socio-economic features. Our empirical findings indicate that the economic impact of an epidemic changes as the socio-economic characteristics of the economy evolve. During the *pre-capitalism* era (in which agriculture was the main sector, non-skilled human capital the only factor of production and wages were fully devoted to support family members), the effect of an epidemic shock on growth of GDP per capita is positive. This effect is driven by the increase in the worker-population ratio and in labor productivity. In the *industrial-capitalism* period (characterized by a higher capital stock and the presence of profit-seeking entrepreneurs), an epidemic shock results in a drop in growth of GDP per capita due to an immediate drop in real wages. In the *financial-capitalism* era (characterized by a higher stock of technology and developed and influential financial markets), a positive epidemic shock implies a five-years-lagged drop in GDP per capita growth, thanks to countercyclical interventions by government.

However, estimating the economic impact of epidemics during this era is even more challenging, as the last century has been characterized by a rapid economic and financial development and many more variables must now be taken into account. Most importantly, since the last important epidemic that occurred more than 50 years ago (i.e., the Hong Kong flu) to nowadays, financial-capitalism has evolved further. In particular, a rise in the degree of globalization and financial integration, an increase in international labor mobility, and a global and instantaneous diffusion of news will definitely influence the way the economy reacts to epidemic shocks.

The first projections of 2020 economic performance seem to confirm our view about the inconsistency of historical-based empirical literature with current experience. According to OECD (http://www.oecd.org/economic-outlook/june-2020) and United Nations (http://population.un.org/wpp) forecasts, world GDP per capita should exhibit a 5% drop at the end of 2020, a substantial different reaction compared to those estimated for the 1900 – 2019 period.

All together, these facts suggest that the COVID-19 represents a new type of shock that the modern world has never faced. The novel coronavirus represents thus an important challenge especially for policymakers, who will no longer be able to support their choices with historical evidence.

[11] The Swine flu of 2009 cannot be considered as a relevant epidemic due to a very low number of confirmed deaths in England (see footnote 4).

Appendix A. Data details

Table A.1
Data details.

Stylized facts			
ID	Variable	Source	Sample
TO (UK)	Trade openness (UK)	Ryland and Dimsdale (2017) & World Bank	1800 – 2019
TO (World)	Trade openness (World) & World Bank	http://ourworldindata.org/	1870 – 2019
SP	Real share price index	Jordà et al. (2016)	1870 – 2016
LTIR	Real long term interest rate	Jordà et al. (2016)	1870 – 2016
LUP	London underground passengers	http://www.gov.uk/government/statistical-data-sets	1950 – 2018
MSP	Monthly stock price returns	Ryland and Dimsdale (2017) & OECD	1750 – 2020*
Empirical analysis			
ID	Variable	Source	Sample
Pop	Population	Ryland and Dimsdale (2017) & Office for National Statistics (ONS)	1500 - 2019
GDP	Gross Domestic Product	Ryland and Dimsdale (2017) & ONS	1500 - 2019
GDP p.c.	GDP per capita	Ryland and Dimsdale (2017) & ONS	1500 - 2019
RW	Real wages	Ryland and Dimsdale (2017)	1500 - 2016
CPI	Inflation	Ryland and Dimsdale (2017)	1500 - 2016
PSurplus	Primary surplus (% of GDP)	Ryland and Dimsdale (2017)	1500 - 2016
RC	Real consumption	Ryland and Dimsdale (2017)	1500 - 2016
RI	Real Investment	Ryland and Dimsdale (2017)	1500 - 2016
LK	Labour-to-capital ratio	Ryland and Dimsdale (2017)	1500 - 2016
LP	Workers-to-population ratio	Ryland and Dimsdale (2017)	1500 - 2016
SP	Real share price return	Ryland and Dimsdale (2017) & OECD	1500 - 2019
P	Epidemic death rate	Graunt (1662), Creighton (1891) Creighton (1894), Edwardes (1902) Eichel (1922), Slack (1985) Wrigley and Schofield (1989), Kohn (2008), McLean et al. (2010), http: //en.wikipedia.org/wiki/2009_swine_flu_pandemic_in_the_United_Kingdom	1500 - 2019
W	Wars death rate	Sorokin (1937),Clodfelter (2017) http://www.britishbattles.com/	1500 - 2019**
C	Extreme climate events (dummy)	http://en.wikipedia.org/wiki/List_of_natural_disasters_in_the_British_Isles	1500 - 2019

Notes: * indicates partial data ending in August. ** COVID-19 death rates projections for 2020 (proxied by UK data) used in Table 1 are taken from Institute for Health Metrics and Evaluation.

Appendix B. List of historical events

- List of epidemics: Great epidemic of London (1500); 2nd English sweat (1507); Plague (1545); Influenza epidemic (1562); London plague (1563); Oxford black assize (1577); London plague (1578); London plague (1593); London plague (1603); Great fever (1625); Plague (1626); London plague (1636); Tiverton typhus (1644); Spotted fever (1661–1664); Great plague of London (1665); Smallpox (1667–1668); Comatose fever (1674); Smallpox (1681); Typhus and smallpox (1685–1686); London fever (1709–1710); Influenza epidemic (1712–1713); London fever (1714–1715); Typhus (1718–1720); Febrile epidemic and cholera (1726–1729); Influenza epidemic (1733); Smallpox in London (1737); Typhus and smallpox (1741–1742); Dysentery (1743); Asiatic cholera (1832); Influenza epidemic (1833); Diarrhoea, influenza, typhus, and smallpox (1837); Smallpox (1838–1841); Smallpox and influenza epidemic (1847–1849); Cholera (1854); Typhus, diphtheria, and scarlatina (1862–1866); Smallpox (1871–1872); Influenza epidemic (1891–1892); Influenza epidemic (1895); Typhoid epidemic (1900–1902); Spanish flu (1918–1919); Scandinavian flu (1951); Asian flu (1957–1958); Hong Kong flu (1969–1970); Swine flu (2009); COVID-19 (2020–?).
- List of wars and conflicts considered:[12] Battle of Flodden (1513); Fourth Italian war (1545); English civil war (1642–1646); Second English civil war (1648); Third English civil war (1650); First Anglo-Dutch war (1652–1654); Second Anglo-Dutch war (1665-1667); Third Anglo-Dutch war (1672–1674); War of the Spanish succession (1701–1714); The war of the quadruple alliance (1718–1720); The war of the Austrian succession (1743–1747); The seven years' war (1756–1763); American revolutionary war (1775–1881); Glorious first of June (1794); Napoleonic wars (1797–1815); First Afghan war (1838–1842); First Sikh war (1845–1846); Second Sikh war (1848–1849); Crimean war (1854–1855); Second Afghan war (1878–1880); First Boer war (1881); War in Egypt and Sudan (Mahdist war) (1882–1898); North-West frontier of India (1888–1897); Great Boer war (1899–1902); The Anglo-Aro war (1901–1902); The British expedition to Tibet (1904); World War I (1914–1918); The Third Anglo-Afghan war (1919); The Anglo-Irish war (1919–1921); Great Iraqi revolution (1920); Somaliland campaign (1920); World War II (1939–1945); Palestine emergency (1946); Indonesian war of independence (1946); Malayan emergency (1948–1960); The Indonesia-Malaysia conflict (1962–1966); The Troubles (1969–1998); Gulf war (1991); War in Afghanistan (2001–present); Iraq war (2003–2011).
- List of extreme events: Great heat and drought (1540–1541); Bristol channel flood (1607); Famine (1623–1624); The great thunderstorm (1638); London drought (1665–1666); The great frost (1683–1684); Plymouth Sound storm (1691); Great storm of 1703 (1703); Great frost of 1709 (1709); Tornado (1729); Flooding and storms (1770); Great hurricane (1780); Year without a summer (1816); Lewes avalanche (1836); Night of the big wind (1839); Great Sheffield flood (1864); Great gale of 1871 (1871); Tay Bridge disaster (1879);

[12] The dates in parentheses indicate the years in which the conflicts involved the English army.

Blizzard of January 1881 (1881); Great Blizzard of 1891 (1891); United Kingdom heat wave (1911); Thames flood (1928); Winter of 1946–1947 (1946–1947); Lynmouth flood (1952); North Sea flood (1953); United Kingdom heat wave (1955); Winter of 1962–1963 (1962–1963); England and Wales dust fall storms (1968); Great flood (1968); Hurricane (1968); Two-year drought and UK heat wave (1974–1976); Gale of January 1976 (1976); North Sea storm surge (1978); Great storm (1987); Burns' Day Storm (1990); Winter of 1990–1991 (1990–1991); Easter floods (1998); Flooding (2000); European heat wave (2003); Boscastle flood (2004); Flooding (2005); Storm Kyrill (2007); United Kingdom floods (2007); Great Britain and Ireland snowfall and floods (2009).

Appendix C. Additional empirical facts

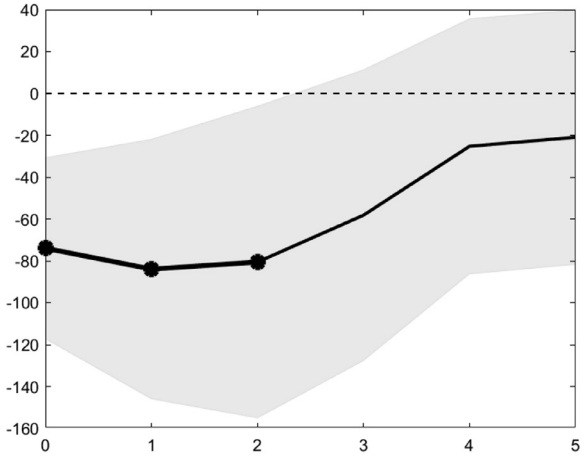

Fig. C.5. Response of primary surplus (in % of GDP) to epidemic shocks in the financial capitalism period (1900–2016) *Notes*: This figure depicts the impulse response – estimated by Jordà (2005)'s local projections – of UK primary surplus to a one s.d. shock in the epidemic death rate. We include wars death rate and a dummy taking value one if an adverse climate event occurred, zero otherwise. To control for autocorrelation we include two lags of the dependent and control variables. Significant estimates are denoted by dots. Grey bands indicate 90% confidence bands. Standard errors are corrected for heteroskedasticity and autocorrelation (Newey and West, 1987; 1994).

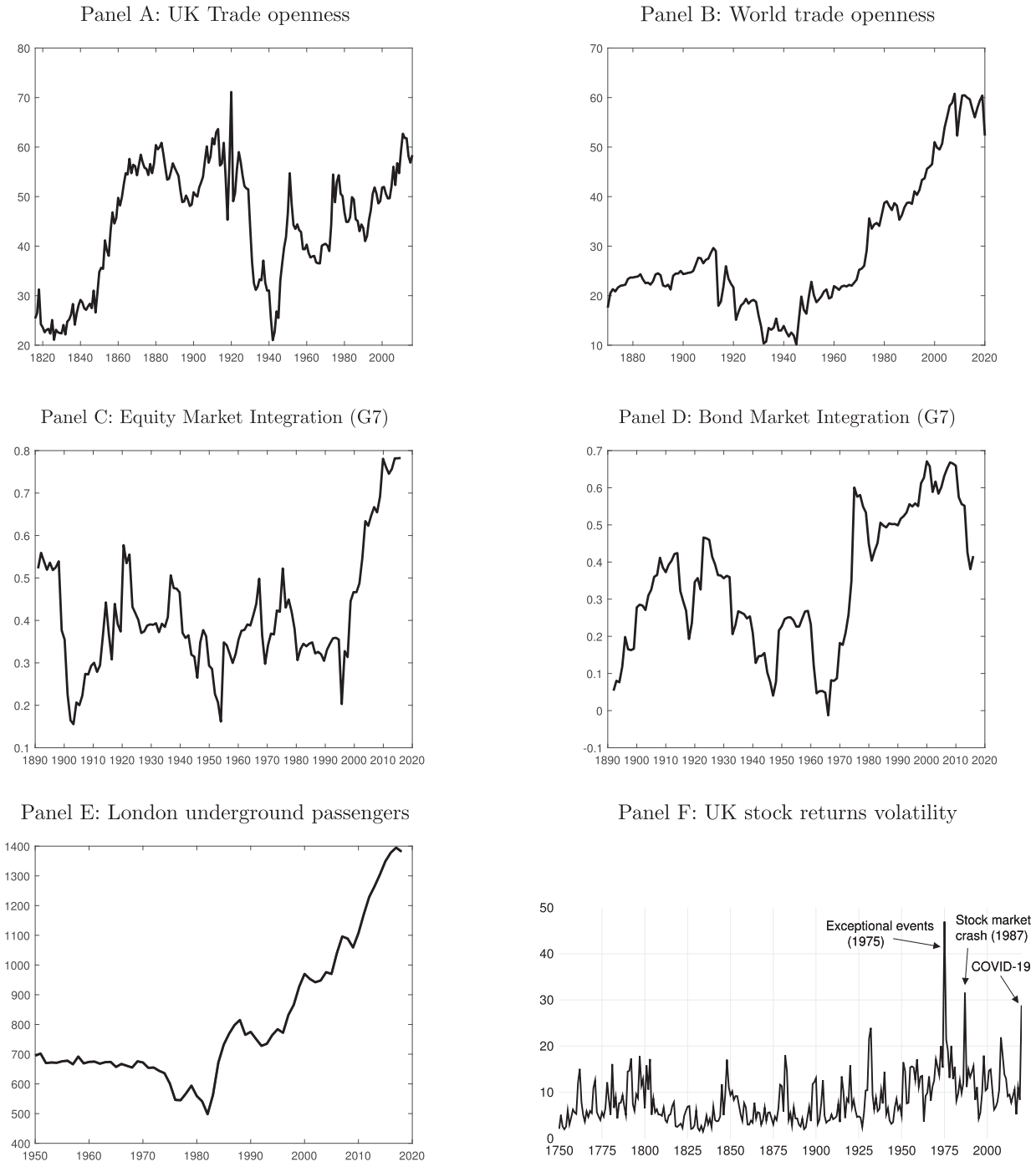

Fig. C.6. Financial-capitalism: stylized facts *Notes*: Panel A (B) depicts trade openness in the UK (World). Trade openness is defined as the ratio between the sum of imports and exports and GDP. Panel C (D) shows the evolution of the degree of equity (bond) market integration in the G7. The cross-country average standard correlation – computed using a rolling window of 20 years – is used as proxy for equity and bond market integration. Panel E shows the number of passengers (in millions) of the London underground. Panel F reports the dynamics of the UK stock market return volatility. Full details on data are reported in Appendix A and Appendix B.

CRediT authorship contribution statement

Michael Donadelli: Conceptualization, Writing - review & editing. **Licia Ferranna:** Data curation, Resources, Writing - original draft. **Ivan Gufler:** Investigation, Software, Validation. **Antonio Paradiso:** Methodology, Formal analysis, Supervision.

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