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Covid Economics Issue 6, 17 April 2020

The 1918 epidemic and a V-shaped recession: Evidence from municipal income data

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Date submitted: 8 April 2020; **Date accepted:** 9 April 2020

We combine high-quality vital statistics data with annual income data at the municipality level to study the economic aftermath of the 1918-inuenza epidemic in Denmark. Controlling for pre-epidemic trends, we find that more severely affected municipalities experienced short-run declines in income, suggesting that the epidemic led to a V-shaped recession, with relatively moderate, negative effects and a full recovery after 2-3 years. Month-by-industry unemployment data shows that unemployment rates were high during the epidemic, but decreased again only a couple of months after it receded. This evidence also indicates that part of the economic downturn in 1918 predates the epidemic.

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1 Introduction

The Covid-19 Pandemic and the associated policy responses have very rapidly disrupted the economies of most countries in the World. As economies shut down to prevent the virus from spreading, millions of people lose their jobs and unemployment rates have been predicted to rise to levels that the world has not witnessed since the great depression. How much is the pandemic going to depress the economy and for how many years? Such questions are naturally important, but difficult to answer, since such major health shocks are rare and the current crisis seems almost unprecedented.

This paper leverages evidence from the 1918-influenza epidemic to help answering these questions. We combine high quality vital statistics with annual income data for 76 Danish municipalities in a differences-in-differences (DiD) analysis, which exploits excess influenza deaths in 1918 across municipalities to measure the local severity of the epidemic. We find that pre-epidemic local economic activities is predictive of the severity and one should accordingly be cautious when interpreting the economic effects of the epidemic. Nevertheless, controlling for pre-epidemic trends, our analysis indicates that the epidemic at most led to a V-shaped recession with no significant medium or long-run effects. Panel C of Figure 2 illustrates this V-shaped effect on the economy. We find an average decline in income per worker of around five percent from 1917 to 1918 and this decline is larger in more severely affected municipalities.[1] We also provide evidence from monthly unemployment data for 61 industries at the national level as well as annual level municipality banking data. While the unemployment evidence indicates that an economic downturn was underway the last half of 1917—almost one year before the influenza arrived in Denmark—we see that unemployment rates were high during the epidemic months, but bounced back to more normal levels already in the summer of 1919. We do not find that banks located in more severely affected municipalities performed worse after the epidemic.

The severity of the Covid-19 pandemic has naturally spurred renewed interest in the short and medium run effects of pandemics and the public health response on economic activity. Given some similarities with the current pandemic, economists have recently presented different estimates of the economy wide impact of the 1918 influenza pandemic. Using U.S. city evidence, the study by Correia et al. (2020) shows that the epidemic had negative effects on economic activities in the manufacturing and banking sectors, while cities rolling out more aggressively non-pharmaceutical interventions (NPIs) performed better in these sectors afterwards. Barro et al. (2020) exploit international evidence from 43 countries to show negative effects on GDP per capita growth. They also report evidence suggesting

[1] This simple quantification does not take into account the pre-epidemic trends and should be viewed as an upper bound average effect.

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that the pandemic had strong short-run negative effect. We contribute to this research by documenting a V-shaped effect of the epidemic using—by historical standards—high-quality within-country data. We also digitized data on NPIs, but do not find any robust evidence indicating that municipalities implementing more NPIs experienced less or more income growth after the epidemic.[2] In addition, we provide, to our knowledge, new evidence on the severity of the epidemic by showing that the short-run pre-epidemic economic activity is associated with excess influenza deaths in 1918 and that the severity of the first wave in 1918 is predictive of the second wave in 1920.[3]

There is also some less recent papers studying the economic effects of the 1918-influenza pandemic. The paper by Brainerd and Siegler (2003) finds a positive effect of the epidemic on GDP per capita using U.S. state evidence. In a similar vein, Garrett (2009) finds positive effects on U.S. Wages. The work by Karlsson et al. (2014) finds that the 1918-epidemic increased long-run poverty, decreased capital returns, but had no effect on earnings in Sweden. There is also a larger related literature studying the effects of health/mortality on different long-run economic outcomes. See for example the papers by Acemoglu and Johnson (2007), Bleakley (2007), Weil (2007), Cervellati and Sunde (2011), Hansen (2014) or the review in Weil (2014). We contribute to this literature by demonstrating that the 1918-epidemic health shock only had short-run income effect and no measurable effects in the longer run.

2 Background

In this section, we provide background information on the 1918-influenza epidemic and on how World War I affected Denmark since the onset of the epidemic overlapped with the end of World War I.[4]

2.1 The 1918-Influenza epidemic

The first wave of the influenza reached Denmark in the summer of 1918 and it is generally believed that marines, patrolling the Sound between Denmark and Sweden, were the first to being reported infected, which dates the first cases to July 8th. Unlike many other countries, the number of influenza cases is known for because a reporting system had been in existence since 1803. The number of influenza cases

[2]We are somewhat cautious when interpreting these non-findings as our NPIs are not coded with the same detail as those used in Correia et al. (2020).

[3]The finding that the epidemic was facilitated by economic activities is consistent with the evidence reported in Adda (2016), who shows that the spread of infectious diseases, such as influenza, is generally related to economic activities.

[4]This section draws on the work by Kolte et al. (2008) and Heisz (2018) for the subsection on the 1918-epidemic. For the subsection on World War I, we draw on Christiansen et al. (1988), Hansen and Henriksen (1984) and Gram-Skjoldager (2019).

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was 34,877 in 1917 and then rose sharply to 496,755 in 1918. In 1919 and 1920, the numbers were 236,217 and 174,736 respectively. For 1918, the total number of influenza deaths were about 4,150 in the urban municipalities for which reliable data exist. These municipalities had a population of circa 1,2 million people or 41 percent of the total population in the census year of 1916. We show how epidemic severity varied between these municipalities in Section 4.

The incidence of the disease was highest among the age group 5 to 15 years, whereas mortality was highest among infants and 15 to 65 years old in 1918. More detailed data on mortality for 1918 reveals that most of the mortality was concentrated in the age group 15 to 44 years with the peak being in the age group 20 to 34 years. These patterns were similar in 1919 and 1920. Danish authorities responded to the epidemic by extending the school holiday until September 2nd, and the capital, Copenhagen closed its schools in the beginning of October 1918. Moreover, theaters and cinemas were closed by the end of the same month. Many, but not all, Danish municipalities followed the example of Copenhagen. For example, what is now the second largest city, Aarhus, did not close its schools during the epidemic. Danish newspapers of the times show that many municipalities had introduced some non-pharmaceutical interventions (NPIs) by the beginning of November.

Historical national accounts reveal that GDP contracted by 3 percent in 1918 (Hansen 1974), though it should be kept in mind that annual GDP data for this period should be interpreted with caution as many of the underlying series needed to compute GDP were not available at the annual level. Yet, there is circumstantial evidence suggesting that both the epidemic and the introduction of NPIs had some adverse economic effects. For example, newspaper articles suggest that absenteeism was a problem in some businesses. In line with this, Trier (2018) mentions this was true for the railway, the postal service and telephone companies. Yet, there are also signs that the disease led to a lack of labor in some municipalities. Moreover, parts of Copenhagen are described as being a ghost town during the epidemic. Newspapers at the time also write about unemployment in the entertainment business due to theater closures.

2.2 World War I

In August 1914 when World War I broke out, the Danish government issued a declaration of neutrality and there was never any battles on Danish soil. Denmark's main trading partners were Britain and Germany. Denmark's main export was agriculture, while it imported coal and fertilizer from Britain and coal and other industrial products from Germany. The warring parties attempted to block the Danish trade, but Denmark managed to maintain its trade and experienced a boom-like situation from

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1915 to 1916.

In February 1917, Germany declared unrestricted submarine warfare, which implied that all ships bound for England sailing within a certain range from the French and Italian coasts would be torpedoed regardless of whether they were neutral or not. This meant that the Danish ships almost stopped sailing routes via the North Sea because of this danger. The result was that important parts of foreign trade came to a halt: Exports to England and imports of coal and fuels. The U.S. joined the war in April 1917 and immediately banned exports of grain and fodder to neutral countries, which exacerbated the situation further. The result was that Denmark oriented its trade more to Germany, though this could not compensate from the loss of overseas deliveries of raw materials, fodder and fuel. According to the historical narrative, the situation led to lower production in 1917-18 and increasing unemployment as we demonstrate below.[5]

3 Data

We combine different data sources to construct a municipality level data set annually from 1904 to 1929, containing mortality counts for different causes of death (all causes, influenza, pneumonia, and influenza), population size, total taxable income, number of tax payers, along with other various municipality characteristics, which we describe as they are introduced. All the data sources are reported in Appendix Table A1. We are able to include 76 municipalities, which constituted the Danish so-called market towns in 1918.[6]

All mortality rates (by cause) are constructed by scaling the mortality counts by municipality population size and multiplied by 1,000. There are different reasons to believe that the quality of the mortality statistics is high for historical standards. First, Egedesø et al. (2020) observe that disease registration on pre-printed forms had been in place in municipalities since 1856 and the cause of death had to be verified by a medical doctor. Second, Lindhardt (1939) states that the Danish historical mortality statistics were viewed as being in the very front rank in terms of quality by foreign and Danish investigators.

Our main economic outcome variable is the average taxable income per tax payer. Denmark introduced income taxation in 1903 (Philip 1955), for which reason taxable income is available from 1904 onwards. Generally, the principles for income taxation remained the same throughout our study

[5]According to Jensen (2020), Russia was Denmark's third or fourth largest trading partner at the time, and trading relations were disrupted by the October revolution.

[6]The number of Danish market towns increased to 87 after the reunion between Southern Jutland and Denmark in 1920.

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period. There was an exemption of 800 Danish kroner in Copenhagen and of 700 Danish kroner in the market towns. The income tax was progressive and rates were initially very low but increased in 1912, 1915, and 1919. For most income-tax payers, the rates were in the range of 3 to 8 percent in 1919.

To supplement our data on income, we have also digitized monthly unemployment rates for the period 1915 to 1919. The data were collected by the unions and processed by Statistics Denmark. Coverage is of 61 industries. Most of the data cover blue collar workers, but also white collar professions, e.g. office workers. Further to obtain data on NPIs, we have consulted newspapers from 1918-1920, various books and archival sources. We have collected data on whether municipalities closed schools, cinemas and theaters during the 1918 autumn part of the epidemic. Finally, we also employ data on total bank assets collected by Statistics Denmark and digitized by Abildgren (2018).

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4 Research strategy

This section starts by describing how we measure the impact (or severity) of the 1918-influenza epidemic. We next investigate how different pre-epidemic municipality characteristics correlate with severity, which is important in its own right in terms of understanding the spread of the disease, but such balancing tests are also crucial in our attempt to study the causal economic impact of the shock. Here we also provide preliminary evidence of how the epidemic influenced outcomes. The final subsection describes our main estimation approach.

4.1 Measuring epidemic severity

We measure the impact of the epidemic using mortality data rather than case data, since mortality data are generally believed to be more reliable. Most other papers, on this particular topic, follow a similar strategy (Brainerd and Siegler 2003; Hatchett et al. 2007, for example). While the recent papers by Barro et al. (2020) and Correia et al. (2020) use influenza (and pneumonia) mortality rates, we calculate the local intensity of the epidemic by excess influenza deaths as:

$$Epidemic_{t,c} = M_{t,c} - \bar{M}_{1904-16,c}, \tag{1}$$

where $M_{t,c}$ is the influenza mortality rate in year $t \in (1918, 1919, 1920)$ per 1,000 people in municipality c and $\bar{M}_{1904-16,c}$ is the unweighted average influenza mortality rate from 1904 to 1916. In this way, we measure the local severity by the excess influenza mortality rate in year t of the epidemic. Besides this number being more realistic in terms of the actual mortality penalty associated with the epidemic, using the *excess* rate, instead of just the annual rate, also has the advantage of taking into account that some areas might just be more unhealthy than others for unrelated reasons.

The epidemic hit most areas in Denmark during 1918, but some more remote areas were not affected before the first months of 1919. In addition, the influenza swept the country in a second wave in 1920. Appendix Figure A.1 shows the excess mortality rate for the three epidemic years. The left (right) panel shows the rates for the most (less) populated municipalities sorted from the bottom up. As expected, the excess influenza mortality rate was highest in 1918. The most affected municipality had around 10 excess influenza deaths per 1,000 people. The largest municipality and capital, Copenhagen, had around 3 excess deaths per 1,000 people, which is close to the municipality average (unweighted = 3.16; population weighted = 3.26). In an international perspective, Denmark was not that severely affected: According to Barro et al. (2020) one of the worst hit countries in the World was India with 41 influenza deaths per 1,000 people in 1918, while their corresponding U.S. number is 3.90.[7] The US-city epidemic intensity in Correia et al. (2020) is substantially higher with an average of around 6.86, however, they also include pneumonia deaths and do not consider *excess* rates. The distribution in epidemic severity appears more similar with a one standard deviation, in the Danish municipalities, being equal to 1.8, while the U.S. city number is 2.0.

4.2 Descriptive evidence

We now focus on the excess influenza mortality rate in 1918—since this epidemic year constitutes our baseline intensity measure going forward—and study how it correlates with different pre-epidemic municipality characteristics. We next show the development of the main outcomes by epidemic severity, which is going to provide us with the first evidence on the impacts epidemic.

Despite that it has been argued that the geographic distribution of the epidemic severity has a component of randomness (Brainerd and Siegler 2003; Almond 2006), research by Clay et al. (2019) for example documents that excess U.S. city mortality in 1918 is positively correlated with factors such as illiteracy, infant mortality, and pollution. We provide new insights to this by showing that short-run economic activity is an important explanation of epidemic severity.

Specifically, Panel A and B of Figure 1 report the correlations between epidemic intensity and economic activity during the war years, as measured by logged income per worker in 1917 and income per worker growth from 1916 to 1917, respectively. We find positive and statistically significant corre-

[7] In Barro et al. (2020), Denmark had a 1918 influenza mortality rate of 1.7, which is substantially smaller than our municipality weighted average, suggesting that the cities were more affected by the virus compared to the countryside.

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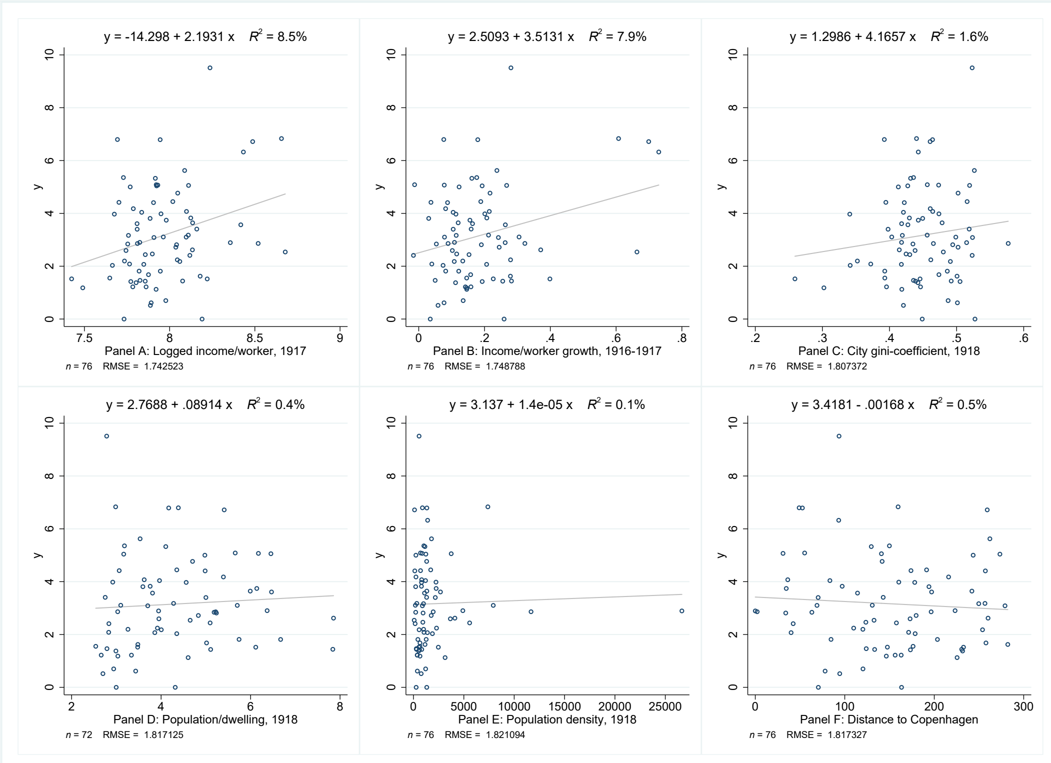
Figure 1: Pre-epidemic municipality characteristics of the 1918-influenza epidemic

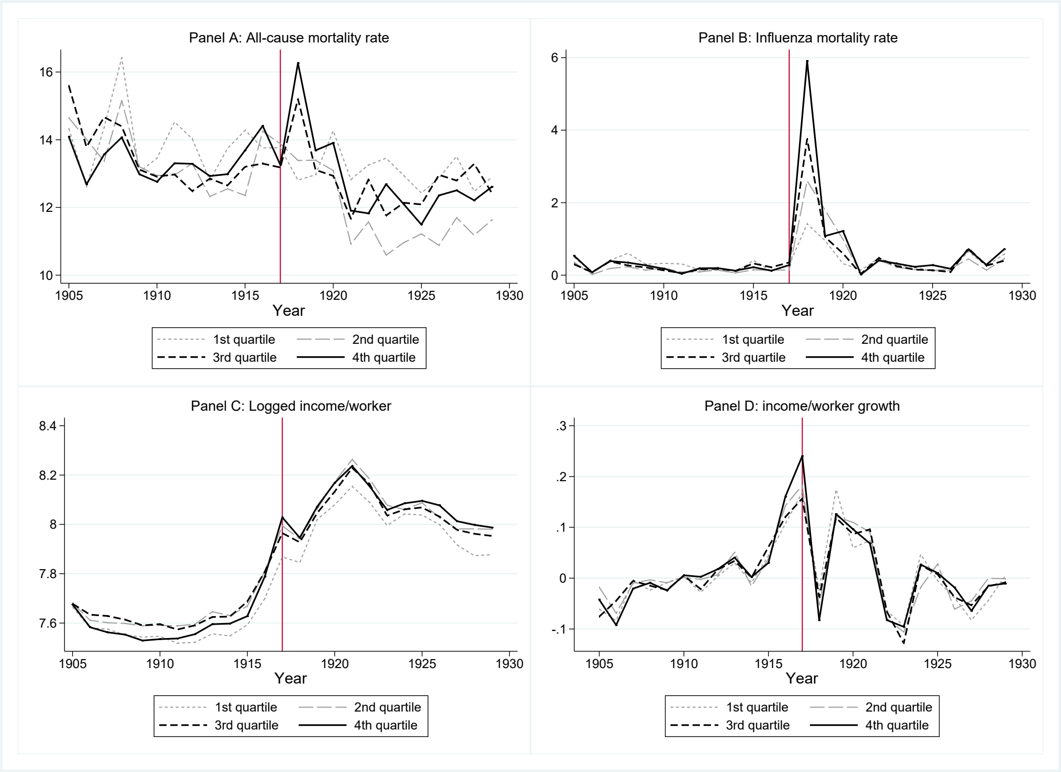


Notes: This figure shows different municipality level correlates of the 1918-influenza epidemic. Panel A: logged income/worker, 1917; Panel B: income/worker growth, 1916-197; Panel C: Gini-coefficient, 1918; Panel D: population per dwelling in 1918; Panel E: population per km2 in 1918; Panel F: distance to Copenhagen in kms. The outlier in Panel E is Copenhagen and removing this observation does not change the reported relationship.

lations with relative high R-squared values. As will also become apparent in our later event-studies, these correlations are *not* driven by longer run differences in income levels across municipalities. For example, logged income per worker four or more years before the epidemic is not a good predictor of the severity. We only have within city inequality data staring in 1918, but for this year we find a positive correlation with severity (Panel C), albeit the estimate is insignificant and the R-squared value is substantially lower. Panels D and E of Figure 1 show that the number of people per dwelling (in 1918) and population density are not very good predictors of severity. Finally, Panel F documents that severity is unrelated to distance to Copenhagen.

Next, we display the municipality average development of the all-cause mortality rate, the influenza mortality rate, logged income per worker, and annual income per worker growth rates by quartiles of $Epidemic_{1918,c}$ in Figure 2. While this exercise is mainly meant to show the broader development of

Figure 2: Mortality and income by epidemic severity in 1918, 1905-1929



Notes: This figure reports the annual average of all-cause mortality rate, influenza mortality rate, logged income per worker, and the annual change in logged income per worker (or income/worker growth). We compute these averages for 4 groups according to the epidemic severity in 1918, where the most/least affected municipalities would be placed in the 4th/1st quartile. The vertical red lines (in 1917) separate the pre and post epidemic periods.

the outcomes over the sample period, these group-averages (by treatment intensity) provide us with the first evidence on how the epidemic influenced the economy. The municipalities belonging to the 4th quartile of the epidemic severity are the most affected ("highly-treated group"), while municipalities belonging to the 1st quartile are the least affected ("control group").

Panel A shows that the all-cause mortality rate is trending downwards in all four groups with sharp increases during the epidemic years. As expected, the most-affected municipalities experience the largest increases in 1918. The influenza mortality rate, in Panel B, varies from year to year with no clear time trend and increases more than ten-fold in 1918 for the most-affected municipalities. We note that the all-cause mortality rate is increasing by less than the influenza mortality rate, indicating evidence of so-called harvesting effects. However, we do not see such differences in our event-study framework below, implying that our strategy of controlling for municipality fixed effects takes this

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matter into account.

Panel C of Figure 2 displays the development of logged taxable income per tax payer, which we refer to as income per worker. We see that income per worker is generally increasing over the sample period with a pronounced downturn from 1917 to 1918, coinciding with the timing of the epidemic. The average decline, across all municipalities, in income per worker was around 5 percent. Interesting for our analysis, we see that the most/least affected municipalities experienced the largest/smallest income increases in the intermediate years before the epidemic, followed by the largest/smallest declines from 1917 to 1918. Finally, Panel D shows the corresponding development for the annual growth rate in income per worker. Again, we see a significant drop in the annual growth rate between 1917 and 1918 and this drop is more pronounced for more severely affected municipalities. Our event-study estimates below shed more light into these dynamics and reveal to what extent these differences are statistically significant. However, these preliminary patterns are indicative for the epidemic having negative effects on income growth, while at the same time suggesting that one should be careful when interpreting this evidence due to pre-epidemic trends.

4.3 Estimation approach

Our estimation strategy compares outcomes before and after the epidemic in 1918 between less and more severely affected municipalities, as measured by $Epidemic_{1918,c}$ given in eq.1. This type of strategy is often referred to as differences-in-differences (DiD) with a continuous measure of treatment intensity. We consider both DiD and event-study estimates. Our event-study specification takes on the following form:

$$y_{ct} = \sum_{k=1906}^{1929} \beta_k \left(Epidemic_{1918,c} \times 1\left[\tau = k\right]\right) + \gamma_c + \eta_t + \varepsilon_{ct}, \tag{2}$$

where y_{ct} is the outcome (mortality rate by cause, logged income/worker, or the annual growth rate of income per worker) in municipality c in year t. The 1918-epidemic severity measure is interacted with a full set of year fixed effects, where the omitted year of comparison is 1905, γ_c and η_t are municipality and year fixed effects.[8]

We use 1918-influenza severity as treatment intensity and not the 1919 or 1920 measures (or some average/sum of those) because of this event-study specification, which we utilize to think about reverse causality (in the form of pre-epidemic trends) and dynamic treatment effects. For example, one could

[8] In the DiD specification, the 1918-epidemic severity measure is interacted with a post 1918 indicator instead of year fixed effects, and we include additional controls.

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argue that the severity in 1919/1920 is endogenous to the initial epidemic and taking some average/sum of the three years could prevent us from seeing pre-epidemic trends clearly and separating out treatment dynamics.

5 Main Results

Our baseline event-study estimates are shown in Figure 3. We start by explaining how the epidemic affected the all-cause mortality rate and the influenza mortality rate (Panels A and B). These results are interesting for different reasons. First, they allow us to check if the epidemic was harvesting within our empirical setup as the descriptive evidence indicated. Second, we can study if the epidemic was related to the changes in the mortality environment both before and after the epidemic; can one really think of the shock being unanticipated and temporary? Third, we can study if initially hard-affected municipalities were less/more severely affected during the final wave of the influenza epidemic in 1920.

Panel A demonstrates that the 1918-severity is unrelated to the all-cause mortality rate prior to the epidemic, so particular unhealthy municipalities were not harder hit by the epidemic. We find that $\beta_{1918} = 0.95$ meaning that one additional influenza death translates into a one-to-one increase in the all-cause mortality rate, suggesting that our empirical design is not capture harvesting effects. Panel B shows two spikes for the influenza mortality rate—one in 1918, which is almost there by construction, and another one in 1920. Thus, municipalities harder hit in the first wave were also more severely affected in the final wave of 1920. Indeed, we also find that $Epidemic_{1918,c}$ is a robust significant positive predictor of $Epidemic_{1920,c}$.[9]

Next, we discuss our finding on how the epidemic influenced municipality economic activities. In the remaining two panels of Figure 3, we report the event-study estimates for logged income per worker (Panel C) and annual income per worker growth rates (Panel D). We find that more-affected municipalities were developing similarly to less-affected municipalities up until around World War I after which the former group experienced larger income increases. This pattern suggest that reverse causality is likely to be an issue when quantifying the effect of the epidemic on income. The interpretation could be relative straightforward, albeit to our knowledge this has not been stressed before in the context of the 1918-influenza epidemic: short-run pre-epidemic economic activities somehow facilitated the spread of the influenza or increased its severity. At the onset of the epidemic, we see that more-affected mu-

[9]In Appendix Figure A.2, we document that the pneumonia and TB mortality rates did not respond to the epidemic. One might interpret this as suggesting little co-mortality or competing risk with these diseases and/or that most deaths during the epidemic were classified as being influenza deaths (and not pneumonia, for example).

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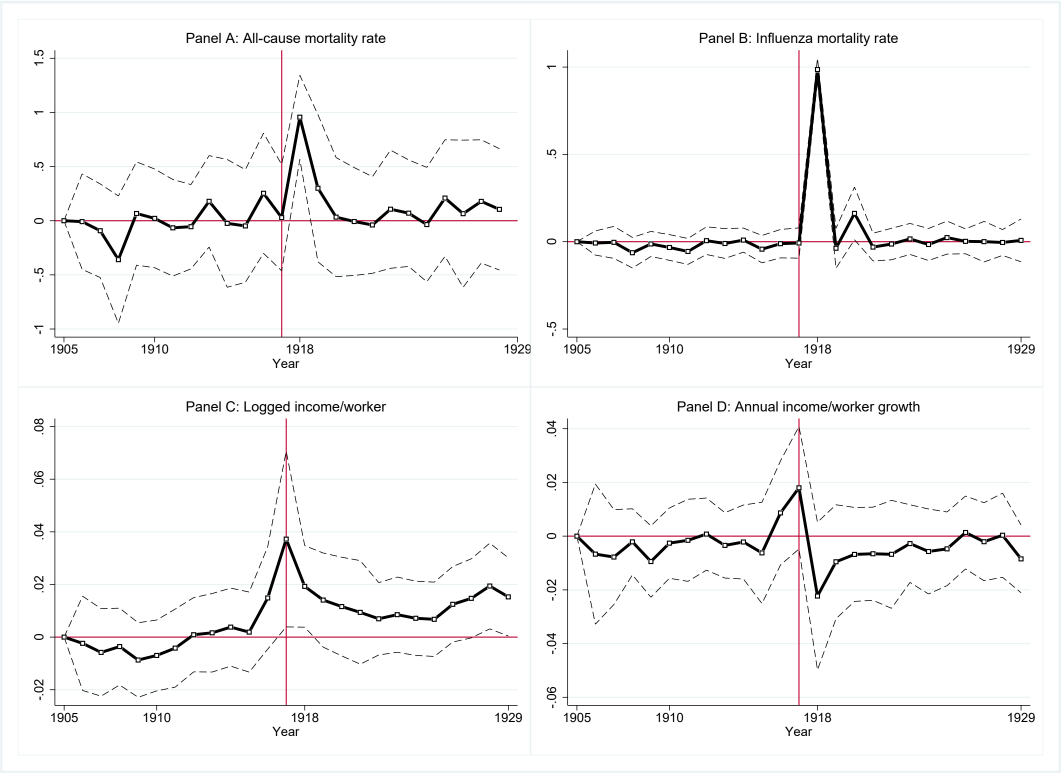
Figure 3: Event-study estimates for mortality and income



Notes: This figure shows the event-study estimates from estimating eq. 2 for the all-cause mortality rate (Panel A), influenza mortality rate (Panel B), logged income per worker (Panel C) and the annual change in logged income per worker (Panel D). The vertical red line (in 1917) separates the pre- and post-epidemic periods.

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nicipalities show sharp declines in income (Panel C) or more negative growth rates (Panel D). These effects become numerically smaller and statistically insignificant the subsequent years, implying that the epidemic only had relatively short-lived effects on municipality-level economic activities.[10]

Finally, we quantify the average effect of the epidemic on annual income growth by reporting DiD estimates in Table 1, paying careful attention to the pre-epidemic income trends. In all specifications, we use pre-epidemic data starting in 1910, but similar results are obtained when starting in 1905. Column 1 (Panel A) reports a negative and statistically significant baseline estimates, using the full period from 1910 to 1929, implying that a one-standard deviation increase in epidemic intensity is associated with a decrease in annual income growth of 1.25 percentage points. This is a dramatic negative growth effect, also considering that the post-epidemic period goes up until 1929. In column 2, we attempt to mitigate the issue of reverse causality by including logged income per worker in 1917 interacted with the post indicator. This reduces the magnitude of DiD estimate substantially and becomes statistically insignificant.

The structure in columns (3) and (4) of Panel A is the same, but here we only use a shorter post-epidemic period from 1918 to 1921 and keep the pre-epidemic period unchanged (1910-1917). Therefore, these estimates give the short-run impact of the epidemic on the economy. We see that the estimates become larger in numerical magnitude from this. However, the specification in which we control for pre-epidemic economic activities shows that the our main effect is statistically insignificant (column 4). Ignoring this fact, the magnitude implies that a one-standard deviation increase in intensity is associated with a decrease in the annual growth rate of 0.47 percentage points.

The remaining columns in Panel A report the medium and long-run effects by using the post-epidemic periods 1922-1925 and 1926-1929, which therefore excludes the short-run negative effects. Basically, we compare growth rates between more and less affected municipalities before the epidemic to growth rates 4-10 years after. We find some non-robust negative effects in the medium run (columns 5 and 6), while there is not much evidence suggesting that the epidemic changed growth rates in the longer run (columns 7 and 8).

Finally, we follow an alternative approach in dealing with the fact that pre-epidemic income-growth predicts of the severity of the epidemic by excluding the war years from the pre-epidemic period and controlling for "convergence" by including logged income per worker in 1914 interacted with the post indicator. These results are reported in Panel B of Table 1. We first note that the DiD estimates are numerically smaller than compared to the estimates in Panel B when *not* controlling for convergence

[10]Appendix Figure A.3 shows a similar patterns if we look at growth rates in total taxable income.

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Table 1: DiD estimates

	Depedent variable: annual growth rate of income per worker							
	Panel A: Baseline sample							
	All years		Short run		Medium run		Long run	
	Pre-period: 1910-1917 Post-period: 1918-1929		Pre-period: 1910-1917 Post-period:1918-1921		Pre-period: 1910-1917 Post-period: 1922-1925		Pre-period: 1910-1917 Post-period 1926-1929	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Epidemic x Post	-0.00735**	-0.00113	-0.0128**	-0.00266	-0.00637*	-0.00120	-0.00368	0.000197
	(0.00329)	(0.00124)	(0.00554)	(0.00239)	(0.00325)	(0.00220)	(0.00231)	(0.00116)
Initial income x Post		-0.158***		-0.259***		-0.132***		-0.0991***
		(0.0138)		(0.0218)		(0.0167)		(0.0107)
Observations	1,592	1,592	908	908	908	908	984	984
R-squared	0.459	0.486	0.401	0.465	0.535	0.553	0.507	0.521
	Panel B: Alternative sample without war years:							
	All years		Short run		Medium run		Long run	
	Pre-period:1910-1914 Post-period:1918-1929		Pre-period: 1910-1914 Post-period: 1918-1921		Pre-period: 1910-1914 Post-period: 1922-1925		Pre-period 1910-1914 Post period: 1926-1929	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Epidemic x Post	-0.00418**	-0.00364**	-0.00980**	-0.00887**	-0.00318	-0.00271	-0.000488	-0.000227
	(0.00169)	(0.00176)	(0.00379)	(0.00405)	(0.00247)	(0.00241)	(0.00108)	(0.00109)
Initial income x Post		-0.0981***		-0.172***		-0.0867***		-0.0480***
		(0.0212)		(0.0411)		(0.0294)		(0.0171)
Observations	1,364	1,364	680	680	680	680	756	756
R-squared	0.403	0.407	0.384	0.398	0.382	0.388	0.237	0.240

This table report our baseline DiD estimates. The outcome is the annual change in logged income per worker, which is approximately equal to the annual growth rate. The variable Epidemic is explained in eq (1). Post is an indicator variable equal to one after 1917. Initial income is in Panel A logged income per worker in 1917 and in Panel B logged income per worker in 1914. All specifications include municipality and year fixed effects. Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

(i.e., the odd-numbered columns).[11] However, in Panel B we do find negative significant effects even when controlling for convergence, but these are relatively short lived. In particular, all estimates from the medium and long-run specifications are statistically insignificant (columns 5-8).

Thus, one important takeaway from Table 1 is that the epidemic at most had short-run negative effects: Controlling for pre-epidemic trends in income, we find that—in the short run—one additional influenza death per 1000 people in 1918 reduced income growth by 0.2 to 0.8 percentage points (based on estimates reported in column 4 of Panels A and B in Table 1).

6 Further evidence

6.1 Month-industry unemployment rates

This subsection documents that unemployment rates were high during the epidemic months, bounced back shortly after the epidemic receded and that part of the economic downturn in 1918 potentially predates the epidemic, using national monthly unemployment data by industry from 1915 to 1919. We have unemployment data for 61 industries, providing us with close to 3,000 observations.

In Figure 4, we display the cross-industry average unemployment number from January 1915 to December 1919. Consistent with our income data, we see that average unemployment rates were low during the war years from the January 1915 to around June/July of 1917. The average unemployment rate for this period is around 6.8 percent. The unemployment rate starts to increase more than what can be explained by seasonal variation in the last half of 1917, which is almost one year before the epidemic in Denmark. Thus, we can argue that the economic downturn in 1918 predates the epidemic with some confidence (or at least that it is rooted before the epidemic). The vertical red lines indicate the epidemic period in Denmark. We do see that unemployment rates were high during November and December of 1918 when the epidemic peaked in Denmark, but not much higher than compared to the same months the previous year. Finally, we see that unemployment was back to its pre June-1917 levels already in the summer of 1919, and so if there was any effect of the epidemic on unemployment, it was short lived, consistent with the income evidence.

Of course, this conclusion is only based on time series evidence and the reported averages might mask shifts in unemployment across industries caused by the epidemic. This issue could have been addressed with unemployment data at the municipality level, however, such data do not exists to our

[11] Thus, one might conclude from this that reverse causality is leading to a numerical upward bias in the estimated reported in Panel A.

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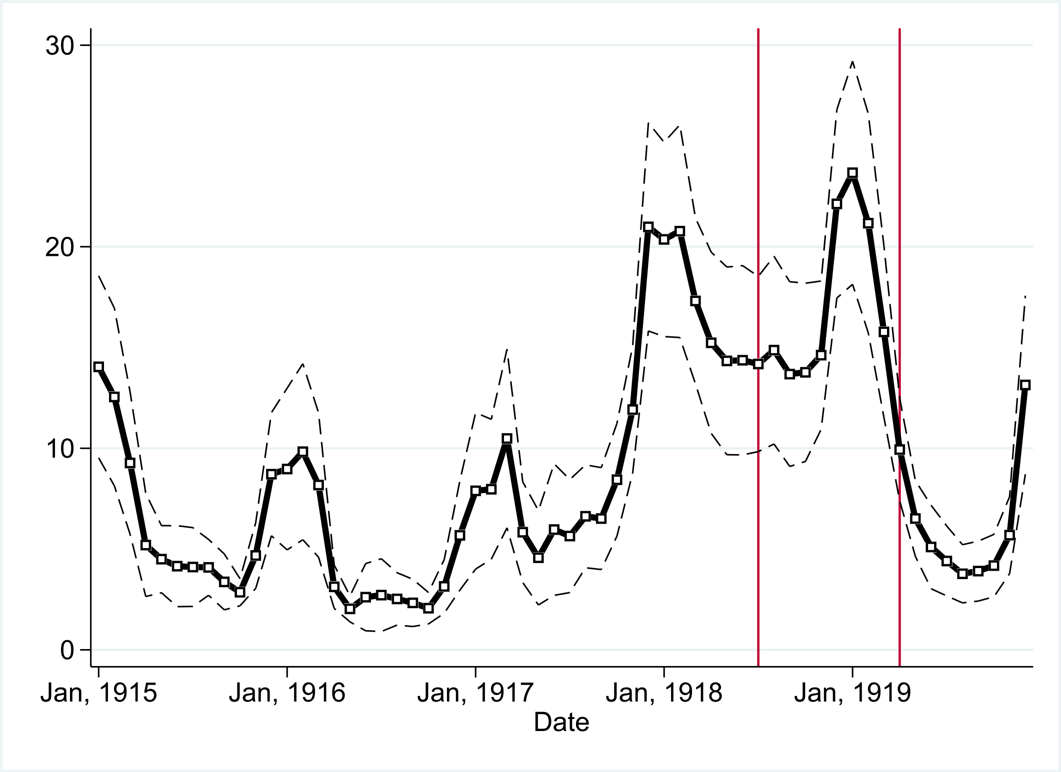
Figure 4: Monthly unemployment rates, 1915-1919



Notes: This figures show the unweighted average unemployment rates (in percent) across 61 industries with 95 percent confidence bands from January 1915 to December 1919. The vertical red lines indicate the epidemic period. Number of unemployment observations are 2,997.

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knowledge.

6.2 NPIs and epidemic effects on banks

This subsection studies how municipality NPIs affected excess influenza mortality rates, and short-run economic income growth, followed by an analysis of how the bank sector was influenced by epidemic severity.

The main NPIs, which was implemented at the municipality levels, included the closing of schools, cinemas, and theaters. We were able to find evidence of NPIs for 73 out of the 76 municipalities used in the baseline analysis. We know when these NPIs were introduced, but we do not have information on the first outbreak of the epidemic at the municipality level, so we cannot construct similar intervention variables as constructed by Hatchett et al. (2007) and used in the analysis by Correia et al. (2020). 59 municipalities closed schools, 18 municipalities closed theaters, and 26 municipalities closed cinemas.

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We construct indicators out of these data as well as an NPI index, which is equal to the sum of the different NPIs. For example, if a municipality closed schools, theaters as well as cinemas, the index takes on the maximum value of three. Appendix Table 2 reports the NPI results. We find that the closing of schools and cinemas reduced the severity of the 1918 epidemic, although the coefficients are not significant at any conventional levels. The closing of theaters is associated with higher epidemic severity (see column 1). It is important to stress that this evidence is only suggestive and higher frequency mortality data are required to assess obvious endogeneity issues (e.g., municipality might introduce NPIs because of many influenza deaths).

Using the short-run specification for annual income growth without the war years, the remaining columns show limited effects on income. If anything, closing school is associated with less growth, though this finding is not robust to specification choice (in terms of significance; compare columns 3 and 4). This conclusion is the same if we include the war years of if the post period is extended (i.e., the medium and long-run effects)

Appendix Table 3 reports the banking results. We consider total bank assets as the outcome in the first two columns and the growth rate of assets in the remaining. Since, in some municipalities, there are more than one banks operating, these specifications also include bank fixed effects, besides the usual municipality and year fixed effects. Regardless, all four estimates are small and statistically insignificant, suggesting that the 1918-influenza epidemic had little impact on the banking sector. Event-study analysis reveals that these non-findings are not driven by differential pre-epidemic trends (available upon request).

7 Lessons and perspectives

This paper has provided evidence showing that the 1918-influenza epidemic led to a V-shaped recession in Denmark with moderate short-run effects on economic activities as measured by income and unemployment rates. One might wonder if this pattern is specific to Denmark and what lessons can drawn for the current Covid-19 pandemic. First, while Denmark was not among the worst-affected countries according to Barro et al. (2020), some Danish municipalities had 1918-influenza mortality rates comparable to countries such as the U.S. and the U.K. In addition, some municipalities but not all implemented NPIs like in those countries. Therefore, our result for the 1918-epidemic is not necessarily specific to Denmark.

Second, while the Danish 1918-influenza experience gives hope that the economic aftermath of the Covid-19 pandemic is going to be short lived, it is important to stress the limitations in using the experience of the 1918-influenza pandemic to inform us about the future effects of the Covid-19 pandemic. For one thing, while the Danish municipalities implemented NPIs, they were far less restrictive than the lockdowns observed in many countries today. In addition, the 1918-influenza had a very different age-profile, mainly killing people of working ages. Finally and importantly, the 1918-influenza epidemic hit during a period of time in human history, where most deaths were due to infectious diseases. For example, the leading causes of deaths were pneumonia and tuberculosis before 1940. Thus, being sick from an infectious disease was not by any means something unusual, while today this is very different in most developed countries and one might speculate that the Covid-19 pandemic is going to change long-run behavior for this very reason.

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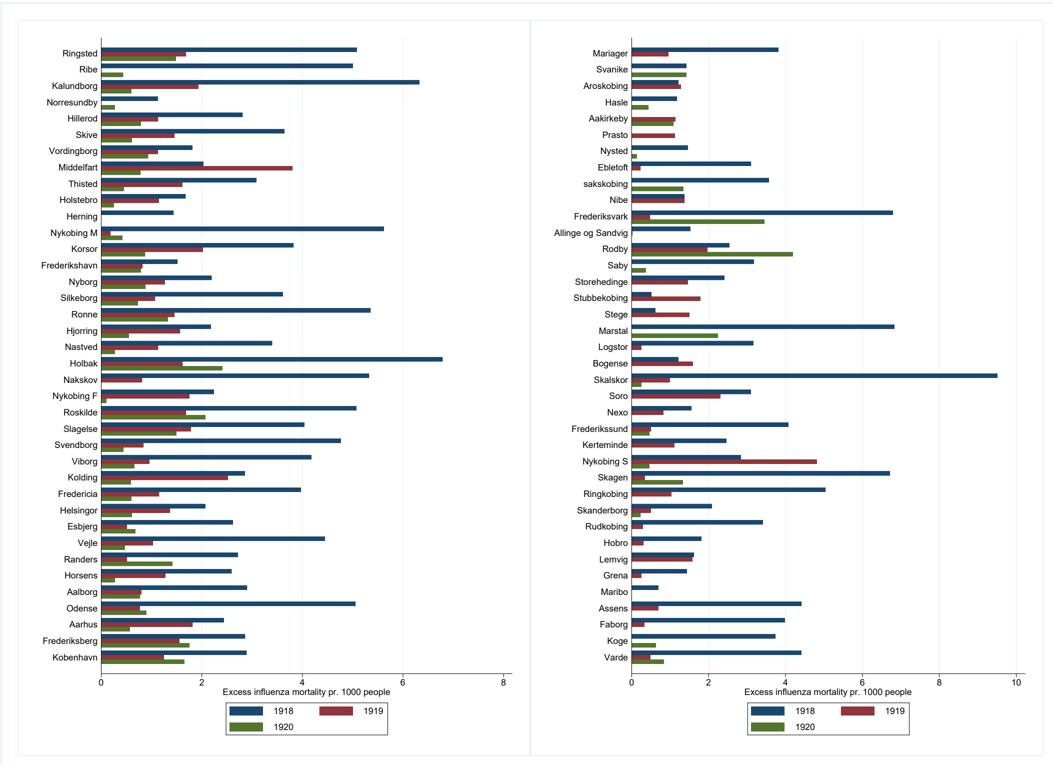
A Online Appendix

A.1 Additional tables and figures

Figure A.1: Epidemic severity by municipality and year



Notes: This figure shows excess influenza mortality rate per 1,000 people as calculated in eq.1.

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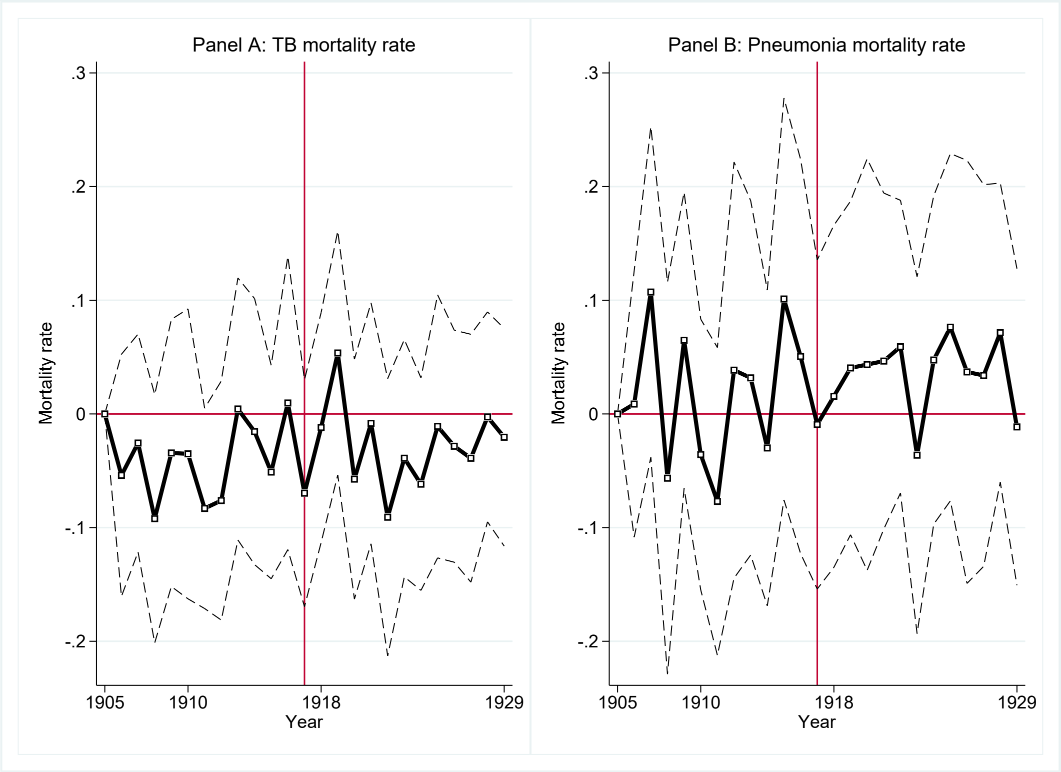
Figure A.2: Event-study estimates: Tuberculosis and pneumonia mortality rates



Notes: This figure shows the event-study estimates from estimating eq. 2 for the tuberculosis (TB) mortality rate, and the pneumonia mortality rate. The vertical red line (in 1917) separates the pre- and post-epidemic periods.

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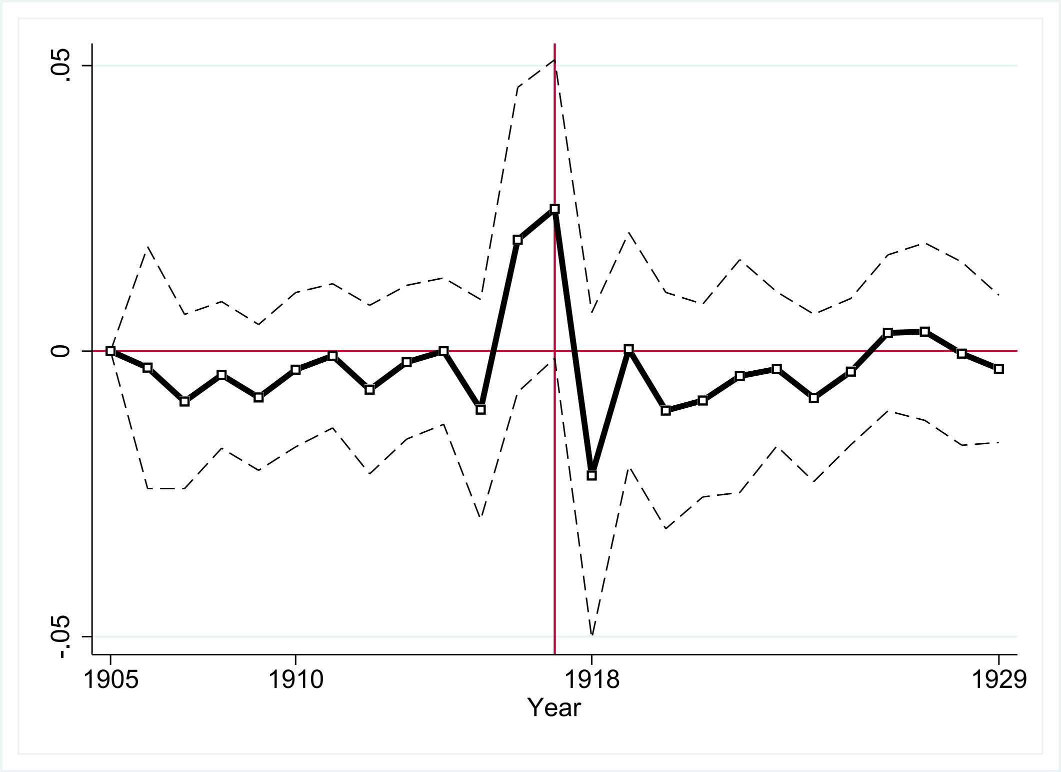
Figure A.3: Event-study estimates: Annual total taxable income growth



Notes: This figure shows the event-study estimates from estimating eq. 2 for growth rates in total taxable municipality income. The vertical red line (in 1917) separates the pre- and post-epidemic periods.

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Appendix Table 1: Data explanation

Variable:	Explanation and source:
Income:	Total taxable income of the inhabitants liable to pay taxes. Source: Statistiske meddelelser (1905-1929).
Taxpayers:	Number of inhabitants liable to pay taxes. Source: Statistiske meddelelser (1905-1929).
Death rate:	Number of deaths excluding stillbirths per 1,000 people, as stillbirths are only available from 1901. Source: Cause of Death Statistics (1905-1929).
Influenza rate:	Number of deaths from influenza per 1,000 people. Source: Cause of Death Statistics (1905-1929).
Pneumonia rate:	Number of deaths from any form of pneumonia per 1,000 people. Source: Cause of Death Statistics (1905-1929).
TB rate:	Number of deaths from any form of tuberculosis per 1,000 people. Source: Cause of Death Statistics (1905-1929).
Population:	Number of inhabitants. Source: Cause of Death Statistics (1905-1929).
Population density:	Number of inhabitants in 1890 per 1890 acreage of the city. Source: Cause of Death Statistics (1918) and DigDag.
Gini:	The Gini coefficient for the inhabitants liable to pay taxes calculated using the lowest point in the intervals of the income distribution. Source: Statistiske meddelelser (1918).
Dwellings:	Number of dwellings in 1918. Source: Statistiske meddelelser (1919).
Total assets:	Total assets of banks, 1900-1920. Source: Statistiske undersøgelser (1969) and Abildgren (2018).
Unemployment rate:	Average unemployment rate across occupations (1915-1919). Source: Statistiske meddelelser (1919).
Non Pharmaceutial Interventions (NPIs):	NPIs are measured by whether a municipality closed schools, cinemas or theathers. Sources: Newspapers, archives and various books.

Notes: This table describes the main variables used in the analysis.
DigDag is a geographic database of Denmark's historic administrative division, see `http://www.digdag.dk/`.

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Appendix Table 2: Effects of NPIs

	Dependent variable:					
	Epidemic 1918		Income per worker growth rates			
	(1)	(2)	(3)	(4)	(5)	(6)
NPI: Theater	1.361*					
	(0.686)					
NPI: School	-1.070					
	(0.716)					
NPI: Cinema	-0.877					
	(0.633)					
NPI index		-0.0732				
		(0.248)				
NPI: Theater x Post			-0.00872	0.00626		
			(0.0145)	(0.0149)		
NPI: School x Post			-0.0111	-0.0234*		
			(0.0154)	(0.0140)		
NPI: Cinema x Post			0.0178	0.00836		
			(0.0145)	(0.0136)		
Epidemic x Post				-0.0115***		-0.00988**
				(0.00382)		(0.00377)
NPI index x Post					0.00263	0.00201
					(0.00591)	(0.00535)
Observations	73	73	653	653	653	653
R-squared	0.111	0.001	0.381	0.391	0.380	0.389

This table report effects of NPI on the epidemic intensity in 1918 (columns 1 and 2) and on income growth (columns 3-6). School is an indicator equal to one if the municipality closed public schools. Cinema is an indicator equal to one of the municipality closed cinemas. Theater is an indicator equal to one if the municipality closed theaters. Post is an indicator variable equal to one after 1917. The specifications in columns 3-6 include municipality and year fixed effects. In these specifications, the pre-period is 1910-1914 and the post period is 1918-1921 Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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Appendix Table 3: Effects on bank assets

	Depedent variable:			
	Logged total assets		Annual growth rate in assets	
	(1)	(2)	(3)	(4)
Epidemic x Post	0.0108	0.00662	-0.000993	-0.000778
	(0.0185)	(0.0168)	(0.00573)	(0.00579)
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Population controls	No	Yes	No	Yes
Observations	1,134	1,134	1,100	1,100
R-squared	0.977	0.978	0.484	0.485

This tables report DiD estimates for the banking sector. The outcome variable is logged total bank assets (columns 1 and 2) and logged annual differences in total bank assets (columns 3 and 4). The variable Epidemic is explained in eq (1). Post is an indicator variable equal to one after 1917. All specifications include municipality, year, and bank fixed effects. The equal-numbered columns include control for municipality population size. Cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1