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DO PANDEMICS IMPACT MACROECONOMIC VARIABLES? A CLIOMETRIC APPROACH

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Abstract. The objective of this article is to study the impact of major pandemics on GDP/capita, wages and prices. The originality of our work lies in a cliometric approach relying on a database spanning multiple centuries (1280-2018), using various series from De Granges et al. (1855), D'Avenel (1894), Baulant (1971), INSEE (1988) and Maddison (2020). In order to analyse the impact of major pandemics on the economy, we use the outlier methodology (Darné and Diebolt, 2004). This method consists in detecting atypical points affecting the evolution of a time series. It relies on real shocks and not on simulated ones; it is therefore more suitable for historical analysis. We detect events which significantly affected the evolution of the economy during a determined period. The following question is tackled: over the period 1280-2018, did pandemics significantly influence the evolution of GDP/capita, wages and prices (wheat) and if so, what has been the nature of this impact? Having outlined the history of pandemics and reviewed the literature linking our variables to health shocks, we present our results and observe a differentiated impact of pandemics between variables. First, only GDP/capita is significantly affected by health shocks. Second, wages and prices seem to be unaffected by pandemics; variations appear to be directly linked to institutional events like the introduction of taxes, the presence of guilds, and changes in worker statuses (Jedwab et al. (2020)), and to structural events as food shortages and crop failures (Boyer et al. (2019)).

Keywords: Cliometrics, GDP, Infectious diseases, Outliers, Prices, Wages
JEL classifications: C32. E32. N33.

1 Introduction

The coronavirus pandemic has shed light on the problem of the impact of infectious diseases. However, COVID-19 is far from the first disease in human history to have a global negative impact. There have been four main global pandemics over the past 1000 years: the plague, the cholera, the flu, and the coronavirus. In recent scientific history, the global impact of pandemics has clearly been underestimated. As Humermovic (2019) argues, these phenomena have profoundly shaped our society and resulted in extensive economic and demographic changes. To better understand what follows, a distinction between epidemiological terms is in order. According to Grennan (2019), "the terms endemic, outbreak, epidemic and pandemic relate to the occurrence of a health condition compared to its predicted rate as well as to its spread in geographic areas". "An endemic condition occurs at a predictable rate among a population. An outbreak corresponds to an unpredicted increase in the number of people presenting a health condition or in the occurrence of cases in a new area. An epidemic is an outbreak that spreads to larger geographic areas. A pandemic is an epidemic that spreads globally". Based on this, we use the term pandemics here to describe mass global infectious diseases. Pandemics have occurred throughout human history; some of the worst ones, like the Antonine Plague and the Justinian plague, date back to over 2000 years ago. These two plagues were the first pandemics to be well-documented by physicians like Galen. This paper, however, examines a database that spans the 1280-2018 period, which means we focus on medieval, and pre-modern pandemics such as the plague, cholera, or the flu.

These pandemics are the origin of massive changes in our society. According to Barbara et al (2021) there are several channels of transmission of epidemics to the economy. They have an impact on the supply side through the labour force, working hours and productivity. They also impact the demand through consumption and business investment. The aim of this paper is to understand and focus on the economic changes due to pandemics since the middle ages. To understand how and in which measure pandemics imply changes in human history, we can take a few examples. To begin, the second plague during the fourteenth century generated a ceasefire during the Hundred Years' War (1347-1350) and disrupted the social order with riots and the apparition of phenomena such as the flagellants and the Jacquerie in France (Jedwab et al. (2020)). These historical movements got directly generated by the plague,

troops needed to recover from the epidemic in their rank and workers had seen their conditions worsen. During this time, the Black Death was responsible for at least 30% of the population death, and this type of demographic shock implies many economic changes.
After the plague, came the time of cholera, an infectious disease transmitted through water. Cholera hit as a pandemic with seven different waves between 1817 and 1975. These waves killed millions of people. One of the most interesting waves of the cholera pandemic is the second one, which hit France in 1832. The second wave of cholera is the only which happened within the limit of our database. It was not the deadliest or the largest pandemic, but it killed around 100 000 people in France and close to 1 million globally.
While Cholera was spreading, the flu appeared in many countries. The flu comes from many mutations, the type of flu that we are interested in here is, more precisely, the Spanish flu (1918-1920) which had a massive impact at the time. This disease spread largely after the WW1 and hit the world in 3 waves within 9-month intervals. Due to the post-war context, it's clear that the military troops movement contributed to a massive diffusion of the Spanish flu. This results in 500 million infections and 50 million deaths at least.
While our database contains the data from these three major pandemics, we did not include the recent coronavirus outbreak, as it is a recent and modern disease. However, it was during the COVID-19 pandemic that the question of the economic impact of infectious diseases was raised. Many papers, empirical or theoretical, attempt to explain the consequences of this pandemic. Atkeson (2020) shed light on the use of epidemiological model (SIR model) to explain the economic impact of a disease. His work has inspired many other authors to use this type of model and embed them into a growth model to explain the impact of a disease such as coronavirus. Eichenbaum et al. (2020), Bloom et al. (2020) used those models to explain the economic impact of an infectious disease. Eichenbaum et al. (2020) study the behaviours of people in times of infectious diseases and how it affects their labour supply and consumption. They show that an agent cuts back consumption and labour during a severe outbreak and that this decision negatively affects the extent of the recession. Authors have documented the trade-off between the economic impact and protection from the disease. Bloom et al. (2020), as the previous authors, used a SIR model to demonstrate the economic consequences of an infectious disease. They give guidelines to policymakers based on different hypotheses, like different disease characteristics, population dynamics and country heterogeneities. In the end, they demonstrate that the economic impact transit mainly through labour loss.

This literature thus yields important insights into the impact of infectious diseases. On the more empirical side, Carillo and Japelli (2020) show that the Great Influenza is responsible for a decline of 6.5% in GDP per capita growth in Italia, during the period, with regional variation depending on the mortality rate from the disease. This estimation is consistent with the work of Barro et al. (2020) who found a 6.2% drop in GDP per capita during the Spanish flu. Using a simulation, Lee and McKibbin (2004) found that SARS accounts for a loss of 2.63% of GDP for Hong Kong and 1.05% for China. Overall, it appears that pandemics are GDP-lowering events. However, whether this also applies to wages and prices and over longer periods remains to be investigated.
In this paper, we consider whether infectious diseases impact GDP, wages, and prices through history. To do so, we use a database on GDP, wages, and prices of France from 1280 to 2018. To our knowledge, this paper is the only to study pandemics with such long-term data. To tackle our research question, we relied on a classical cliometrics approach: the outlier methodology, which allows us to observe the real impact of pandemics on our variables. The paper is divided into four sections. First, we discuss the main pandemics that occurred during the timeframe under study. Second, we shed light on the links between pandemics and our variables. Third, we present our database and describe our main variables. Fourth, we implement the outliers method on our data and explain the results. Lastly, we conclude with final remarks.

2 Infectious diseases throughout history

In this paper, we focus on the pandemics that hit France between 1280 and 2018: plague, flu, and cholera. The first disease of interest is the plague, an infectious disease caused by the bacterium Yersinia pestis. This disease has multiple manifestations, including fever, weakness, and headaches. Its incubation period is known to take between one and seven days. There are three types of plague; each one affects a different part of the body and causes different symptoms. The first is the pneumonic plague, which infects the lungs, causing respiratory problems; the second is the bubonic plague, which affects the lymph nodes, making them swell; and the third is the septicemic plague, which infects the blood and can cause tissues to turn black and die.
The first plague pandemic was the "Justinian's plague", which originated in North Africa (Ethiopia or Egypt) and spread in the eastern Roman Empire and nearby countries. Even if bubonic diseases were reported before the Justinian plague (Zietz and Dunkelberg, 2003), this is the first undoubted outbreak of

the plague. It occurred in 541-543 and killed around 100 million people across the Roman Empire (Piret and Boivin, 2020). It appears that this pandemic hit by waves and followed a pattern of 8 to 12 year-cycles for two centuries before it eventually disappeared.

The second plague pandemic was the Black Death. It emerged in East Asia around 1334, spread across Central Asia and arrived in Europe in 1347 through land and trade routes (Huremovic, 2019). We estimate that the plague killed around 200 million people until the early 19th century, in multiple waves. More specifically, we estimate that the Black Death killed 25 million between 1347 and 1351 (the first wave) (Huremovic, 2019) and over 150 million by 1400. The Black Death was responsible for the death of at least 30% of the population death and was followed by multiple waves over centuries. This pandemic is a major concern in this paper because of its extent and social impact. It affected the social order in many ways. The flagellants movement appeared (Cohn (2004b, 87)) in the decade following the Black Death. In 1358, northern France was shaken by the Jacquerie, a major peasant and bourgeois revolt (Jedwab et al., 2020). It even affected the composition of society: Alfani (2020) for instance observed a narrowing of inequalities in Toulouse, where the Gini index of wealth inequality dropped from 0.752 in 1335 to 0.606 in 1398 (Alfani, 2020).

The government's response was initially primarily religious (Huremovic, 2019); scientific authorities, at a loss, blamed the pandemic on the alignment of three planets (Horrox, 1994). The medical response was weak, with a prevailing belief in the inhalation of aromatic vapours and other magical protections (Hajar, 2012). However, the plague was recognized by the authorities to be contagious, and control measures were implemented to keep the spread of the disease in check, including quarantine, the disposal of the victims' bodies and possessions, sanitary cordons, the separation between healthy and infected people and mandatory isolation measures. The first known quarantine took place in Ragusa in 1377, where all new arrivals had to spend 30 days on a nearby island called Lokrum (Mackowiak and Sehdev, 2002). However, the preponderant role of rats was underrated and only discovered during the 19th century (McEvedy, 1988). Due to this lack of information, it proved difficult to contain the disease. Plague doctors emerged during that time. Their role was to assist people and keep records of deaths.

The third plague began during the 17th century. It probably broke out in northern France in 1623 and spread to England, France, Germany, the Low Countries, Switzerland and Italy. In parts of France and Italy, this third plague is usually considered the worst one. France was hit by multiple waves, in 1603,

1628, 1652 and 1668 (Alfani et al., 2012). To underline the severity of this plague, Alfani et al. (2012) showed that in the city of Lyon alone between 1628 and 1629 this disease killed about 35,000 persons. On a more global scale, it killed around 2.2 million in France (11-14% of the population) and at least 8 million in Europe (Alfani et al., 2012). It should be noted that the plague is a re-emerging infectious disease. Between 2010 and 2015, 3,248 plague cases were recorded; however, there is now a vaccine for the disease.

The second main infectious disease in the history of France is the cholera, which spread during the 1832 pandemic. Cholera is a gastrointestinal disease caused by the bacteria vibrio cholerae and comes from India (Piquemal, 1959). It is first identified based on clinical symptoms of acute watery diarrhea, which must be treated with drugs and rehydration. Seven major cholera pandemics have been recorded throughout history. The second hit France with a death count of 100,000 (Piquemal, 1959). This infectious disease appeared to be endemic in Asia until 1817; it then travelled from Asia to India and spread around the world through globalization. At the time, to answer the problem, the central planner locked down travellers and merchants coming from the contaminated part of the world. Five additional major pandemics occurred in the nineteenth and twentieth centuries. Cholera is transmitted through water. The toxin responsible for the disease was only discovered in 1959. The seventh cholera pandemic was the worst one, with the most extensive propagation in terms of geographic spread and duration. In late 1992, the disease broke out in Bangladesh. Cholera cannot be eradicated because of its inherent existence in aquatic ecosystems. In the most recent period under study, between 2008-2012, around 1.3/4 million cases and 95 000 deaths per year have been recorded (Piret and Boivin, 2020). Climate change and environmental degradation may accelerate the spread of the disease; curbing it will require sanitation and safe water supplies. Three potential vaccines are being developed.

The third main disease is the flu. Generally called influenza, it appears to have first infected humans in 1510 (Piret and Boivin, 2020). The Russian Flu (1889-1893) was the first documented pandemic related to this virus. Influenza rapidly spread worldwide (4 months) and caused a total of 1 million deaths in three-year cycles (Piret and Boivin, 2020). The best-known influenza pandemic is the Spanish flu, which spread silently before it was identified. It was the first global pandemic in the era of modern medicine. The pandemic, whose origin is uncertain, also came in waves. In the period 1918-1920, the

disease spread across the world in three waves within a nine-month interval (Taylor and al., 2020). The first and least lethal wave hit during the spring and summer of 1918. The second, more lethal one, hit many countries in September-November of 1918. Two-thirds of the mortality occurred in 1918. A third wave hit in the spring of 1919. A fourth wave hit a few countries in 1920. The movement of military troops contributed to the mass spread of the disease. This resulted in 500 million infections and 50 million deaths at least, meaning a 10 to 20% death rate Johnson and Mueller, 2002). The young and the old were mostly hit. The most common clinical manifestations were acute, aggressive bronchopneumonia and acute respiratory distress syndrome (ARDS). Studies based on US census data found that children with a mother who was exposed to the Spanish flu were of poorer health and had shorter lives. All strains of influenza in the following years and centuries have come from the Spanish flu. These descendants have hit many times: the Asian Flu of 1957-1959 killed 1-2 million, including high numbers of young children, the Hong-Kong flu (1968-1970) killed 0.5/2 million; more recently, the H1N1 virus of 2009 caused 148,000-240,000 deaths (Huremović, 2019).

On a side note, during the 1980's the HIV pandemic began in the USA. This disease hit the gay and poorer population with huge mortality rates, leading to the widespread stigmatization of those communities. It affects 40 million people globally and has killed 40 million since 1981 (around 1 million people per year). HIV currently remains a major concern for sub-Saharan African countries. It has been the target of considerable public health investments in prevention and research (Bloom and Mahal, 1995).

3 Pandemics, growth, wages, and prices

Many papers have debated the link between growth and infectious diseases from a theoretical and empirical points of view. In the early of 2000s, Philipson (2000) examined the interplay between economics and infectious diseases, focusing on the difference between two different types of modelling: economical and epidemiological. He stressed the link between rational epidemics and public health intervention. Using economic tools, the paper addresses multiple issues in pandemics management, Pareto optimality of policy, vaccination and global public intervention during pandemics. The conclusion emphasized the importance of the elastic behaviour linked with mortality and diffusion of the disease. Other papers describe the link between economics and infectious

diseases through different means. Augier and Yaly (2013) use an OLG model on health policies; Chakraborty et al. (2010) link development and health with a general equilibrium model; Bell and Gersbach (2013) focus on growth, infectious disease and human capital formation. While each of these looks at a different aspect of the long-term link between economics and diseases, none of them displays a genuinely interdisciplinary approach. To the best of our knowledge, the first attempt to introduce a disease spread model into an economic growth model dates back to Goenka and Liu (2012). Previously, one of the main methods use to model infectious diseases was to include a probability of death for the agent. In their paper, they consider an epidemiological block known as the SIS model. This epidemiological model consists in splitting a population into two compartments: Susceptibles and Infectives, which can be described as a separation between non-infected and infected agents. A susceptible agent has a probability of contracting the disease through contact with an infective; an infective can heal from the disease and return to the susceptible group without acquiring any immunity. The authors assume that infectives are too ill to work, as a result of which labour force only consists of susceptibles. In that case, the disease impacts the economy through labour, by depleting the working force. They point out that periodic cycles (flip bifurcation), as well as chaos around the endemic steady state, are possible, since the disease is infective enough, in a discrete-time Ramsey framework with endogenous labour supply. Interestingly, they stress that it is possible to control chaos at the endemic steady state by considering vaccination or isolation to apply the OGY method. Based on this, Goenka and his co-authors (2014, 2016, 2021) developed many other models considering growth and infectious diseases. After the first COVID-19 wave, the question of the short-term effect of infectious diseases on the GDP piqued the interest of numerous economists, including Acemoglu (2020), Alvarez (2020), Atkeson (2020), Eichenbaum (2020), and many more. For example, Alvarez et al. (2020) considered a dynamic general equilibrium model with an infectious disease that evolves following a SIR model behaviour. The authors focus on a central planner solution where the government determines the evolution of lockdowns in function of a trade-off between the value of agents' deaths (with the statistical value of life) and the lockdowns' impact on GDP. Because of the presence of the epidemiological block, the optimization program appears to be non-convex; thus, Alvarez et al. (2020) could only provide a numerical solution using early data from the Covid-19 pandemic. Their simulation results show that the implementation of a strict lockdown during the early stage of the pandemic, to be then gradually eased, is optimal. The disease disappears in the long run due to the immunity

hypothesis that characterizes the SIR model.
Using a more quantitative approach, Ismahene (2021) shows the long-term negative impact of a disease on economic growth. The author uses panel data (FMOLS and DOLS) and highlights the negative impact of malaria, HIV, IID on growth in the long term. This effect is more negative in the long term on developing countries due to their weaker public health systems. The apparition of diseases negatively impacts trade openness, mostly in developed countries. The author concludes that a policy aimed at reducing the impact of diseases is needed to promote economic growth and trade openness. Bhargava et al. (2001) examine the effects of health on economic growth. To do so, they model the proximate determinants of economic growth for five-year intervals. They measure disease prevalence using the "adult survival rate", finding that a 1% change in ASR is associated with an approximate 0.05% increase in growth rate, meaning that a pandemic significantly lowers the GDP. Barro et al. (2020) remind us that GDP and massive macroeconomic disasters are negatively linked. Drawing on a database of 43 countries, including GDP, population, human mortality, war mortality etc., they use an econometrics regression model and find that the GDP dropped by 6% to 8% during the Great Influenza.

The second objective of our paper is to analyse the impact of pandemics on wages. Malthus theorized the impact of a pandemic on the population as an increase in wealth due to mass deaths. According to Malthus, pandemics play a regulatory role in population growth; just like wars, pandemics are necessary to avoid overpopulation. A lower population due to the apparition of a disease implies a growth in wages because of the new distribution of wealth in the economy. Indeed, an epidemic with high mortality among the working population could result in higher wages due to labour scarcity (Jorda et al., 2022). The literature seems to confirm this point of view and agree that pandemics drive wage growth. For example, the Black Death, which killed massively and impacted 25% to 40% of the labour supply, was linked with a wage increase of 100% (Taylor and al., 2020). Wages in England doubled during that period (Robbins, 1928). Clark (1998) shows that wages and population seem to be linked: when the population increases wages decrease and conversely. Consequently, higher fertility results in lower real wages. This statement is true before the Black Death (1210- 1300). After that, between 1300-1349, a period during which the plague hit Western Europe badly, causing mass deaths, we observe an 86% increase in wages. By the 15th century, wages were 64% higher than before the plague. However, it is notable to note that the impact

on wages seems to be delayed by one generation: the Black Death's effect on wages was not visible before the 1370s. This sluggishness can be due to the worker status and institutional rigidity (Clark, 1998). The authors noted that the effect of population dynamics on wages and land rents depends on the degree to which land and capital could be substituted for labour in production. This means that pandemics will have more impact on wages if workers are not substitutable to capital.

Overall, the Black Death seems to have favoured an increase in wages, but this statement can be contrasted with the fact that profits stagnated and farmers struggled with the rising wages. This observation can be a signal that wages growth was slower than expected. This raised a main point, wage variation seems to be constrained by structural events. Heckscher (1955) writes that in France: "the effects of the Black Death provided a powerful motive for the first interference on the part of the state. The great pestilence had led to a rise in prices and particularly in wages, and the king took this as a motive for making the local bodies in Paris, above all the guilds, dependent on the royal institutions". Heckscher (1955) explains that this increasing regulatory oversight actually made labour markets freer. "The decree tended to make it easier for strangers to practice their crafts within the town; it even stipulated that any person who was able to practice a craft or introduce a commodity might do so and allow others to do the same". This kind of example shows that even during pandemics, institutions can put pressure on prices and wages to drop In France, during the Black Death, the main form of taxation was the land tax (called taille), which was levied on peasants. The collection of this tax began after the Black Death to finance the Hundred Year's War against England. The taille was not the only tax; other different direct taxes were introduced during the pandemic. Taxation appears to be one of the many forces that applied pressure on the labour market.

The statutes applying to workers played an important role during the Black Death period, as wages were massively impacted by an institutional response to the shock. In France, the government limited nominal wage growth during the 1350s with a 1351 statute regulating wages, prices, and guild admittance (Jedwab et al. (2020)). In the seventeenth century, the third plague seems to have had no positive impact on real wages, even in Southern Europe where epidemic mortality was as high as during the Black Death (Alfani,2020). There is doubt about the effect of pre-Black Death pandemics on wages. Postan (1950) found the link between population and wages not to be straightforward. He showed that the decrease in population pushed workers to return to a rural economy, causing further tension in urban labour markets. In that case, wages

in cities are not getting at the level they should be with the lowering of the population. Regarding the Spanish flu, Basco et al. (2021) found a 12% to 0% decrease in wages and a 1% increase in the mortality rate. The short-term impact on wage was a roughly 30% drop. Moreover, the authors discuss two ways in which pandemics affect wages: first by depleting the labour supply (increasing wages), and second by deteriorating global health, requiring social distancing and lowering demand. Regarding the modern period, Bloom and Mahal (1995) have analysed HIV. They found it led to an insignificant impact on GDP per capita and wages. The authors also studied data from 1310 to 1449. Authors cannot reject or confirm the fact that real wages do not exhibit a differential rate of growth during periods of the major medieval plagues in England. They are going against medieval historians who report a rapid rise in wages following the Black Death. During pandemics, it has overall been reported that wages are sluggish and adjustments imperfect due to institutional and structural constraints. For now, it appears unclear whether wages grow or not during pandemics. The debate is still going on, and we are here trying to give an answer.

Finally, we analyse the potential effect of pandemics on prices. Indeed, the effect of pandemics on prices remains unclear. On the one hand, a smaller population reduces demand and may have a negative impact on prices. On the other, it also reduces the workforce and may have a positive impact on wages, especially in rural areas, leading to rising prices, especially for grain(Routt, 2008). The impact also depends on the nature of the goods. While increased demand for health products may lead to higher prices in the short term, the downturn in global demand may lead to price decreases (Jaravel and O'Connell, 2020). Thus, the deflationary or inflationary character of epidemics depends on the relative weight of the transmission channels (Baqaee Farhi, 2020) and the institutional control of the cost of production. Wages were mostly state-controlled in the Middle Ages, meaning that prices were indirectly controlled too (Fisher, 1965). Later on, with Spanish influenza, inflation seems to have appeared. Taylor and al. (2020) linked the higher death rate with the higher inflation rate during that period. A distinction can be made between modern and pre-modern times: wage and price sluggishness appear to have characterized earlier pandemics such as the plague; then, macroeconomic variables were more volatile during pandemics such as Spanish influenza or HIV.

4 Database

Our database covers the 1280-2018 period on three main variables: GDP, wages, and prices for France. The series comes from several sources such as De Granges et al. (1855), D'Avenel (1894), Baulant (1971), INSEE (1988) and Maddison (2020).

Figure 1: Database head (Wages, Prices, and GDP are in dollars)

Years	GDP	Wages	Wheat Prices
1280	1321	NA	NA
1281	1288	NA	4,9
1282	1253	NA	7,81
1283	1237	NA	4,49
1284	1219	NA	1,17
1285	1253	NA	11,2

Our data begins in 1280 and ends in 2018. The GDP series begins in 1280 and ends in 2018 with a gap between 1790 and 1820. The wages series begin in 1400 and ends in 1914 with a one hundred years gap between 1727 and 1815. This explains the high number of NA variables for the wage series. Concerning prices, our series begins in 1281 and end in 1890 without any gap in the series. We can observe our descriptive statistics of the database as follows:

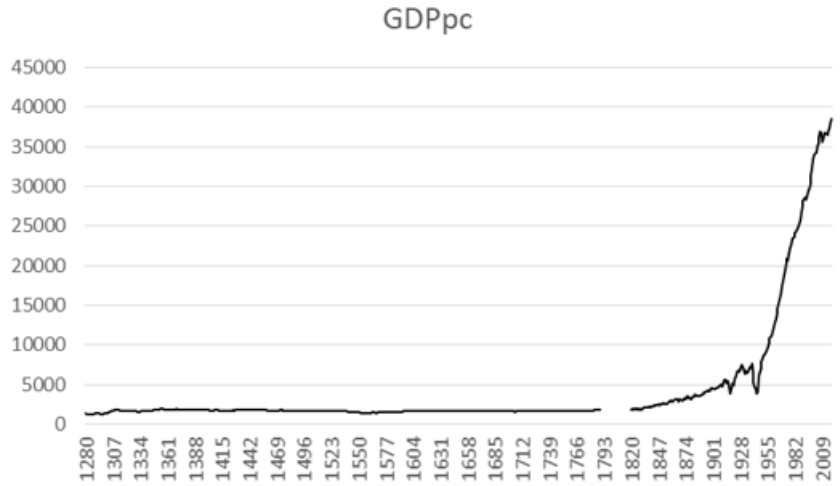
Figure 2: Descriptive statistics (Wages, Prices, and GDP are in dollars)

	GDP	Wages	Wheat Prices
Min	1219	2,33	1,17
1st quater	1659	3	5,957
Median	1728	12	10,94
Mean	4303	21,87	12,095
3rd quater	2276	20	16,395
Max	38516	107,3	46,71
Na's	30	312	129

The GDP per capita represents the wealth of France at a given time and is a

great indicator of the potential impact of pandemics. This requires looking at its variations. Here, we can observe that GDP growth remained very low for a long time. The third quartile is only 40% higher than the first despite the 500-year gap. The number of NA values is small.
Wages and prices series are also needed to observe the global macroeconomic impact of pandemics. Our data are very long-term series from 1280 to 1945 for wages and from 1280 to 1890 for prices. The evolution of wages seems more progressive and constant than the evolution of the GDP.

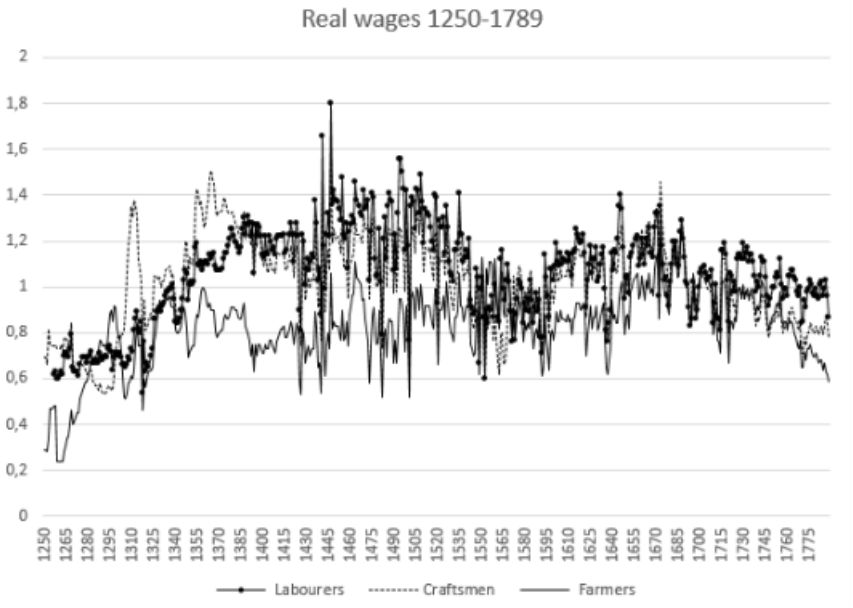
Figure 3: GDP in France 1280-2018



The data on GDP per capita comes from Maddison (2008) and covers the period 1280-2018. It is given in Geary-Khamis dollars. GDP growth began in the early nineteenth century. Some fluctuations can also be observed during the Black Death period, as well as others corresponding to the two world wars and the Spanish flu. As the series gap ends before 1820, the impact of the cholera pandemic is reflected in the data, but not visible in this form.

Figure 4: Wages in France 1400-1904

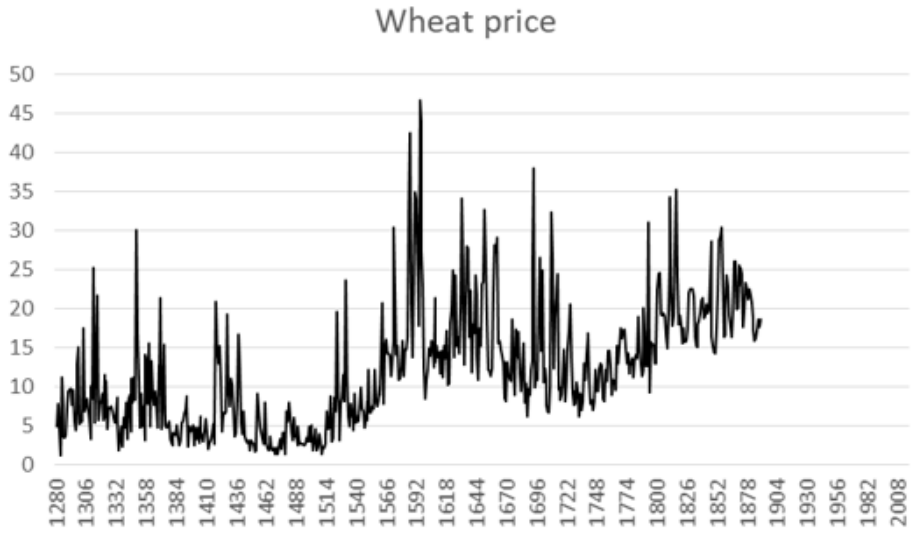
Figure 5: Real wages 1250-1789



The series on wages come from different datasets. For the 1400-1726 period, we use the nominal daily wage of bricklayers in Paris as presented in Baulant (1971). Our series is given in sous tournois with the official equivalence with

the livre tournoi and the franc as: 20ST = 1LT = 0.987 franc. This exchange rate is based on a "silver-metal" equivalence of 1F = 1.0125LT = 4.5 g silver. This equivalence was in force until 1914. For the 1815-1914 period, we use the nominal wage in France provided by Rouzet (2004). It is given with an annual index basis 10 in 1905. In addition to this series, we also use data provided in Ridolfi (2016) on the real wages (Index 1700 = 1) of labourers, craftsmen, and farmers from 1250 to 1789. The series is built from very different sources, computing a five-year moving average and correcting spatial heterogeneity. Indeed, the distribution of wages across space is quite uneven. Some regions (Normandy, Alsace, and Île-de-France) supply most of the wage data, while other regions (Limousin, and Franche-Comté) play only a marginal role.

Figure 6: Wheat price in France 1280-1890



The data on price uses the wheat price from three different databases, spanning the 1280-1890 period: by D'Avenel (1894) for 1280-1800; by De Granges et al. (1855) for 1800-1814 and by the French national statistics institute INSEE for 1815-1890. Prices provided by D'Avenel (1894) are given in francs, and the measure used is the hectolitre. D'Avenel (1894) series are rebuilt and took into account the evolution of the silver power across various centuries. Data published by De Granges et al. (1855) provided wheat prices in francs, and the measure used is the hectolitre. Data provided by INSEE are also given in francs. The wheat prices series are very volatile. Indeed, as Boyer et al. (2019) have noted, they depend on many factors, including meteorological and

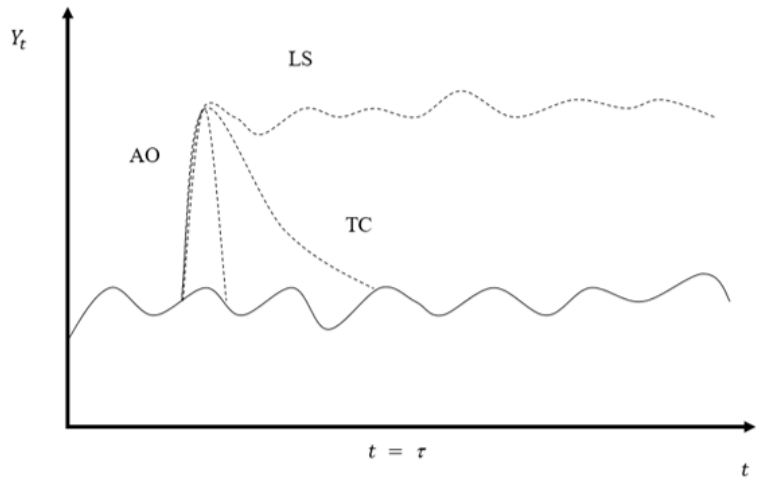
institutional ones. Postan (1950) or Jedwab et al. (2020) have also shown the preponderant role of pandemics in agricultural mutations. They observed mass rural flights during these periods, with a switch in production from wool to wheat due to collapsing demographic dynamics, which in turn put pressure on wheat prices.

5 Empirical analysis

Using longitudinal statistical series, we try to identify which events have affected the evolution of wages, GDP/capita and prices since the thirteenth century. We are especially interested in the impact of the respective diseases. For this purpose, we use the outlier methodology developed by Darné and Diebolt (2004) to detect the existence of possible breaks in the statistical series. The indicators do not follow a regular pattern. There are several breaks, or changes, of varying degrees of importance. The objective of the outlier method is to detect changes in patterns that have had a significant impact on the evolution of time series and to identify the institutional, historical, or economic events responsible for these changes. This method is relatively well suited to historical analysis insofar as it is based on the analysis of real, non-simulated shocks. In statistical theory, an observation is considered exceptional when it deviates (positively or negatively) significantly from its mean value or trend and does so with very low frequency. From a purely statistical point of view, an extreme event is defined as a value two to three times the standard deviation of the series, while an atypical value is defined as a value well above three times the standard deviation of the series. We are only interested here in atypical, outlier, or exceptional values. The analysis of atypical points makes it possible to associate atypical observations with educational, economic, political, or financial events. The challenge is to identify these points, their possible causes, and their effect on the series. The effects on the time series are varied and depend on the type of outlier detected. The literature lists four types of outliers: Innovative Outliers (IO), which represent temporary shocks that can be assimilated to 'noise', Additive Outliers (AO), which are associated with one-off exogenous changes, Temporary Changes (TC), and Level Shifts (LS), which represent ephemeral and permanent structural changes respectively. An AO is generally considered to affect only one observation in the series, but not its future values. A TC causes a rapid change in the level of the series, which quickly returns to its evolutionary path. Finally, a LS affects the level of the

series from a certain point onward in a definitive manner (Fig. 7).

Figure 7: The various outliers



The cliometric analysis performed here will consist in detecting changes in the series and especially the impact of the diseases over the period under study. To do so, we decided to split our data in five parts as suggested by Ridolfi (2016). These parts are the following: Before 1345 (pre-plague period) / 1345-1550 (First Malthusian cycle after Black Death) / 1550-1690 (Rise of the great inflation and stabilization) / 1690-1789 (pre-revolutionary period)/ 1815-1915 (post-revolutionary period).

6 Results

The outlier detection gives the following results. For each outlier detected, we try to explain the event affecting the evolution of the series. To do so, we rely on various historical references (Levasseur, 1900; Menant, 2013; Sardon, 2020) as well as multiple websites (see Websites listed in the bibliography). During the pre-plague period, the impacts that we observe only concern wages and essentially come from low yields and food shortages. Over this period, GDP/ capita, prices and bricklayers' wages are not impacted by special events. Contrary to the pre-plague period, during the First Malthusian cycle after the Black Death, the GDP was affected by two key events: the poor harvests of

the 1340s, which led to a decrease in French wealth, and the Black Death, which had a positive impact due to the population decrease. At the same time, bricklayers' wages and prices were not affected by the great disease. On the contrary, they were essentially affected by meteorological events which impacted harvests. Craftsmen, labourers, and farmers' wages experienced one-off impacts, probably due to local events. During the 1550-1690 period, the GDP experienced two one-off negative impacts: the fourth war of religion and a very cold winter which destroyed harvests. At the same time, while bricklayers' wages did not exhibit significant variations, craftsmen, labourers, and farmers' wages were negatively affected by many one-off events. These were essentially linked to meteorology, in particularly cold winters. Over the pre-revolutionary period, the GDP saw a permanent positive impact due to some meteorological events, but also due to a pandemic in western France. Another positive impact occurred temporarily: the beginning of the revolts that led to the French Revolution. Wheat prices were affected by poor yields and meteorological events as shown by Boyer et al. (2019). Over this period, in addition to weather (the very cold winter of 1709) and institutional events (the proportional land tax in 1716), wages seem to have also been affected by epidemic episodes, especially the plague of 1720. This is the only sub-period in which pandemics appear to have affected wages. Finally, during the post-revolutionary period, the GDP/capita experienced two positive events – the two world wars- and two negative events: the Spanish flu and the crisis of 2008. Wheat prices witnessed a one-off positive impact and a permanent positive impact during the two cold winters of 1793 and 1795 associated with the Terror. Another permanent, but negative impact occurred in 1848 with the hunger revolts due to the grain crisis. Ultimately, it appears that epidemics mainly impact GDP/capita. However, these effects seem to be temporary and limited, as pointed out by Barbara et al. (2021). As for price changes, they are essentially due to climatic variations that affect harvests. Overall, the effect of pandemics on wages remains ambiguous in the sense that the impacts identified essentially relate to crises, except for a few local epidemics.

Figure 8: Outlier detection 1250-1344

Year	Type	Value (units of standard deviation)	Duration of Effect	Sign	Event
GDP / capita					
Wheat price					
Bricklayers nominal wage					
Craftsmen real wage					
1253	TC	4.7	Temporary	(+)	
1270	LS	4.1	Permanent	(–)	Beginning of the series of shortages
1318	AO	11.1	One-off	(–)	Peak of the famine
Farmers real wage					
1259	LS	5.8	Permanent	(-)	Mass starvation
1318	TC	8.4	Temporary	(-)	Peak of the famine
Labourers real wage					
1270	LS	4.5	Permanent	(-)	Beginning of the series of shortages
1318	AO	12	One-off	(-)	Peak of the famine
1320	TC	4.2	Temporary	(-)	Revolt of the pastoureaux
1325	LS	3.5	Permanent	(+)	Low cereal harvest but exceptional grape harvest

In our first timeline, it seems that only wages are affected by events of any kind, mostly food shortages and social instability. Food issues have a mostly permanent impact on wages. Indeed, half of the outlier appears to have a permanent impact and the other has a temporary effect. Famines are negatively correlated to wages; we could have expected the opposite with the decrease in labour supply, but famine may lower productivity, which in turn accounts for the decrease in wages. The Pastoureaux crusade is an exception, being the only event affecting wages that is not related to a food shortage issue.

Figure 9: Outlier detection 1345-1550

Year	Type	Value (units of standard deviation)	Duration of Effect	Sign	Event
GDP / capita					
1345	TC	6.6	Temporary	(-)	Poor harvests
1354	TC	4.8	Temporary	(+)	Black death
1396	TC	3.5	Temporary	(+)	
Wheat price					
1419	TC	3.6	Temporary	(+)	Extraordinary shortage
Bricklayers nominal wage					
1415	AO	4.3	One-off	(+)	Heavy rains; high food prices
1420	TC	9.7	Temporary	(+)	Episode of scalding
1436	AO	4.2	One-off	(+)	Very expensive wheat - Many deaths
1445	LS	3.5	Permanent	(+)	Ordinance of Sarry-les-Châlons: land tax became a permanent tax in France, to finance the military reforms
Craftsmen real wage					
1425	TC	3.7	Temporary	(-)	
1441	AO	6	One-off	(+)	
1447	AO	5.2	One-off	(+)	
1482	AO	4.1	One-off	(-)	Frumentary crisis of 1481-1482
1501	AO	5.7	One-off	(-)	Plague in Brittany
1520	AO	4.1	One-off	(-)	Poor harvests
1549	AO	3.8	One-off	(-)	Suppression of the salt tax in the south west
Farmers real wage					
1441	AO	5.9	One-off	(+)	
1447	AO	4.4	One-off	(+)	
1482	AO	4	One-off	(-)	Frumentary crisis of 1481-1482
1501	AO	5.8	One-off	(-)	Plague in Brittany
1520	AO	4.4	One-off	(-)	Poor harvests
1549	AO	4.9	One-off	(-)	Suppression of the salt tax in the south west
Labourers real wage					
1425	TC	3.8	Temporary	(-)	
1441	AO	6.1	One-off	(+)	
1447	AO	5.6	One-off	(+)	
1482	AO	4.3	One-off	(-)	Frumentary crisis of 1481-1482
1494	TC	4	Temporary	(+)	Restoration of the privilege of the Lyon fairs
1501	AO	5.9	One-off	(-)	Plague in Brittany
1520	AO	4	One-off	(-)	Poor harvests
1549	AO	3.5	One-off	(-)	Suppression of the salt tax in the south west

In this second timeline, GDP/capita is temporarily affected by events such as pandemics or famines. It is the first time that we observe a significant impact of a pandemic on GDP. However, wages are not affected by the Black Death. This can be explained by the institutional regulation discussed earlier in this paper. Again, the events with the biggest impact on macroeconomic variables seem to be food shortages, and this is the case for both wages and prices here. However, in this timeline, the effect seems to be more temporary than previously. The only event to have a permanent effect is an institutional event (a tax reform), which underlines the power of institutions in that period.

Figure 10: Outliers detection 1551-1690

Year	Type	Value (units of standard deviation)	Duration of Effect	Sign	Event
GDP / capita					
1573	AO	5	One-off	(-)	Beginning of the fourth war of religion
1583	AO	5.6	One-off	(-)	Very cold winter
Wheat price					
Bricklayers nominal wage					
Craftsmen real wage					
1553	AO	3.8	One-off	(-)	Cold winter
1672	AO	5	One-off	(-)	Cold Winter in Brittany
Farmers real wage					
1553	AO	5.2	One-off	(-)	Cold winter
1672	AO	4.4	One-off	(-)	Cold Winter in Brittany
Labourers real wage					
1553	AO	4.1	One-off	(-)	Cold winter
1594	TC	3.8	Temporary	(+)	
1672	AO	5.2	One-off	(-)	Cold Winter in Brittany

In this third timeline, the climate appears to have caused temporary distortions in both GDP and wages, with food shortages due to agricultural issues. We observe that prices are not affected by these events and macroeconomic disasters mostly have temporary or one-off effects. The price stability is counterintuitive: in fact, we could have expected a climate-related food shortage to cause wheat prices to increase. However, we observe that wages are being driven down, and as a part of the production cost, they compensate for the rise of the wheat prices due to its rarefaction.

Figure 11: Outlier detection 1691-1789

Year	Type	Value (units of standard deviation)	Duration of Effect	Sign	Event
GDP / capita					
1701	LS	8.9	Permanent	(-)	
1783	LS	4.5	Permanent	(+)	Hot summer; freezing winter; epidemic of pneumonia in western France
1787	TC	11.6	Temporary	(+)	Beginning of the revolts
Wheat price					
1694	AO	3.9	One-off	(+)	Poor harvests ; famine
1709	TC	4.6	Temporary	(+)	Very cold winter
Bricklayers nominal wage					
1716	TC	3.1	Temporary	(-)	Implementation of the "proportional land tax"
Craftsmen real wage					
1709	AO	3.8	One-off	(-)	Very cold winter
1715	TC	5.7	Temporary	(+)	Cold winter
1720	AO	4.7	One-off	(-)	Black plague epidemic
Farmers real wage					
1696	TC	4	Temporary	(+)	Very mild spring; good harvests
1709	LS	4.7	Permanent	(-)	Very cold winter
1715	LS	6.9	Permanent	(+)	Cold winter
1720	AO	5.1	One-off	(-)	Black plague epidemic
Labourers real wage					
1709	AO	3.8	One-off	(-)	Very cold winter
1715	LS	6	Permanent	(+)	Cold winter
1720	AO	4.6	One-off	(-)	Black plague epidemic

In this fourth timeline, we observe different permanent effects on different variables. The 1783 event seems to be linked to an epidemic in the west of France and to have permanently affected GDP/capita. However, the black plague pandemic seems to have lowered wages temporarily without significantly affecting GDP/capita. The rest of the events are mostly food shortages and affect all the macroeconomic variables. Here, prices are pushed on the rise by food shortages and bad weather, and that is surely due to the fact that wages are not affected as negatively as before.

Figure 12: Outliers detection 1815-2018

Year	Type	Value (units of standard deviation)	Duration of Effect	Sign	Event
GDP / capita					
1921	AO	3.8	One-off	(-)	Spanish flu
1939	TC	4.2	Temporary	(+)	WW2
1946	LS	5.5	Permanent	(+)	WW2
2009	TC	4.6	Temporary	(-)	Crisis of 2008
Wheat price					
1793	AO	11.7	One-off	(+)	Very cold winter + the Reign of Terror
1795	LS	4	Permanent	(+)	Very cold winter + the Reign of Terror
1848	LS	4.3	Permanent	(-)	Grain crisis ; hunger revolts

In this fifth timeline, the Spanish flu has a significant impact on the GDP with wars and the mains financial crisis. However, we find that even the Spanish flu is a one-off event. During this period, wages do not appear to have been affected by macroeconomic disasters. Wheat prices remain affected by meteorological events; as observed previously, wages are fluctuating enough to absorb the increase.

7 Conclusion

The aim of this paper was to analyse the impact of pandemics on the economy. We have focused in particular on GDP/capita, wages and prices. In the literature, the impact of pandemics on GDP is generally negative (Barro, 2020) and the influence on wages appears positive (Jorda et al. 2020), whereas the impact of pandemics on prices remains unclear (Routt, 2008). The originality of our paper is that it relies on a very long time series from various sources. Indeed, our data cover the 1280-1945 period. To our knowledge, these data have never been used in historical economic analysis. Here, we have performed a cliometric analysis using the outlier methodology. We find that wages and prices seem to respond to climate or institutional events, such as a particularly cold winter or a new tax. However, while pandemics seem to have a temporary and limited impact on GDP, they appear not to exhibit a long-term impact

on the economic structure. Institutional, societal, and agricultural events are more pertinent to explain long-term permanent effects on all macroeconomic variables. Based on these findings, in further research, we hope to explore which type of macroeconomic events have a long-term impact on GDP and explain the apparition of cycles.

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