FACULTY OF POLITICAL SCIENCE

BACHELOR’S DEGREE IN POLITICS, PHILOSOPHY, AND ECONOMICS

FINAL THESIS IN MACROECONOMICS

2016-2017 Academic Year

ECONOMICS AND EPIDEMICS:

AN HISTORICAL ANALYSIS ON THE EFFECTS OF INFECTUOUS DISEASES ON ECONOMIC DEVELOPMENT OF FOUR MAJOR OUTBREAKS

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To my mother, my greatest inspiration for passion, tenacity, and dedication.
To my father, who has taught me to always be curious, humble, and to cherish every discussion.
To my sister, my teacher in generosity and methodology, companion in every adventure.
To Agnese and Cobi, who have shown me what unconditional love means, always.
To Benedetta, who's smile has lit up my worst days and has inspired me to be a better person.
To Dario, my best friend and academic companion, for the endless debates.

Thank you.

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INTRODUCTION: ECONOMICS AND HEALTH

Economics and epidemiology are descriptive sciences that might seem different, but are in fact very similar. In the following research, I will use the tools that both sciences provide in an historical context in order to explain the social and economic development of our world today. The relationship of health and economics go well beyond their common descriptive characteristics, and they can be used to describe one another. Much discussion in the literature is devoted on understanding how economic changes and the spread of an infectious of disease actually affect each other. Bhargava, Jamison, Lau, and Murray (2001), for example, modeled the real economic effects of health on economic growth and found that the adult survival rate did affect greatly economic growth, but mostly only in low-income countries–the outcomes were much less obvious in developed countries. It in fact remains largely debated in the literature whether epidemics are actually detrimental the economic development of countries. Some, like Pamuk (2007) and Clark (2003) look at the demographic effects that pandemics have on our society, and observe a long-run "revolution" of changes in the structure of the population, observing a general growth trend in decades after the breakout of an epidemic. Critiques of this approach, such as Deaton (2003) argue that these are just apparent effects, as inevitably those that will suffer the most from epidemics are the less wealthy, seemingly dropping poverty levels, but realistically having much more detrimental effects on the workforce and output of a country. Regardless, it is obvious that much more is at work in the relationship between economics and epidemics, and it is important to calculate the importance of epidemics when analyzing the mechanism between health and society's evolution. I have decided to focus much more on health crises, rather than health as a whole, for two main reasons. Firstly, health crises happen at definite points in history, and allow for a much more detailed evaluation and assessment of effect once closely observed. Second, health crises are usually gateways to improvements, so prove to be good defining moment not only in the medical field, but also at social and political scale–we will see this further in the work. Still, epidemics do not have a definite effect on economics, and is hard to draw a conclusive line on the whole topic; for this reason, my analysis will be on three main aspects that all change inevitably with time, development, and growth. I have identified three main social characteristics that favor the spread of an infectious disease[1]: changes in the population, changes in people's interconnectivity, and changes in the economy. With these three variables, I will first analyze their significance singularly, explaining then their relationship with epidemiology, and finally to observe their interactions applied to some specific cases, to try to prove their significance on the development of an infection in society and the advancement of our wellbeing. It is without doubt that epidemics are a social phenomenon as much as a natural one, and I would like to focus much of the attention of the work on this–rather than approaching the topic analytically, I tried to expose the research from a social perspective. Epidemics changed countries, reshaped societies, and inevitably boosted us to move forward. Unlike natural

[1] To define them as the main characteristics would be too simplistic, but their interaction is of sure importance

disasters, epidemics' damages are a lot subtler and require a longer development; for this reason, I mostly analyze periods that go between a 20 to 5 years' time span to try to assess the economic effects of a disease. This stylistic choice is because, as I will demonstrate, epidemics might seem to have almost positive effects on personal wealth during or immediately after their spread–a bias that I tried to control for with this time stalling. I should also denote that this is not a strictly economic valuation, as plenty of work has been done from far more qualified researchers than myself which would have made my work repetitive and unoriginal. Instead, I tried to merge different fields of social sciences to put in one body of work the essence of three macro areas of research, trying to come to some common conclusions[2]. Much of the focus on the significance of the relationship between economics and epidemiology is on public health costs, and it rightly should be. For this reason, I will also talk extensively about public health responses, expenses, and their contributions–often too underrated–to the improvement to our wellbeing. I will not focus on specific policies and various international bodies' responses, as I thought that would have diverted too much form the scope of this thesis and would have given a more political context to my work, risking sounding too critical. My criticism of any work or action described in the following research is never just my own, as I am in no position to condemn the academic work of anyone; instead, I take inspiration on critiques by researchers before me that I agree with and apply them into proper context.

One mechanism has proved to be of central importance in the research, and that is the increase in health parallel to the improvement in wealth–all the body of work that I have analyzed points to this fundamental relationship that wealth equals health. Of course, it is not so simple to determine what "health" is; at first glance, we might think of simply the possibility of falling ill, but on second glance we might take into consideration personal wellbeing, happiness, and satisfaction. These are realms too broadly defined and too hedonistic to be taken into consideration by my simple analysis, but I would like to briefly mention them in this introduction to not undermine their importance.

A famous research by Angus Deaton and Daniel Kahneman (2010) debates the fact that, while wealth inevitably makes it easier to be happier, there is no direct correlation between the two fields, and in fact the value of money "making us happier" is set at roughly $75,000.[3]Happiness is essential to our wellbeing, behavioral economists and doctors alike will agree upon this fact, but if money in fact does not "buy happiness" then why does it seem like wealthier people are definitely healthier? In this research, I will try to highlight the fact that less accessibility to proper care and hygiene, inevitably tied to wealth, tend to overweight the importance of happiness in our personal health equation, and how being less health inevitably makes us less happy–it is a vicious cycle. While it might seem at times grotesque, the context of my research is a positive one: like a phoenix form its ashes, our society has witnessed its rebirth from devastating

[2] Of course, these last are always derived by esteemed economists and health researchers, mine is more a derivation of their much more detailed works.

[3] Defined as an annual income, the research was based on a survey of 1000 Americans: https://www.theguardian.com/money/2016/jan/07/can-money-buy-happiness

pandemics, and my analysis hopes to highlight our endurance in addition to our failures, as well as our strength to move forward and learn from our mistakes. I hope that I have created something meaningful and not too redundant.

CHAPTER 1: DEMOGRAPHY AND HEALTH: COMING TO TERMS WITH A GROWING POPULATION

"The battle is over", cries Paul Ehrlich opening his book 'The Population Bomb', "In the 1970s, hundreds of millions of people are going to starve to death" (xi). Ehrlich of course was referring to the endlessly complex relationship between economics and demographics, a problem resurged in the 1970s' with the sprouts of food prices, and which daunts still today policy makers and mathematicians alike. Malthusian ideologies of world economic development in relation to population growth were the leading belief in the field at the time, and perhaps rightly so–population had grown exponentially since the Second World War, a rate that was unprecedented in the history of mankind. (Bloom et al. 2001) Still today three decades later Ehrlich's book, and almost three centuries since Malthus' theory of population growth, the picture seems similarly grotesque. With the sixth billionth baby born in 1999 (Bloom et al. 2001) and population in Asia and developing countries that still have not reached their population peaks, projections expect us to increase by roughly 2 billion people in less than 30 years.[4] While Malthusian growth logics have largely been dismissed today as erroneously pessimistic[5], some aspects of his peculiar observations might provide us with a useful starting point for an important analysis: specifically, the problem of space. When talking about the population of the world, Malthus saw a problem of resources allocation and physical space, famously saying "all the members [of society] of which should live in ease, happiness, and comparative leisure; and feel no anxiety about providing the means of subsistence for themselves and families." (Malthus 1798) At the then levels of production, with an unbound number of birth–much higher than the number of deaths–the space for producing enough food to feed all of those people seemed to be missing. The Malthusian Theory of growth of course could not take into account the extraordinary economic development of Latin America and Asia, which reached economic maturity late into the 80s, enabling them to enter in the food supply chain at industrial level. It also could not predict the demographic transition that Europe and much of the developed country would experience. However, while far off from the problems of means of production, it is hard to dismiss the problem of space that Malthus observed in the 18th century. A growing population means, unavoidably, less space. There are some implications that are often dismissed while talking about the relationship between demographics and our quality of life–the health ones.

What I would like to present in this chapter is the close relationship between demography and health which, directly connected to the economic cycle, poses some interesting points of departure for the whole purpose of this research.

[4] Estimates are taken from https://ourworldindata.org/future-world-population-growth/ considering the scenario of medium fertility projections.
The current world population, 7.5 billion, was taken from http://www.worldometers.info/world-population/ on May 11th 2017

[5] Much literature can be found about the wrong assumptions of Malthus. On the internet a quick search will yield many results, however I referred to this article I particularly liked: http://www.economist.com/node/11374623

Figure 1 shows the past and projected population growth, divided by regions, estimated by the United Nations.

World population by world regions, 1400 to 2100 – Max Roser[11]

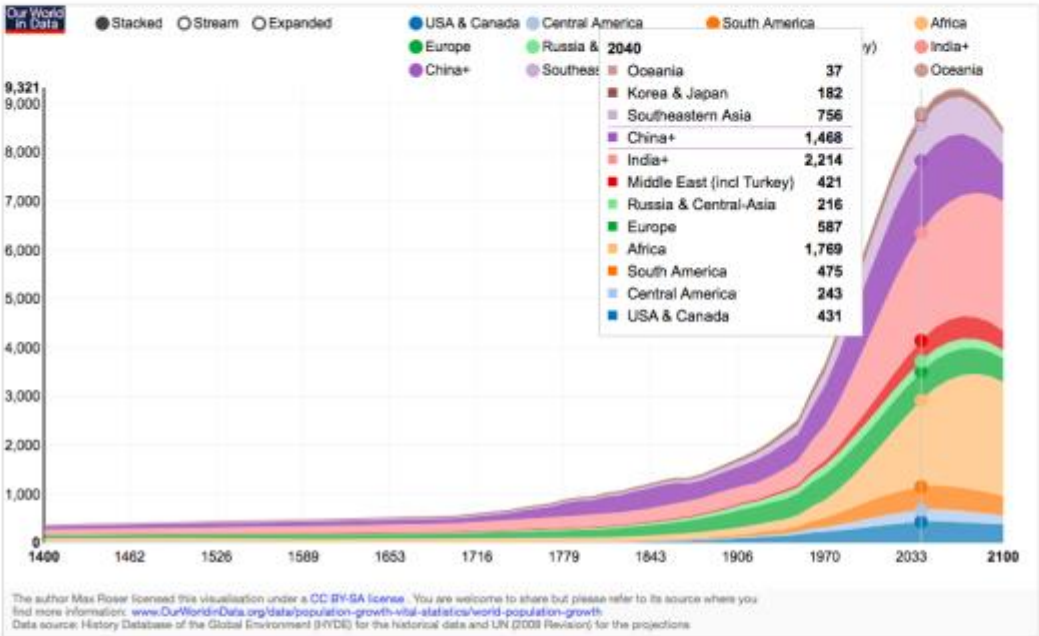


Figure 1- Expected population growth of the World by regions

source: ourworldindata.org

In 2040, the majority of the world will have still not reached peaked population. By peak population, it is intended the level in which birth rates and death rates both decline, and the population slowly starts to decrease[6], this is different from peak population growth, which refers to the rate of growth of population (this last has already been reached in the 1960s). This still has not happened, and we find two important consequences in regards; first, we still are not sure how we will be able to manage our space once this maximum population will be reached. Second, the population of the world is still, generally, considered to be younger than older. The problem of allocation of resources was largely misinterpreted by Malthus, and the "Green Revolution"[7] has allowed the world to mass-produce food with only a 1% increase of the cultivated lands. (Bloom et al. 2001) It turns out that technological innovation and a faster spread of education, along with a sharp reduction in poverty were much faster than anticipated, which has led today's economist to widely accept the "neutralist" ideology of the effect of demographics on economic growth[8]. Still, the relationship between demographics and economics cannot be dismissed, as the former remains one of the strongest determinants of the latter. However, while much attention has been devoted to the effects of population on economic growth, less is said about the contrary.

[6] My definition of demographic transition follows the one presented by John Bongaarts in his article for the NIH: "**Human population growth and the demographic transition**" https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781829/

[7] The "Green Revolution" is intended as a large increase in crop production in developing countries achieved by the use of artificial fertilizers, pesticides, and high-yield crop varieties.

[8] "Neutralist" widely believe that population growth neither hinders nor incentives economic growth.

The recent growth of population, which peaked in the 1960s with an increase rate of 2% yearly, is unprecedented in history: the population has grown more in the last 100 years than in the previous millennium[9], but population growth is no singular event. People's life expectancy, birth and death rates have always fluctuated, and these variations tend to happen under similar circumstances producing similar effects. I would like to discuss and analyze them below.

A growth in population is tied to a growth in economic prosperity. We can observe this now, where society is more prosperous than it has ever been[10], but equally throughout history. A cardinal example is the Post-Second World War baby boom, initiating the biggest population growth ever recorded in history[11] but, prior to that, the High Middle-Ages' growth in Europe between 1000 and 1300, brought about by high yields in crops and an increase in general prosperity.[12] Demographic transitions are not immediate, as it takes time for people to grow accustomed to lower mortality rates and start having less children.[13] Here happens the population growth. This is usually triggered by innovation, technological advancement, and improvement, key factors for economic growth. For example, the population growth in East Asia is often closely related to the "Asian economic miracle" during which their "demographic transition occurred with relative rapidity, over a 50- to 75-year period. the fastest demographic transition to date." (Bloom et al. 2001) Demographic transitions are an index of development, and an important part in that. When East Asian cities such as Shanghai and Beijing grew their population into the billions, per capita income rose annually at a rate of 6% for almost 30 years. (Bloom et al. 2001) While, as previously stated, economist now largely believe that population growths have a neutral effect on economic growth, the opposite is not true, as economic growth deeply affect population structures, enabling them to change.

This in turn leads to an expansion of cities. This is an often overlooked phenomenon, but the way cities grow is important to analyze in order to comprehend the effects of demographic transition on health. When the population of the High Middle Ages suddenly started to expand, cities found themselves with much more densely populated urban areas, increased waste production, and increased social contacts. It is generally well-known that cities in the Middle Ages lacked sanitation, and the sudden densely-packed medieval cities served as an extremely efficient transmission network for the Plague of 1347, which is what made it so deadly (Deaton 2004). The management of an expanding city population is no easy task. Two effects are inherent to this: urbanization and gentrification. Urbanization refers to the expansion of the inner-city to its outskirts, with

[9] According to Max Roser, "population increased more than 400% over the 20th Century".
[10] "In 1820, 94% of humanity subsisted on less than $2 a day in modern money. That fell to 37% in 1990 and less than 10% in 2015." http://www.economist.com/news/books-and-arts/21706231-human-life-has-improved-many-ways-both-recently-according-swedish-economic
[11] "The second period, beginning with the onset of modernity (with rising standards of living and improving health) and lasting until 1962, had an increasing rate of growth."
https://ourworldindata.org/world-population-growth/
[12] Historians believe that there was a warming of the climate that lead to much less harsh climatic conditions, allowing for good cultivations and an easier life.
[13] As reference, this graph shows a detailed explanation of when peak demographic growth happens
http://www.bbc.co.uk/schools/gcsebitesize/geography/population/population_change_structure_rev4.shtml

a structured expansion of the livable area. At the beginning of the 1950s, for example, East Asia counted 75 million people living in urban areas, roughly 29% of its population. By 1995, this figure had skyrocketed to 2.53 billion people, amounting to 38% of the total population of East Asia. (Kim & Choi 1997) Figure 2 shows how just two people infected affected more than 200 other cases in Singapore with Severe Acute Respiratory Syndrome.[14] This was because of the new extremely populous cities in Eastern Asia, which allowed the disease to spread through cities at an alarming rate.

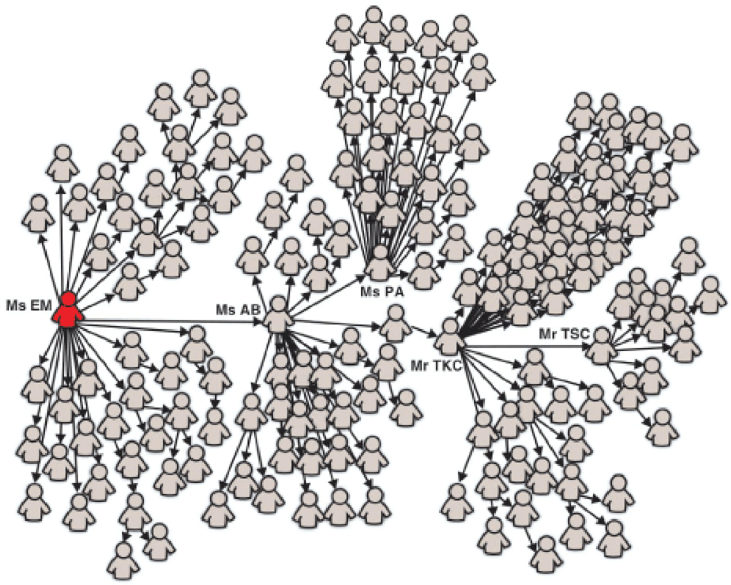


Figure 2- SARS spread through super-spreaders

Source: who.org

Gentrification, a later effect, represents the moving out of the poorer part of society as neighborhoods and areas of the city become increasingly more requested and therefore more expensive. As not all of the economic expansion happens homogenously, the quick urbanization of cities has historically brought a vicious cycle, "Rapid expansion of urban areas and rapid conversion of agricultural land to non-agricultural and industrial uses have often brought about serious problems for providing adequate infrastructure and social support services." (Kim & Choi 1997) As urban city centers become more crowded, some citizens are forced to move out to the periphery, where proper public care and structures cannot keep up with the rapid expansion of a city, and therefore are missing initially. We have then the poorer and less healthy part of society (therefore the one more in need) migrating to an area with less provisions, and therefore more prone to diseases. Urban expansions thus far have created a deep social divide, one that see a younger, more prosperous generation living in modern and well-kept urban centers, pushing out a more susceptible part of society, which has to adapt to lower living standards, live off lower wages, and often relocate to areas poorly serviced. These last, too tend to have an impact on an another strata of the social structure, namely the agricultural community. Cities expand and take away agricultural land, forcing the relocation of agricultural

[14] http://harvardmagazine.com/2007/03/the-sars-scare.html

workers farther from the city, or in more extreme cases ending their activities. Urbanization has socio-economic, cultural, and environmental effects, all which go to affect people's health.

Some people are worse off. Inequalities are inherent and impossible to avoid in any social structure, and as cities grow the effect of gentrification creates the first major divides in the cities. These are cultural as much as physical differences, which split the population in very distinct groups which will benefit from public goods differently, "Poor health is more than just a consequence of low income; it is also one of its fundamental causes" (Bloom 2000). First of all, it is important to properly define gentrification as a process that is essentially and most importantly profit-driven. Secondly, it must be seen as an historical progression, which has happened during the expansion of cities during the High Middle Ages and beginning of the Renaissance as much as during the 50s Industrialization.[15] Lastly, gentrification is on the one hand a revival of cities, often cited as the driving force of renovation and a sign of economic prosperity. On the other, it is also the driving force of inequalities in cities, making them more unequal than ever.[16]

As some incomes and population increase, property value, because of an obvious higher demand for housing, equally starts to accelerate. Cities modernize and innovate starting from the core, therefore making the central areas usually the more sought after in the process of urbanization. However, the growth in income is usually concentrated in some areas of the economy, so not all citizens will benefit from it in the same way. Figure 3 shows the differences in prices for housing in regards to their distance from the central business district (CBD) in the United States' top cities.[17] The intra-generational aspect of the graph shows us clearly how the process of gentrification is led by innovation, as prices close to the city center become more expensive with passing time. Between 1980 and 2010, we see a rise of almost 40% in prices. This is worrisome, because the average citizen with a house in 1980 and most likely still alive in 2010 will have had experienced a rough transition.

[15] "We define gentrification as a profit-driven racial and class reconfiguration of urban centers, targeting working-class communities that have suffered from a history of disinvestment and abandonment."
http://www.acphd.org/media/341554/development-without-displacement.pdf

[16] https://www.citylab.com/equity/2016/09/downsides-of-the-back-to-the-city-movement/501476/

[17] https://www.citylab.com/transportation/2015/11/why-the-wealthy-have-been-returning-to-the-city-center/416397/

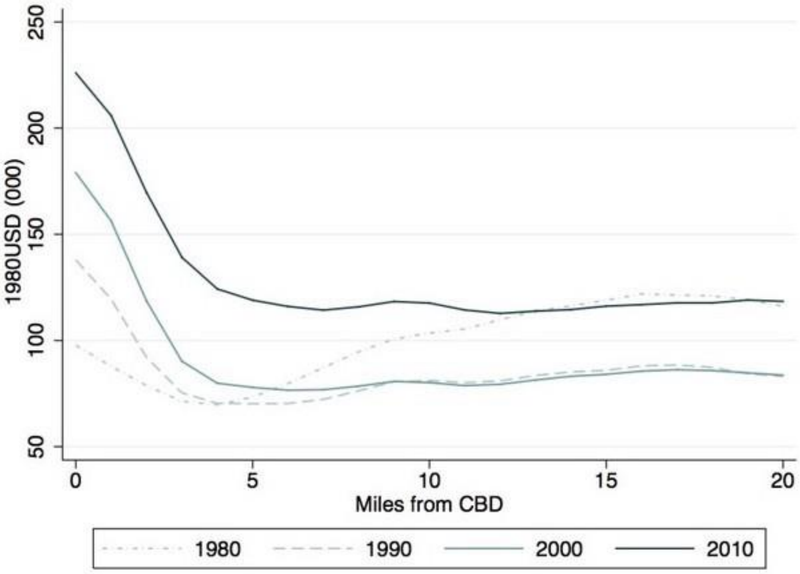


Figure 3- difference in housing prices in respect to their distance from the city center in the US

Source: citylab.com

Usually, the first to face the pressure of gentrification are the working-class communities, which tend to live in areas where commercial and residential land is cheap. There is a clear loser in the process of gentrification, which will inevitably see their income decrease and living situation worsen, and the health implications are many. First of all, the working-class is more prone to falling ill due to the nature of their occupation, "It is now well recognized that people in lower socioeconomic status (SES) groups on average are less healthy than people in higher socioeconomic groups." (Stronks et al. 1997) Second, as mentioned before, quality of life in the periphery cannot keep up with the expansion of the city, and it will take some years to service the suburban area. In the Middle Age, the move to the margins of the city meant living closer to the livestock, vessels of deadly diseases. The Black Plague, which wiped out 25% of the World population of 1347, was first transmitted through rats' ticks, and the spread of the disease initially affected the poor population that lived outside of the city (in fact, cities like Florence and Siena's immediate response was a closure of all gates to the center)[18]. The efficacy of the Plague, apart from its very easy transmission, was that it affected an already weak part of society. In desperate search for better health, citizens rushed to the city, infecting much more densely populated areas, where the transmission of the disease proved to be terribly effective. Poor hygiene and lack in medical experience where the icing on the cake, reason while the Black Plague was so devastating even if so short lived–a mere two years in small waves to wipe out a quarter of the population (Bell & Lewis 2005). A more recent case is in Eastern Asia. The expansion of Asian cities that lasted throughout the 90s forced citizens to start living in areas previously used for agriculture, and the effects of that were later felt. Even if its morbidity was low, in 2003 Severe Acute Respiratory Syndrome (SARS) was one of the most detrimental diseases to the economy of Eastern Asia in the last century. A mixture of poor public health measures and responses costed Eastern Asian countries like Japan and China a decline in tourism that

[18] Angus Deaton has proved several examples of the first public health measures in history to prevent spreads of epidemics, I refer to his paper "Health in an age of globalization" published in 2004 for this particular detail

peaked at 70% (Bell & Lewis 2005). SARS was a relatively easy disease to contain and cure, however it affected a part of the population that had almost no access public health, so localization of cases proved to be extremely hard. Moreover, while China did its best to hide the outbreak, reports of the disease were hard to pinpoint since most of them initially happened far from hospitals. SARS proved exceptionally effective because of the crowded cities of Eastern Asia. Figure 4 shows the population of Eastern Asia in detail.[19]

Population of Eastern Asia (2017 and historical)

Year	Population	Yearly % Change	Yearly Change	Migrants (net)	Median Age	Fertility Rate	Density (P/Km²)	Urban Pop %	Urban Population	Eastern Asia's Share of World Pop	World Population
2017	**1,624,853,705**	0.38 %	6,075,980	-178,000	38.2	1.56	141	63.1 %	1,024,474,501	21.62 %	7,515,284,153
2016	**1,618,777,725**	0.4 %	6,490,784	-178,000	38.2	1.56	140	62 %	1,003,837,174	21.78 %	7,432,663,275
2015	**1,612,286,941**	0.46 %	7,393,319	-196,000	38	1.55	140	60.9 %	982,409,704	23.27 %	7,349,472,099
2010	**1,575,320,344**	0.5 %	7,756,131	-243,700	36	1.52	136	55 %	865,825,690	24.16 %	6,929,725,043
2005	**1,536,539,691**	0.53 %	8,051,133	-241,800	33	1.48	133	48.7 %	747,566,473	25.08 %	6,519,635,850
2000	**1,496,284,026**	0.65 %	9,509,212	-88,700	31	1.48	129	42.3 %	632,395,736	26.09 %	6,126,622,121
1995	**1,448,737,966**	1.14 %	16,029,206	-219,100	28	1.96	125	38 %	550,368,244	27.28 %	5,735,123,084
1990	**1,368,591,934**	1.69 %	21,968,485	-69,900	26	2.62	118	34.1 %	467,014,408	28.2 %	5,309,667,699
1985	**1,258,749,508**	1.41 %	17,075,486	65,000	24	2.45	109	31 %	389,655,304	28.35 %	4,852,540,569
1980	**1,173,372,076**	1.49 %	16,767,162	2,900	23	2.86	102	27.6 %	324,399,865	28.89 %	4,439,632,465
1975	**1,089,536,264**	2.18 %	22,284,671	-214,300	21	4.43	94	25.7 %	280,117,034	29.59 %	4,061,399,228
1970	**978,112,907**	2.55 %	23,134,008	160,900	20	5.56	85	25.2 %	246,155,292	29.44 %	3,682,487,691
1965	**862,442,868**	1.82 %	14,859,539	-105,900	22	5.6	63	17.2 %	148,294,275	28.57 %	3,322,495,121
1960	**788,145,172**	1.53 %	11,509,243	21,500	22	5.04	68	23 %	181,384,167	28.57 %	3,018,343,828
1955	**730,598,959**	1.85 %	12,802,634	-105,900	22	5.6	63	20.3 %	148,294,275	28.93 %	2,758,314,525

Source: **Worldometers** (www.Worldometers.info)

Figure 4- Population of Eastern Asia

Source: worldmeters.info

As we can see, population growth and density have grown steadily since the mid 50s, and between 2000 and 2005 we see the first significant increase in people living in urban areas, as well as a higher population density than ever before. This contributed immensely to the spread of the disease, which wreaked havoc once cases started to be reported in the inner city. SARS was hard to grasp, because estimates of survival rate fluctuated immensely and doctors were unable to receive cases in time, this is because of a number of reasons. Firstly, the disease initially affected manual labor workers and farmers[20], where a blend of cultural and economic factors restrained them from going to the doctor. Second, the less wealthy lived in no proximity of hospitals, and since the development of the infection was rather quick, a majority happened out of reach. Third, the high fluctuation between the morality rates was largely due to the fact that those affected, poorly serviced and out of reach of hospitals, varied from workers to the elderly. The high fluctuation of the mortality of the disease was much more a reflection of the inequalities in the Asian cities at the time than anything else. Finally, the Asian government was very well aware of the detrimental economic effects that a public health crises could bring to the country[21], and being cases so scattered in the outskirts of the major living hubs, it denied the

[19] Data is taken from http://www.worldometers.info/world-population/eastern-asia-population/ which elaborates on the United Nations population forecast.

[20] The disease was initially transmitted through animal workers, and strains of a similar animal disease were used to later find a vaccine for the virus.

[21] "The Chinese government sacked its health minister and another senior official yesterday in an attempt to establish credibility for its handling of the Sars health crisis as the death toll continued to mount." https://www.theguardian.com/society/2003/apr/21/china.sars

existence and the mortality of the disease at the beginning of the outbreak.

Populations age. David E. Bloom is a prolific demographer that has contributed a lot to the literature with his work on the importance of population structure in society for economic growth. Population structure refers not to the number of people, but instead on how those people are, taking in consideration variety of factors, including health, age, and employment. Population structure is essential to demographic analysis, and has some critical implications to the health of citizens at any particular time. Bloom, in his work, argues how it is wrong to give small importance to the structure of the population in regard to population expansion. Indeed, it is important to take into consideration, as countries like China, which have benefitted greatly thanks to their boom in population, will soon have to start facing the realities of declining fertility rates and of a rapidly aging society.[22] Bloom, in a 2003 publication on the importance of age structure in the demographic transition, more specifically analyzes the demographic "dividend"[23] in growing societies represented by three distinct mechanisms. The first is labor supply; countries greatly benefit from population growth with an increase in productivity and a growing working force, increasing per capita production force as the 29 to 59 age cohorts increase in the mid period of population growth[24]. The second is savings, as the "demographic transition also encourages the growth of savings, thus improving a country's prospects for investment and growth…The young and the old consume more than they generate, unlike working-age people, who tend to have a higher level of economic outputs, and also a higher level of savings." (2003) When the baby boomer generations reach around the age of 40, investment will tend to rise. Finally, human capital changes refer to improvements in education, drops in mortality rates and improved well-being, which makes the labor force more productive, skilled, and richer. The demographic dividend, while initially convenient, of course proves to be hard ground to adapt on as populations age. Government policies must shift greatly as they come off the wave of economic prosperity brought from demographic growth, and change to accommodate lower production levels, less investments, and more demanding citizens[25]. Adapting to these changes is no easy task, and here stands the biggest problem with population structure. As time passes, dependency ratios (the ratio between the non-working part and the productive part of society) increase and labor markets lose workers. These effects can be diverted if fertility rates are at replacement level (2.1), meaning that there will be a next generation benefitting from the improvements of the previous one. Otherwise, adapting to new demands might prove to be hard from the policy point of view, and the long-term effects of an aging population might be hard to counter.[26] Historically, populations were plagued by short and miserable lives, and the demographics of the pre-modern

[22] The Chinese government is very well aware of that, and in fact has recently taken away its infamous "once child policy" established under Mao's dictatorship https://www.nytimes.com/2015/10/30/world/asia/china-end-one-child-policy.html?_r=0

[23] Demographic dividend occurs when the proportion of working people in the total population is high because this indicates that more people have the potential to be productive and contribute to growth of the economy.

[24] These are considered to be the most productive years of a worker's life.

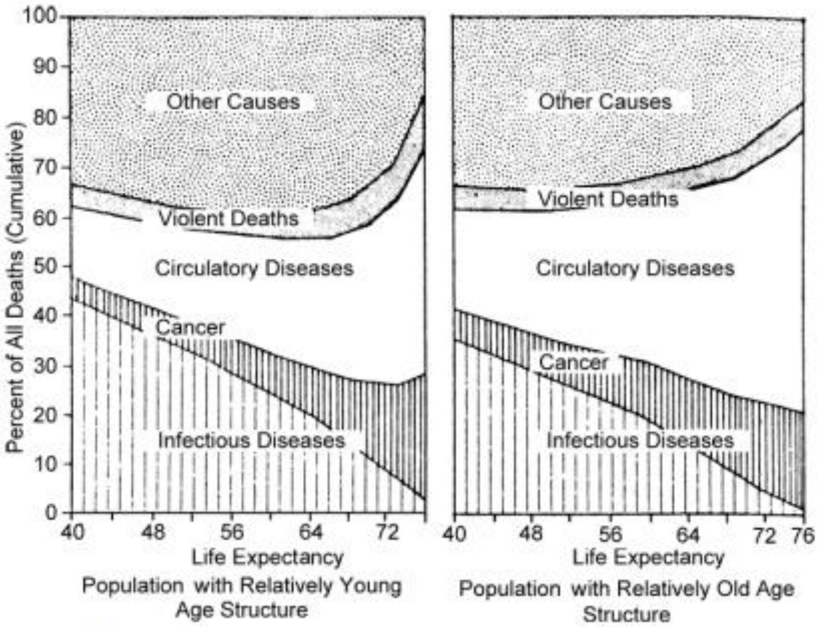
[25] Robert J. Barro has done extensive econometric research on the relationship between health and wealth in his paper "Health and Economic Growth" published in 2013 in the Annals of Economics and Finance. However, the scope of his research is far more detailed and complicated to be discussed further in this thesis.

[26] Japan, Italy, and China have been trying to boost their fertility rates in the past year with results that, for now, won't allow them to succeed.

era were characterized by extremely high fertility and death rates. These can be explained through the frequency of wars that decimated populations, lack of hygiene which exposed people to a higher number of diseases, and the frequent outbreak of epidemics (Orman 1971). Figure 1 already showed us that population growth, for that matter, was always relatively slow. The turn of the 20th century growth is characterized by a cut in mortality rates, which made people live for longer. This is of course, because of a number of reasons, but for the purpose of this analysis I take into consideration the importance of an increase in hygiene and improvements of medicine which helped the first "Global" demographic transition. This were the improvements and challenges of the 20th century, and as our society escaped the death trap of pre-modern society, we are now faced with a new demographic challenge (Orman 1971). As people age, they become more susceptible to diseases, their productivity falls, and they require more health care. A big part to public health planning goes to dealing with the elder part of the population, which still today proves to be a complicated task. In the process of population growth, countries all over Eastern Asia such as Japan, which have seen explosions of their population over the past 50 years, are starting now to feel the repercussions of an ageing society. (Bloom et al. 2001) Populations ageing are a complex matter: on the one hand, aging is a healthy symptom of the economy, as it represents the fact that people live well enough to age for longer. It signifies advancements in technology and science, (usually) a good public health system that takes care of people, and an absence of diseases. (Bloom et al. 2001) However, on the other hand, an older population has some detrimental effects on the productivity of a country. Countries like Japan and Italy fashion some of the oldest people in the world, but as well as some of the lowest fertility rates. Italy in fact has the lowest fertility rate of all countries in the European Union[27], which implies that it does not have a future generation to take over. Japan is the oldest country in the world, with children born today that are expected to live up to 81 (Bloom et al. 2001). They also have an incredible problem with fertility, as the government is unable to incentivize the younger generation to have children.[28] Older nations must increase their spending for older people, and public health budgets have historically had a tough time in deciding where to allocate the majority of their resources: is it more right to invest on the future or to take care of people in the time that they are most in need? In the reality of scarce means, proper allocation is the single most important job in public policy; the relationship between health and wealth has been extensively studied in the field of economics, where the agreement is that indeed, wealth equals health. We have discussed already the effects that wealth has on health through the process of gentrification. I would now like to turn to the opposite effect, namely how poor health affects the economy of a country, to try to assimilate the consequences that an older society might have

[27] Italy's fertility rate is currently at 1.34 children per women, the EU 28 average in 2015 was 1.58. While the Eurostat has still not released its most recent census, numbers were roughly the same in 2016 for Italy, and there were little to no variations to the demographics of Europe as a whole.
http://ec.europa.eu/eurostat/statistics-explained/images/2/2f/Fertility_indicators%2C_2015_YB17.png
[28] The cultural problem of Japan and the lack of "initiative" to expand families is a complex one, a lot can be found about it, for reference I used https://genderdebate.com/2017/01/06/lessons-from-europe-what-japan-can-learn-from-european-family-policies/

on an economy. Growing old is a sign of prosperity and health, however an older society will inevitably be less healthy and will, in the long run, have negative effects on the economy of a country. Unfortunately, high fertility rates are seen as signs of poor development for policy makers, and much work is devoted, in developing country, at cutting those fertility rates through birth control programs, not taking into account, however, taht to reverse the effects is often much harder. (Orman 1971) “An epidemiologic transition has paralleled the demographic and technologic transitions in the now developed countries of the world and is still underway in less-developed societies” writes demographer and epidemiologist Abdel R. Orman, stating that “ample evidence may be cited to document this transition in which degenerative and man-made diseases displace pandemics of infection as the primary causes of morbidity and mortality” (1971) As the structure of the population changes, what affects mortality rates also does. Figure 5 shows the differences in causes of deaths as life expectancy increases.[29]



Source: Department of Economic and Social Affairs. 1962. *Population Bulletin of the United Nations* 6, 110–12.

Figure 5- Major cause of death with different population structure

Source: Abel R. Orman 1971 “The Epidemic Transition: A Theory of Epidemiology of Population Change”

Cardiovascular diseases increasingly gain importance with an older age structure, however it is also clear that infectious diseases and other causes do not necessarily lose any grounds. We have a more susceptible population. Impossible to stop, ageing is an “epidemic” within itself, as it brings along a variety of new factors that are much harder to contain and deal with than classical epidemic breakouts. Cancer, cardiovascular diseases, but also simple flus which young immune systems have little problem resisting become a tougher challenge faced by public health officials (Orman 1971). To see the economic effects of

[29] This graph was taken from a data pulling from the Population Bulleting of the United Nations. The Data was analyzed and explained by Abel R. Orman in his paper “The Epidemic Transition: A Theory of the Epidemiology of Population Change” published in 1971.

changing demographic structures, we can look at a relatively recent extraordinary empirical example, the Spanish Influenza, as “this episode appears to provide a unique opportunity to analyze the effects of a large exogenous shock to population and labor force size on economic growth” (Brainerd and Siegler 2002). In 1918 the world was coming out of its first, great, modern war. World War I had devastating effects on populations, and throughout the whole world we see the first modern rapid decline in life expectancy happening between 1914 and 1918[30]. 9 million soldiers and over 7 million civilians died as a result of the war, mostly being young adults[31]. The fertility rates of Europe after the War[32] are shown in figure 6, where it is clear that the demographic consequences were devastating.

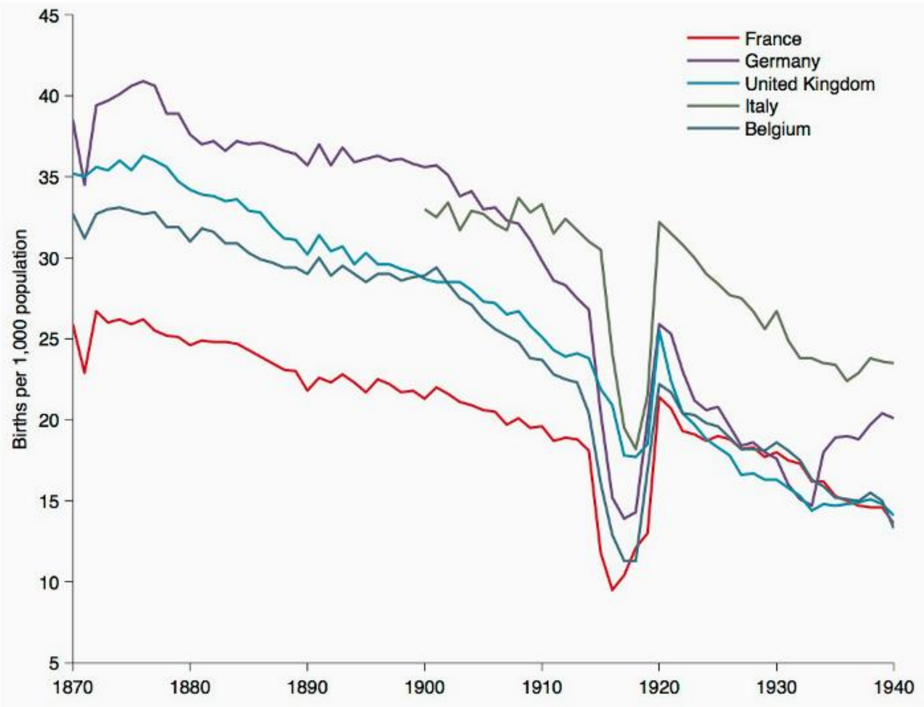


Figure 6- Birth rates of 5 major actors in WWI

Source: voxeu.org

On top of this, a modern devastating disease swept through Europe, North America, and the rest of the world. While Influenza is usually particularly deadly in the older and younger cohorts, the “Spanish” flu was peculiar for killing a lot of people in the 15 to 44 age group.[33] Brainerd and Siegler in their research on the economic effects of the influenza conclude the following:

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[30] After this, only the AIDS/HIV epidemic of the late 80s had similar effects on the population of the World.
[31] The data on total death tools of the First World War is taken from Wikipedia and http://voxeu.org/article/demographic-consequence-first-world-war
[32] North American birth rates are very similar, so it seemed unnecessary to include a graph of America as well. Moreover, the effects of the Influenza were much more devastating in Europe than in the US.
[33] This is why the Spanish Flu was so studied, and its morbidity so devastating. Elisabeth Brainerd and Mark V. Siegler research on “the Economic Effects of the Spanish Flu” published in 2002, along with C.W. Potter’s “History of Influenza” published in 2001 were my main sources for the data on the 1918 flu.

> The influenza epidemic was likely a contributing factor to the immediate post-WWI recessions. U.S. states with higher influenza mortality also had higher business failures between 1919 and 1921 and were shocked further from trend as a result. At least some of the faster growth between 1919-1921 and 1930 in states with higher influenza mortality likely reflects not a change in trend, but a return to trend after this negative shock. Nevertheless, this epidemic was a large shock that had substantial macroeconomic effects.

With a scarcity of the younger population, taken away from the flu and the war, the United States and Europe found themselves with a staggering economic situation. While fertility rates, for the most part, grew again shortly after, the economic effects were long-felt. Killing an estimated 40 to 50 million people, Potter suggests that 50% of the world population was infected (2001) making it the first modern-day pandemic to affect the whole world.

CONCLUSIONS: DEMOGRAPHICS AND ECONOMICS TWO SIDES OF THE SAME COIN

With this first chapter I tried to lay the fundamentals mechanics and logistics to a critical factor in epidemics and health, demographic changes. From the analysis given, a clear cycle emerges. The initial effects of demographic transitions are tied to an economic growth. Here we see two parallel effects happening, a growth in prosperity and a growth in population. These have different repercussion on the environment and on the structure of a society. First, the expansion of cities leads and an increase in population density; the process of urbanization of city centers follows the growth in population to try to accommodate rapid expansions. Inherent to urbanization is then the process of gentrification, a social phenomenon that creates inequalities within different socioeconomic classes. The rise in wages are not homogenous in the expansion of an economy, and therefore some people are forced to move to areas of cities that are less expensive in order to live. “Wealth equals Health” is an important concept to grasp, as it explains that, those less wealthy and therefore less healthy are forced to live in areas less serviced, unable to use public goods the same way. This part of society will now be exposed to a new range of diseases, becoming then perfect spreaders for them. The vicious cycle of increased density, which leads to a push-out of the population is then fertile ground for the spread of epidemics within a society, and I have shown how this process has made some diseases extremely efficient at spreading through densely-packed cities. In the Epidemic Transition described by Omran, this is the first stage, or “The Age of Pestilence and Famine”, more prominent in the post-modern growth of population, but still relevant to our times.[34] The subsequent development in the demography is that of population structure, which tends to be a feature of modernized societies. Advancements in public health, hygiene, and wellbeing allow people to grow older, morphing the dynamics of public policy and, of course, of the economy. The older people get, the more they consume and invest. Workers spend on education,

[34] Omran in his paper also attributes a low life expectancy at around 20 and 40 years for this stage of the Epidemic Transition. These are details that refer particularly to pre-20th century society, however these remain true during the breakout of modern devastating epidemics like the Spanish Influenza and AIDS/HIV.

specialize and increase their salaries. We have discussed extensively that as societies start to "grow old", fertility rates decline and populations stabilize. The oxymoron in this phenomenon is how government first try their best to achieve this, then find themselves having a hard time reversing the process. This is because an older population is less healthy, more exposed to diseases, and less productive, this is the transition to the third stage of Omran's Epidemic Transition, "The Age of Degenerative and Man-Made Diseases". The detrimental economic effects of an ageing population are felt later, and are tough to reverse. The wipe-out of younger generations following the War and the Spanish flu has showed us how the magnitude of the impact at macroeconomic level was felt later with a decrease in investments and a recessing economy shortly after WWI (Brainerd & Siegler 2001). As we can see, a number of different gears move independently in the always changing demographic machine, and in this analysis I did not even take into consideration a myriad of other factors such as changes in the environment and social changes that also affect greatly demographics.[35]With this chapter we lay the groundworks for the functioning of epidemics, and perhaps the most important variable in understanding them. It was briefly introduced how, through just two super-spreaders, SARS in Singapore was able to contaminate over 200 people.[36] This brief introduction will lead us to a much more important analysis, namely the importance of social networks in the spread of a disease. Special care must be devoted to this topic, as most of the public health response and prevention of epidemics is based on the analysis on social interactions. Keeping in mind the dynamics of demographic transitions and social growth, the next chapter is devoted to the importance and expansion of social networks throughout history, which will explain to us in more detail the devastating effects of the aforementioned pandemics.

[35] It well established in the demographic field that social movements, advancements in women's rights and changes in public acceptance of abortion, birth control, and non-marital sex have all greatly affected demographic transitions and changes. These analysis were, however, far from the scope of this chapter. For an expansion on these topics Angus Deaton's "The Great Escape: Health, Wealth, and the Origins of Inequality" published in 2013, as well as Abdel R. Orman's "The Epidemiologic Transition: A Theory of the Epidemiology of Population Change" published in 2005 offer some extremely detailed and interesting explanations.
[36] See Figure 2 for reference.

CHAPTER 2:
THE IMPORTANCE OF NETWORKS IN HEALTH

In May 5th 2000, the world experienced its first internet epidemic. Through the worm ILOVEYOU, computer scientists Michael Buen managed to infect millions of computers at an incredibly fast speed through a simple email. The virus, presented in the form of an electronic message with as subject "ILOVEYOU" and an attachment named "LOVE-LETTER-FOR-YOU.txt" actually contained an invisible malware that copied and auto-sent itself to all recent email contacts once opened[37]. Its propagation was extremely quick and efficient, and spread in matter of hours to the whole world. It is estimated that it made a whopping $5 to $9 billion dollars in damages worldwide, infecting more than 50 million computers in less than ten days–roughly 10% of all computers at the time were affected. More recently, on May 12th 2017, a malicious ransomware–a virus that encrypts all personal data of a computer and asks for a monetary ransom to decrypt them–hit the World Wide Web (WWW) infecting almost 100 countries in matter of seconds[38]. This last was especially malicious, as it targeted major hospitals and used them as springboards to spread through the net. Again through email, the effects were devastating to say the least: hospitals were locked out of patient's files and virtually blocked off form performing their job. Figure 7 shows a map of the affected areas at the peak of the spread of the virus[39]. What differed from the "ILOVEYOU" virus was that it did not start its spread through a single entity, but attacked simultaneously hundreds of different sites, making it extremely efficient in its spread.

However, it was fairly shortly lived: the "kill switch" was found to be a simple internet domain through which the malware (name used for programs that are detrimental to computers) rebooted itself in[40]. By removing it from the internet, the pandemic quickly died out, containing the costs and damages that could have been disastrous.

[37] Many articles can be found on the ILOVEYOU virus of 2000, I trusted this article as a reliable source for information and detailed figures http://news.bbc.co.uk/2/mobile/technology/8570993.stm as well as wikipedia for further clarifications and a timeline of web viruses.

[38] "Hackers Hit Dozens of Countries Exploiting Stolen N.S.A. Tool" https://www.nytimes.com/2017/05/12/world/europe/uk-national-health-service-cyberattack.html

[39] The following is an animated map created by the NYT accessed on 2017-05-31.< https://www.nytimes.com/interactive/2017/05/12/world/europe/wannacry-ransomware-map.html?_r=0

[40] The move was actually "accidental", as the author of the act did not know that the buying of the domain would have caused the virus to come to an halt. https://www.theguardian.com/technology/2017/may/13/accidental-hero-finds-kill-switch-to-stop-spread-of-ransomware-cyber-attack

Figure 7- Peak spread of the May 12th 2017 ransomware at 4:21 pm

Source: nytimes.com

The way we deal with web viruses has extremely strong implications on pandemics management, and the analogy introduced shares some important features of healthcare crises. Most importantly, digital viruses are a perfect example of how important networks are in the spread of a pathogen, and in the age of globalization, the similitudes are many. In the coming chapter, I will try to unravel a key determinant in public health and epidemics–the nature of social networks. The science of networks is an extremely complicated one, ranging in the domains of sociology to physics, and a detailed analysis on their functionality and understanding would be far too complicated for the purpose of this research; however, it is of vital importance to understand their mediating role. The internet is often used in the literature as a mode of comparison and a field of study in public health as global pandemics on the web are all aggregated in the last 30 years, and prove to be good observatories. They also serve as good examples of responses, as the similar nature of web and biological viruses' mode of spread and impact make the study on internet network relevant to social ones. The analysis that follows will focus mainly on the importance of networks in health, with a special attention over the history of the growth of networks. I will give a brief introduction on the functioning of networks, focusing on their structure rather than the math behind them, and I will try to apply them to an investigation of their role in health, but as well in public responses. A whole field of epidemiology is now dedicated to the understanding of the structure of networks, and they have proved to be much more complicated than digital counterparts: it is much easier to retrace the steps of a malware traveling through the internet, than of an infected individual. Nonetheless, network science has proven to be so useful because it provides general guidelines on the analysis of any type of network, allowing a mathematical analysis to a very abstract concept–our relations. The travelling of information through the web is much faster than a travelling individual, although an infected patient will contaminate many more other people in their journey from point A to point B than a virtual virus. This is why it is so painstakingly hard to analyze social networks, and why a lot of devotion is put in quarantining the "patient zero" at the breakout of epidemics.

WHAT ARE NETWORKS?

Networks are a graphical way to represent connections between different actors. From a strictly analytical point of view, when we talk about networks we are talking about "a set of vertices [or nodes] connected via edges" (Dorogovtsev & Mendes 2003). This definition includes the two most basic parts of any networks, vertices and edges. Simply, vertices represent what is connected (people, cities, computers, or animals), and edges represent their connections.[41] The number of connections, or edges, to a given node represent its degree, and edges may undirected or directed, which represent the direction that a connection has. Intuitively, we have two types of network graphs: directed and undirected. The difference stands solely in the feature that that directed networks have on edges, in which information can flow in the direction given to the edge. These represent a cohort of diseases that, perhaps, cannot infect a person once it has already been infected, therefore the pathogen can only travel one way and not back.

Figure 8 shows a simple example of both a directed and an undirected network.

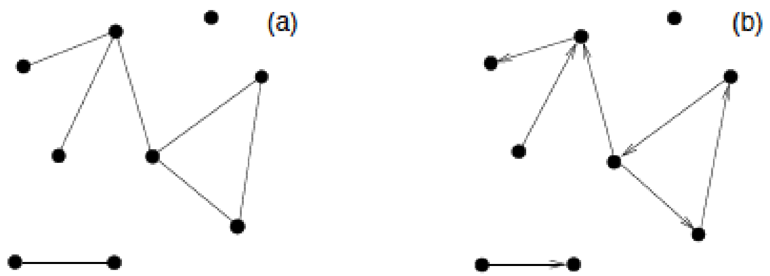


Figure 8- (a) undirected network, (b) directed network

Source: Dorogovtsev & Mendes 2003

For simplicity's sake, this basic definition will suffice in order to understand the importance of networks in epidemics, however networks are usually much, much bigger than these represented, and I will analyze some more complex ones further in the chapter. A feature of network graphs is their connectivity, as they provide a visual representation of how much systems are actually connected. The term "It's a small world" is a well-established and arithmetically accurate property of networks[42] (Caldarelli & Catanzaro 2012). Networks have some other basic properties that we should disclose to understand them better:

[41] Networks have of course a much more complicated definition, but for the scope of this research this will suffice. However, for a deeper understanding of the complex mathematics and functionality of networks, "Evolution of Networks, from Bio Nets to the Internet and WWW" by Dorogovstev and Medes offers a very detailed breakdown.

[42] In 1967 a very famous experiment conducted by the psychologist Stanley Milgram proved that, on average, any two people in the world are separated by a degree of six, meaning that we would have to jump through six connections in order to find a person they have in common.

i- *Giant Connected Component*

Not every node is connected to the other, and some nodes are inherently more connected than others in any given system, however generally all elements of a given system are part of a larger connected system, called a giant connected component. (Caldarelli & Catanzaro 2012)

ii- *Small-world property and self-organization*

The *small-world property* is inherent to virtually any network, even those that are completely randomly generated. This is the demonstration of another important feature of networks, and that is that they tend to self-organization even if they are completely randomized[43]. In fact, when randomly produced, networks tend to be homogenous in their connections, giving a number of edges that is more or less the same to all nodes in a system. (Caldarelli & Catanzaro 2012)

iii- *Hubs*

As stated before, some nodes are more connected than others in systems, and in networks there is a natural tendency for those nodes to always become more connected with passing time. These nodes are denoted as *Hubs*, and have a super-connectivity in the networks they are found in. Generally, it is thought that, in network theory, "the rich get richer". Intuitively if a random new node is to appear in the network, there is a high chance that it will be either directly, or through some degree of separation, be connected to a hub–networks with hubs are considered to be heterogeneous. Hubs are of particular importance in epidemic analysis because they usually represent dangerous "hot" spots where diseases can spread through the world. Just like on the WWW and in the real world, hubs represent major ports through which information and people flow at incredibly high density. (Caldarelli & Catanzaro 2012)

iv- *Characteristics*

Networks also have, as analytical tools, some key characteristics that are used for measurement.

The **geodesic path** is simply the shortest path between two nodes.

The **diameter** is the aggregate length of the longest geodesic path between any two nodes.

The **characteristic path length** is the average length of a path between any two nodes.

Clustering measures the propensity of the connections of any given node to be connected to another.

Centrality measures which nodes are most important to the functioning of a network, and spread the most information. (Tassier 2013)

[43] However, networks that are randomly produced tend to self-organize in a homogenous way. This is a remarkably interesting feature of networks, that although again goes over the scope of this research, Guido Caldarelli and Michele Catanzaro talk about these in their book "Networks: a very short introduction"

v- *Social Connections*

Specifically, in social networks, it is hard to pinpoint connections as not all relations a person has are of the same importance. For example, a pizza delivery guy may be very connected, but his connections are largely informal, therefore it would be difficult to define him as a hub. At the same time, if he were to catch a flu, then he would be a super-connector, through which the pathogen could easily spread. This simple example hits at the nerve-racking problem that it could be to graph out a network designed as such. For this reason, in epidemiology, nodes are typically represented by locations, and edges typically represent people. This is still incredibly hard to visualize as we will see later, however it provides fixed hubs which, in planning a response to the spread of a pandemic, prove easier to control. (Caldarelli & Catanzaro 2012)

Having set these ground features for networks, we can now delve into an investigation on the use of these tools in public health responses.

NETWORKS THROUGHOUT TIME

It is almost impossible to create a comprehensive timetable on the historical growth of social networks, as they were, before the use of network science, a much more qualitative rather than quantitative variable–we have no statistical bureau which provides evidence that we are today more connected than two centuries ago. However, we do have some right claims based on facts upon which we can say that the world has increased its average clustering. Travelling has advanced tremendously the last century, giving the possibility for virtually any citizen in any country to reach any other part of the world in a fraction of the time that it took people even 100 years ago. Therefore, it is safe to say that in 1918, the world as a whole was more connected than in 1437, when motored boats, planes, and cars did not exist. Innovation in transportation technology is, then, a proxy measurement for connectivity, as advancement in the field meant intrinsically more possibility for connections. This is an important implication, especially for dealing with diseases; a person now can travel the world before even showing symptoms, and in the its path infect thousands of other people. This was not possible before the invention of planes, and epidemics were then lived more locally than internationally. Information proves to be another good measuring scale for connectivity, as a more interconnected society is, consequentially, more informed. We can safely assume that daily occurrences in two cities at the two edges of Italy (in Campania and Veneto, for example) were harder to figure out in 1347 than in 1918. Communication, then, is another good metric for understanding the evolution of networks throughout time. Better communication also allow for closer long-distance relationships. Personal interactions, although, prove to be harder to quantify. How can we say that we have better friends now than our ancestors a millennium ago? We cannot, but this is of less interest to us, since in epidemics we are much more interested in indirect contact rather than direct one–we are interested in the pizza delivery guy.[44]

Given these parameters, what can we say about social connections in historical perspective?

- Since transportation has improved throughout history, and therefore connectivity has also increased, the geodesic paths between any two nodes have consequentially shortened, on average.
- Since improvements in communication are closely tied to connectivity (a more connected world inherently yields more transfer of information between different parts of it) improvements in communication technology are a marker for growth in social networks, and signal to us an increase in clustering between every node in a system.
- Advancements in communication technology and transport increase centrality of hubs, and this increase can be seen throughout time.
- Giant Connected Components (GCC) represent a connectivity between seemingly unconnected ecosystems. As transportation and velocity of information have changed throughout time GCC have in increased. Therefore, we can expect the emergence of more GCC with advancements in technology.

Can we observe the aforementioned effects empirically throughout history? In some sense, yes. To prove this, we can analyze two global pandemics in two very different historical times and see their spread, tied to the flow of transportation of the time.

1347 Bubonic Plague

The Black Death was caused by black rats' ticks, which managed to travel throughout Europe through ships. (Deaton 2004) Much literature about the Plague is dedicated to an analysis of the spread of the pandemic through the trade routes that connected the whole of Europe. Starting mainly from Constantinople, the Plague slowly travelled through the Mediterranean, reaching London for the first time in 1348, a year after the breakout of the original pandemic. Figure 9 shows the spread of the pathogen in Europe through the trade routes. It took a long time to infect the whole of Europe, almost four years. This is because the most efficient transportation at the time were vessels, and spread through land was relatively slow–people died before they could reach an uninfected region. In fact, we can see that Eurasia, where the pandemic did not spread through water, was the last area to be hit in 1351.

[44] This is true for the nature of the diseases that I will discuss in this paper, of course for sexually transmitted diseases, it is the contrary. However, the development of informal ties in hsitory can also explain a cultural change in sexual relatinoships, so the development of HIV is proably tracable along the same lines.

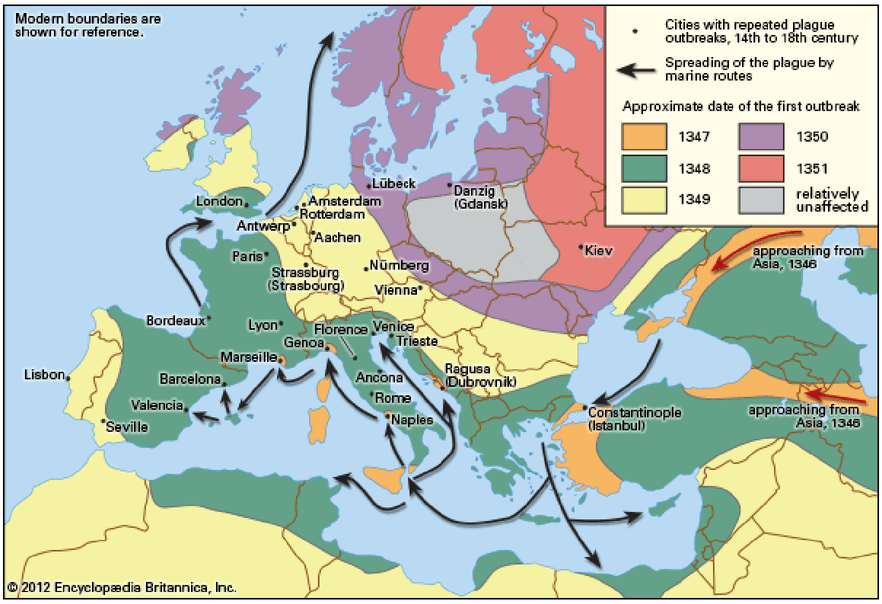


Figure 8- the spread of the 1347 Black Death

Source: Encyclopædia Britannica

Sea travel allowed for a more connected society than before, but also contributed immensely to the success of the Plague to devastate through Europe. If we were to see the map above as a directed network, with the pathogen travelling along the direction of the arrows, we can observe how, because of maritime routes, the geodesic path between any two given nodes (cities) was indeed shortened, and this observation holds true for those cities that are landlocked like Kiev–reaching it took much longer than a city like Valencia, which is much more distant from Constantinople. Since trade routes were central to the 1300s economy, major hubs and aggregate centrality were concentrated in the most important ports. The graph above shows, in fact, that cities like Naples and Genoa, the two most important ports of the time, were the first in Italy to be hit by the epidemic. The networking system of the High Middle Ages was revolutionized by well-established sea routes, which allowed any given infected individual in a city to travel to any point on the coast in much less time than it took by land. This, consequentially, allowed more contact between people, and therefore a higher clustering in the social network of the Middle Ages.

1918 Spanish Influenza

To analyze a disease of similar magnitude of the Bubonic Plague, which wiped out 50% of the European population (Clark 2003), the 1918 Spanish Influenza is often considered one of the worst public health crises in modern history, and the first post-industrial pandemic that affected the world. Killing 25% of the total world population (Potter 2001) it came at a time of transport and communication revolution: at the end of the First World War. Figure 9 shows the spread of the virus between 1918 and 1920.

Figure 9- Spread of Spanish flu 1918-1920

Source: Potter C.W 2001. "A History of Influenza"

World War I showed the deep interconnectivity of the globe, and the Spanish flu proved for the first time that out planet is in fact a giant connected components (GCC). Aviation and fast naval transport revolutionized the conflict, and from the map above we can notice the first major difference from the outbreak of the 1347 Plague: the Spanish flu was globally lived (Brainerd and Siegler 2002). Second, to notice the period of the outbreak; it took just two years for the pathogen to spread from its first outbreaks (denoted by the squares) to quite literally the other side of the globe. In comparison, the Bleak Death took double the time to infect just Europe. Continental travel was also fairly advanced; with railroads connecting some major United States cities[45] and the first instances of non-warfare related aviation,[46] the time it took for a person to travel across a continent was small compared even to half a century before.[47] Defining the beginning of the outbreak has been hard, however historians widely believe that the epidemic started in the United States (Potter 2001) and developed in two major waves of outbreak, one in 1918 and one in 1920. The two, although, are connected– the second outbreak was a consequence of the first which only appeared to have been contained. It should pop to the eye how much the virus travelled in just two years, hitting the point of Southern Africa, Australia, and Asia. Again, visualizing the world as a big network helps us to understand the idea of GCCs. The Bubonic Plague travelled through European trade routes, which connected ports and intrinsically posed some limitations to its spread–as we have seen, cities that weren't major ports took much longer to be infected. Moreover, for the quick nature of the disease, it was virtually impossible for it to travel to, say, North America. So, while the world in 1347 showed great European interconnectivity, it lacked a global connection

[45] The United State also saw their first major (and worst thus far) railroad crash in 1918 in Nashville, Tennessee after two passenger trains collided on the tracks.

[46] The French aviation company "Aéreopostale" was established in 1918, which provided postal services to the French Colonies in Africa.

[47] Railroad transport in the majority of the 1860s was primarily used for transportation purposes, passengers transport only really began after the first Civil War.

aspect. Less than 600 years later, the Spanish flu proved to us that even seemingly disconnected social structures (say, Africa and Australia) were part of a greater GCC. Africa and Australia, both European colonies (French and English respectively) were not directly connected, but both suffered at the same time of the same pandemic, spread by Europe. A common link is fairly easy to pinpoint, and the small-world property of networks proves itself of critical importance to grasp this concept. Innovation in travelling methods and the normalization of public voyage broke out of the trade routes natural containment of a pandemic. Decrease travelling times allowed a more efficient spread of the disease, and the new transatlantic relationship of the early 20th century managed a cross-continental pandemic. Cities in the United States were now, in some way, connected to cities in Australia, and the breakout of an epidemic in the North American continent proved to have devastating effects on the whole world. We can use as metric of connectivity of the time also communication–the First World War standardized telecommunication worldwide, a sign of great interconnectivity. The news of the sprout of a new disease in the United States took little time to reach Europe, one of the reasons why it was so short lived was because of the international cooperation in creating a containment plan.[48] A word should be spent on hubs, which in the case of the Spanish Flu played a smaller role than in the Plague. However, the geodesic path between worldwide hubs was much shorter, and due to the violent nature of the pathogen, accelerated its spread around the world.

THE ECONOMICS OF NETWORKS: WHO IS RICH GETS RICHER

In 600 years the increase in connectivity of the world and the growth of global and local networks was sensational. We have seen how this was driven by technological innovation, and improvements in communication proved to be a good metric–there was a great leap in global communication between the 1347 and 1918. This is no singular process, and we can observe these parallel growths all throughout history. If we were to make, in fact, a comparison of the breakout of the 2009 swine flu with the 1918 Spanish one, we'd see an increased importance of central super-connecting hubs, geodesic paths shortened because of the increased public travelling, and an even more strongly related GCC. The next tassel I would like to introduce is that of economic development, which is a major defining factor in the establishment global hubs in as well as a measure of centrality and clustering. Why do some nodes become more central than others in networks? As we have defined nodes as cities in the global arena, and to define their centrality in the network is to define their popularity. (Caldarelli & Catanzaro 2013) A good and relevant example is air traffic; some airports are super, global connectors–that is, virtually every itinerary can pass through it, no matter what is the destination. Moreover, their high clustering is for flights, people, and airplanes: we could safely assume that any person that is travelling out of their country has a high possibility of having at least a layover in one of them, therefore making every plane likely to land there, and consequentially making most flights to pass through

[48] "The Committee of the American Public Health Association (APHA) issued a report outlining appropriate ways to prevent the spread and reduce the severity of the epidemic". https://virus.stanford.edu/uda/fluresponse.html

them. (Caldarelli & Catanzaro 2013) The advantage of a short characteristic path length to passing through a given hub is not the only feature to make it popular. “Popularity” is a factor that is defined by attractiveness, and cities become attractive because of their prosperity. (Tassier 2013) High air traffic also requires extremely big investments in maintenance and technology, so it is inherent that economic influx is a consequence but also a determinant of major hubs. As mentioned before, the “rich get richer” in networks, and it is true for airports as much as for ports in the 1300s (Genoa and Naples were among the richest cities in Italy, and centers of cultural innovation) (Deaton 2003). The correlation between network growth and economic prosperity is then no arbitrary event, but instead a self-organizing feature of heterogeneous networks with the expansion of their diameter.

I introduced in the first chapter the relationship between economic and demographic growth, briefly mentioning a central theme to this thesis: pandemics seem to happen more often after periods of economic acceleration. “1066 to 1300 was as an era of expansion and economic growth, and 1300-49 a period of stasis or retrenchment”[49] (Clark 2003) comparatively, the United States’ GNP skyrocketed after the War, due to its automation and automobile industry, with a rapid demand of American goods.[50] Intuitively, we can now add to the equation the factor of network growth as a consequence of economic expansion and demographic changes. As discussed, demography and wealth are interlocked factors in the economy of a country; a growth of population inevitably means more clustered networks, and wealthier cities are consequentially more urbanized and densely populated, developing to then become major global hubs, super-connectors of the world. Economic growth stimulates, and at the same time is stimulated, by technological innovation, exactly what fuels networks’ expansion, as I have shown earlier. Characteristic path lengths decrease between richer cities, but clustering and centrality increase with wealth, therefore making richer cities connected to much poorer ones, too (Caldarelli & Catanzaro 2013). As economies become more interconnected, citizens automatically become more tied as well: the social connections of an average New York commuter, then, have now involuntarily expanded to the whole World–the small world property of heterogeneous networks only increases with economic, social, and technological advancement. It might be hard to grasp, but the implication of the world being a GCC means that, with the velocity of travel, an infection can travel across the world in less than 24 hours, therefore connecting citizens in different continents with very short geodesic paths. The pizza delivery guy dilemma becomes an excruciating puzzle when we think that every single person that enters the London tube today has an informal, social connection that is long enough for them to get infected with a variety of diseases, which may have developed less than a day earlier in Shanghai or Singapore–everyone is a super connector for diseases. The concept can be hard to unravel, verbally, so figure 10 tries to simplify the connection between these three key factors in the spread of an epidemic.

[49] I am maintaining the two examples of Spanish Influenza and the Black Death for the purpose of simplicity, I will analyze more cases in the next chapter.

[50] “America's gross national product (GNP) grew from $78 billion to $103 billion” http://www.bbc.co.uk/schools/gcsebitesize/history/mwh/usa/boomrev1.shtml

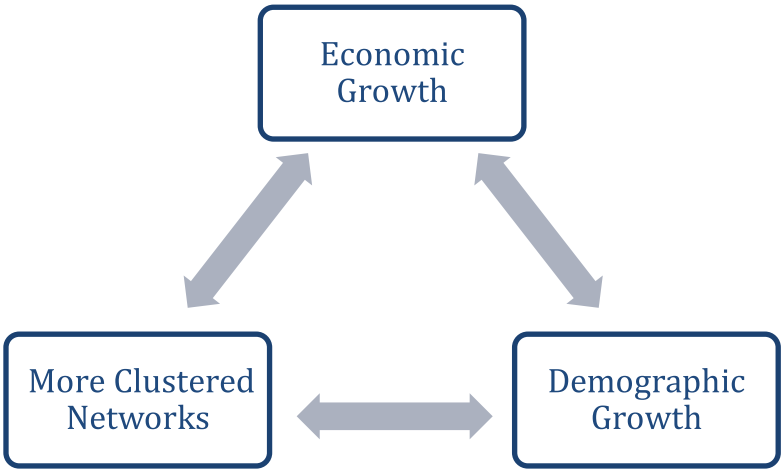


Figure 10- Interconnection between three fundamental variables in epidemiology

Source: self-made graph, Lionello 2017

The observed causal link between economic growth and the sprouts of pandemics should seem much clearer now–the growth of the economy has deep demographic implications, which create favorable conditions for the spread of diseases with increased connectivity. Network analysis is then central to any public health response in today's world, and the key, mediating role that hubs play in the spread of a pathogen is importantly related to their population density and wealth.

PUBLIC RESPONSE TO CLUSTERED NETWORKS: HYGIENIZATION

The discovery of the germ theory in the 1870s is largely considered to be one of the greatest achievements in public health history. Germ theory contributed to the understanding of the importance of hygiene in everyday life, and started a new approach to health in every aspect of life. (Deaton 2013) The discovery of the importance of germs and their role in the spread of diseases has helped science leap forward at incredible speed, from the development of penicillin to the creation of vaccines, to a proper understanding on the importance of clean cities and sterile working environments in hospitals. We may find it ludicrous, but in the early 1900s one of the leading causes of infant mortality was the unclean environment that they were given birth in. (Drevenstedt et al. 2008) Hygiene is a given in our society, and that is because of the high social advancement that precedes us; the Middle Ages, but more in general pre-industrial society, was plagued mainly by poor sanitation. The multiple cholera outbreaks in London in the mid 1800s, for example, were caused by the dumping of sewage waters in the Thames, the primary source of drinking water of the city: a silly lack of sanitization that cost the city thousands of pounds and lives.[51]

[51] John Snow, the father of modern epidemiology and a big contributor to the discovery of germs, solved the epidemic through an observation of networks in the city of the potable water and sewage systems.

This last problem was caused, at its roots, by the problem of overpopulation of the city. (Deaton 2013) London's urban population had soared throughout the beginning of the industrial revolution, and the management of waste of an increased population proved to be increasingly difficult: where was this excess supposed to be allocated? Little evidence at the time showed that biological waste is harmful to our body and that living in the proximity of it meant living next to major diseases' hubs. The revolution came in 1832, when John Snow theorized that the reoccurrence of the cholera outbreaks in London could be due to its waste disposal management, which kept reintroducing the virus back into the system by the dumping in potable waters. (Deaton 2013) This proved to be a remarkable change in public health responses, the beginning of sanitation of urban city centers. Improvements in hygiene has been one of the leading causes of decreases in child mortality and increases in life expectancy in the last 3 centuries. Improvements in sanitary practices decreased immensely deaths by infectious diseases, and better private hygiene decimated transmission within the public. In 1900, the leading causes of deaths in the United States were pneumonia, tuberculosis, and diarrhea causing a third of all deaths in the country, all of which were caused by poor public sanitation.[52] 1903 saw the emergence of public health authorities in the country and across the world, with the introduction of better waste disposal systems, chemical treatment for drinking water and public education on food and personal hygiene–by 1940 TB, which killed 194 people per 100.000 less than 15 years before, was now killing 46 (figures are similar for both diarrhea and pneumonia). Figure 11 shows the inverse relationship between infant mortality and improvements in public health practices and significant medical discoveries.

[52] The rest of the figures I cite and discuss are all taken from a compelling review made by the United Sate's Center for Diseases Control (CDC) about the improvements of health through better hyigene, this is the reference: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm4829a1.htm#fig1

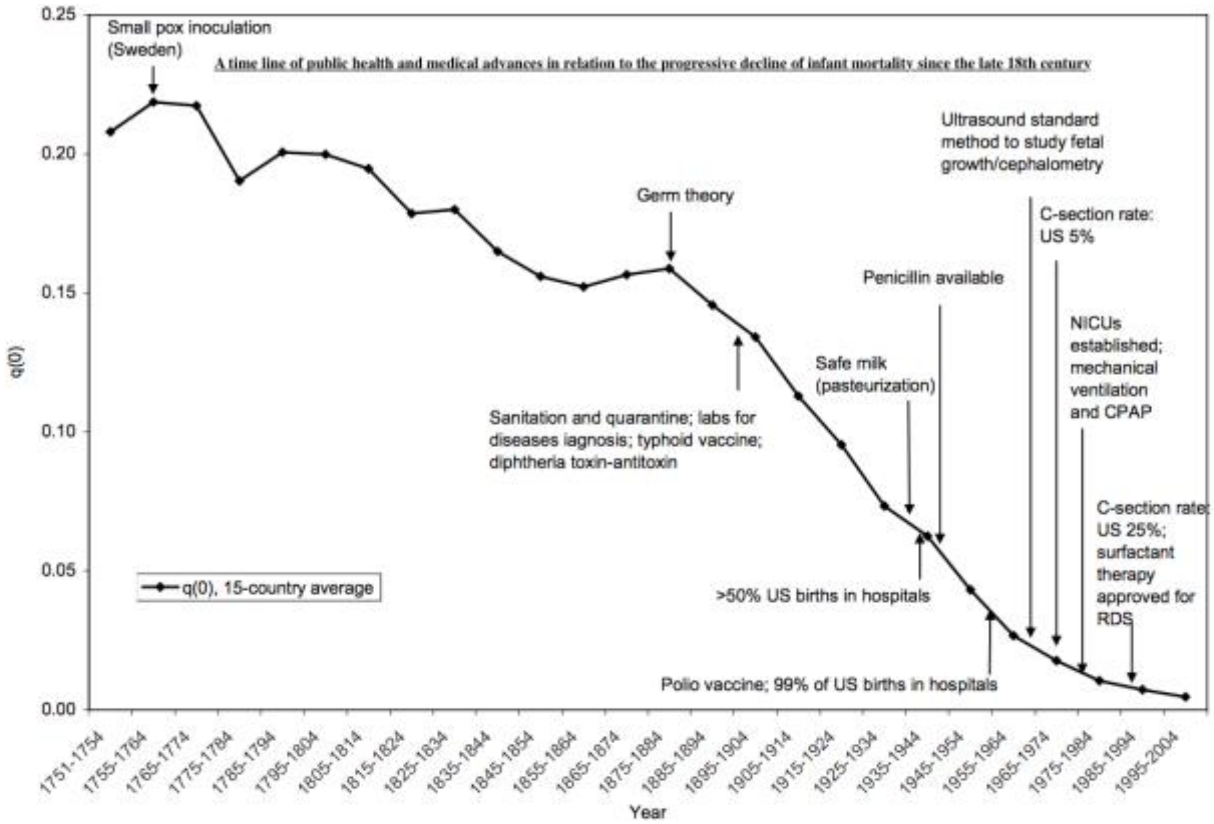


Figure 11- a timeline of public health & medical advancements in relation to child mortality since the 18th century

Source: Drevenstedt et al. 2008 "The rise and fall of excess male infant mortality"

This extraordinary timeline provides a very good visualization of the importance of hygiene in the improvement of our wellbeing. "Several factors, including declines in infection, an increase in hospital births, medical advancements to improve birth outcomes, and better nutrition, have contributed to lower infant mortality …infections were being minimized" in the period that followed the discovery of germ theory, and the graph is consistent with these findings. (Drevenstedt et al. 2008) Improvements in public health through better sanitation, then, are a direct response to more clustered networks, as an increase in population makes us more exposed to disease carriers.

CONCLUSIONS: IS A SUPER-CONNECTED WORLD A HEALTHIER ONE?

The New York Times published on June 1st 2017 an article titled "Popular People Live Longer".[53] This provoking title analyzes the health effects that centrality brings to single individuals; the author, which cross-studied a number of different psychological and economic studies found some captivating evidence:

[53] https://www.nytimes.com/2017/06/01/opinion/sunday/popular-people-live-longer.html?smid=fb-nytimes&smtyp=cur&_r=0

> The results revealed that being unpopular — feeling isolated, disconnected, lonely — predicts our life span. More surprising is just how powerful this effect can be. Dr. Holt-Lunstad found that people who had larger networks of friends had a 50 percent increased chance of survival by the end of the study they were in. And those who had good-quality relationships had a 91 percent higher survival rate. This suggests that being unpopular increases our chance of death more strongly than obesity, physical inactivity or binge drinking. In fact, the only comparable health hazard is smoking. (Prinstein 2017)

A 50% increased chance of survival is a phenomenally large proportion, so are more clustered networks also good explanations for the decreases in mortality rates throughout history? Is being more connected today making us healthier? This makes clustered networks, then, a double-edged sword: it becomes increasingly easy to spread a pathogen through a city, but being around more people seems to be making us live longer. "Likeability" continues the author, is related to a herd connection that we were predisposed to when we were hunters and gatherers, which helped us to adapt to closer contact with disease carriers, "ancestral humans who had no peers to defend them no longer had a great need to be protected from viruses — who would infect them? — so their bodies conserved energy by reducing their vigilance to infection". (Prinstein 2017) This is a suggestive and remarkable finding, which hints to an underlying genetic response of our body to the pizza delivery guy dilemma: the more interconnected we are, the more likely we are to survive to an epidemic. Social behaviors mark our predisposition to living in a more clustered society, making highly central pieces in social networks, then, also the hardest to infect. "The rich get richer" phenomenon seems to be not only a tendency to self-organization, but becomes a survival mechanism, too, not only for itself, but for a whole network–if the super-connector is harder to infect, then there is less likability of the spread of a disease. This is an incredible adaptation tactic, which poses an important implication to the growth of networks throughout history: it might be vital in order to survive.

Aside from this unbelievable genetic effect that networks play in the role of our survival to pandemics, through this chapter I have laid down another important tassel to then allow a deeper analysis in the historical relationship between economics and epidemics. Social networks are the web through which diseases spread, and a public health nightmare–I briefly introduced their complicated structure throughout the chapter. Central to this analysis was the role of technology and innovation, which played an interceding role in the development networks. I have used the technological innovation measurement as a proxy because it proves to be consistently modernizing throughout history, and runs steadily parallel to economic development–one tends to increase the other quite circularly–it is also a much better quantitative measure than social abilities. Keeping in mind the close relationship between economic growth, demographic changes, and network configuration, I shall proceed in an analysis through these aforementioned tools of some of the major pandemics that have affected our world to date. While I have done so already in the two preceding chapters, I will now analyze the deeper connection between epidemics and the economy, having now set the work of demographics in the equation. Decision making in public health is tied to a variety of factors, and it is often too simplistic to criticize measures based on mere cost-benefit analysis. For this reason, I tried to lay two important factors in decision-making in the field, to try to shed light on the plural-dimensional reality of epidemiology. In the following and last chapter, I will talk about public health measures in theory and in practice. I opened this chapter with an analogy between epidemics and virtual viruses. The development of communication through the internet allows information to now travel at unimaginable speed to virtually every part of the world. Not surprisingly, this advancement in communication is followed closely to our advancement in transport, where now pathogens can travel through the whole world not at the speed of the recent ransomware that hit the WWW, but easily in less than a day. Tandem to the development of diseases has grown our understanding of public responses and the importance of networks. The May 12th 2017 ransomware, while virtual, proves yet again to be a good example, of how taking down a central piece of a network can manage to significantly stop the spread of an epidemic. Plotting the map of the internet has been proven to be close to impossible,[54] and the same is true for our social relationships–it might be easy to pinpoint our closes relatives, but hard to visualize the totality of all the people that we come into contact within even a single day. However, in both cases recognizing super connectors can have a much stronger impact than understanding every smaller component. In the internet, it is much more important to look at super connectors like Google than smaller sites when considering a response to a cyberattack and similarly, airports are much more central for responses to epidemics than singular individuals. The reality of giant connected components then holds true for both the Internet and our society, and public health can, perhaps, learn some measures form virtual viral outbreaks in the future with regard to organization and efficient localization of central tassels of the puzzle.

[54] Many physicists have tried, but it will never be precise enough because too many smaller nodes are always left out.

CHAPTER 3:
EPIDEMICS AND ECONOMICS

The following chapter will analyze four periods of global economic growth in history. Tied to that, I will introduce four great epidemics that followed these growths in prosperity. Keeping in mind the dynamics discussed in the previous chapters, I focus more on an analytical explanation, rather than explaining the whole process of demographic changes, networks' rearrangement and economic expansion. Angus Deaton, in his famous book "The Great Escape: Health, Wealth, and the Origins of Inequality" analyzed the close relationship between health and wealth[55]. Indeed, he finally concluded that wealthier people are generally much healthier than poorer ones, making salary, then, and index for mortality. (2013) This inference holds true in the outbreaks of pandemics as well; Lewis, for example, observing the effects that the unraveling of the AIDS epidemic in Africa have had on the economy of developing country saw that, "the better educated, who also tend to be the better off, have altered their behavior leading to a more concentrated impact among lower income groups." (2001) This is an important implication, which makes macroeconomic analysis often inconsistent and unreliable when dealing with economic effects of epidemics. The underlying factor is that, since lower-income groups seem to be more affected, GDP per capita might seem in growth during epidemics.[56] For this reason, this chapter will try to approach the topic from an antecedent point of view–I will first describe periods of intense economic growth, and then expose the epidemics that followed them.

Although, it is important to first and foremost introduce some epidemiological implications to economic analysis. Epidemics can be analyzed through their impact on the labor market, effects on demographics, and long-term economic growth; introducing some economic tools for this chapter seems, then, to be of critical value for a meaningful analysis. Epidemic modeling allows us to see not only the development of an epidemic throughout time, but also gives us a concrete way to understand how to contain and manage the spread of a pathogen.

EPIDEMIC MODELING: AN INTRODUCTION

Epidemic modelling tries to describe the possible scenarios of the spread of an infectious disease. To do this, models plot the fundamental properties of epidemics and their actors, and dissect the breakout of a disease in terms of probability and mathematical equations. The subjects of an epidemic model are differentiated in base of their epidemiological status, which states their relationship with the epidemic as well as their role in the spread of the disease. The categories used are (Tassier 2013):

[55] Deaton analyzed the intergenerational changes in American society, and found that people living in poorer parts of big American cities had much higher rates of mortality on every level, even for those causes of mortality that seemed homogenous within society. For a closer analysis, I read his paper "Mortality, inequality and race in American cities and states" published in 2003 with Darren Lubotsky.

[56] Maureen Lewis analyzes this apparent effect in his article published in 2001 "Epidemics and Economics".

- *Susceptible:* people at risk of infection.
- *Infected:* those already infected.
- *Infective:* infected hosts that can spread the pathogen. It is important to note that not all infected hosts have to be infective.
- *Recovered or removed:* refers to individuals that have become immune, been quarantined, vaccinated, or have died.
- *Exposed or latent:* are hosts that have been infected but yet do not show symptoms of a disease and are not yet infective.

It is important to note that not all epidemics have all the stages, and the epidemiological status of a patient is defined by the biology of the disease. From these stages, we can derive a categorical model that defines the stages that an individual goes through in an epidemic, defining, then, the simple cycle of an epidemic by the relationship between the pathogen and the patient, the most common ones are (Tassier 2013):

- **SI or simple epidemic**, where the host goes from being **S**usceptible to **I**nfected without any recovery.
- **SIS**, where hosts can recover but are then susceptible again.
- **SIR** where they gain immunity once they recovered.
- **SEIR** where the host goes through a period of incubation of the disease, meaning that it is **S**usceptible, **E**xposed, **I**nfected, and then **R**ecovers.

These might seem as simplistic models, and indeed they are–they fail to explain the complex economic, social, and demographic processes that go behind the movement of people between these different stages–but this is, in part, their analytical appeal. Since epidemics incorporate a very wide spectrum of factors, it can prove to be hard, and in fact impossible, to observe all factors and control all variables. By eliminating them from the analysis, we are able to work with logistics and give the epidemic a simple contact probabilistic formula and two basic states of the epidemic: infected or healthy. It might seem odd, but by these simple models we can derive an epidemic threshold, or the number of individuals needed for a disease to become epidemic, and from that a whole range of calculations that allows us to formulate a basic system of response. To better understand this econometric aspect of epidemiology we can observe equation 1, which describes the spreading mechanism of a simple epidemic (or SI model):

$$I_t = (1 + \gamma\alpha)^t I_0 \tag{1}$$

Here, γ represents the number of contact of a single infected individual, while α represents the probability of contact between a susceptible and an infected person resulting in the transmission of the actual disease–therefore, the product characterizes the number of successful contacts a carrier has that transmit the pathogen. If "I" represents the infected individuals, then intuitively "I" subscript 0 is the initial outbreak and "I" subscript t the number of infected individuals in any period. (Tassier 2013) In this simple model, we can account for the fact that as long as α and γ are greater than zero, then in the long run the epidemic will end when every individual in the population is infected. For as simple as this first equation is, it can already give us a few important clues about the speed of the spread of the pathogen. We denoted "I" as the number of infected individuals, we should therefore denote any person not infected, as "S" for susceptible (as every person not infected is at risk of being so). "I + S" then represents our whole population, "N", and equation 1 can then tell us how fast an epidemic might spread to a whole community. If the rate of infection is very low, for example, it might take several number of time periods for every susceptible individual to become infected. Likewise, if the contact between people in a society are rare and few, the pathogen might never reach every person in society and die out before transforming in to an epidemic. With little more than two basic transmission values, we were able to derive the velocity of spread of an infectious disease, and in turn we could calculate how quickly a public health response should be in order to contain the contagion,[57] SI models are simple, but they do exist: AIDS is often taken as an SI model by epidemiologists. Equation 1 also gives us an epidemic threshold, which is represented by the product of $\gamma\alpha$, both of which must always be greater than 0 for the epidemic to spread (Tassier 2013). We can describe a larger and more complicated cohort of diseases by varying the model slightly and creating an equation for an SIS Model, where individuals, once infected recover and go back to being susceptible–equation 2 represents this:

$$I_{t+1} = (\gamma\alpha)^t I_0 \tag{2}$$

In this second equation, the number of infected individuals is always changing, and there is a constant movement of individuals between a state of susceptible and a state of infection, therefore rendering the model an interesting analysis on interactions. The product $(\gamma\alpha)^t$ represents the transmission at any given time, so if we were to imagine a very large t (as t usually does not represent years, but smaller measures of times when talking about epidemics) and a product of $\gamma\alpha$<1, we would get a relatively small number. If t, were to be even bigger, a number like 5.000, then $\gamma\alpha$ would prove to be even smaller–very close to zero, in fact. The model tells us that if $\gamma\alpha$ remains smaller than one (that is, less than 1 person is infected by every infectious individual) then the epidemic will quickly die out. $\gamma\alpha$ must be bigger than 1 for the epidemic to reach epidemic threshold and the pathogen to spread (Tassier 2013). Note that also the opposite is true–as soon as $\gamma\alpha$ becomes bigger than 1, the epidemic starts spreading at a much faster rate. This simple calculation allows us to come to terms with some important implications; first, by understanding the velocity of spread of an infectious disease, we can derive an accurate calculation on the timeframe of action, and avoid any type of waste of resources on infections that do not reach epidemic threshold. Second, we can have a rough estimate of how many people can be potentially infected, therefore rendering action much more efficient. Lastly, by having an assessment of contacts and a perception of successful contacts, we can then quickly act at the root

[57] Of course much more goes behind public health planning, although this proves to be an effective measurement of potential damage that epidemiologists use. Also, any model underlies the problem of contained observation, which does not take into consideration that every individual might react differently to a pathogen and that rates of transmission may vary through the epidemic.

of the problem by minimizing contacts of infected individuals. For example, if we were to imagine any of the two parameters of $\gamma\alpha$ to be much larger than 1, then intuitively the first action to stop an epidemic breakout would be a strong isolation of subjects in order to minimize contacts. Clearly, these are contained scenarios, and extremely simplified for the purpose of this example, however, the value of simple models is specifically this property of simple analysis, which gives good marginal explanations to first response action[58].

Equation 2 fails to keep in consideration also *the steady state* of a pandemic, which closely resembles the equilibrium of economic markets–it is the point in the epidemic where the system is not changing. We can define the steady state for both the susceptible and the infected proportion of the population, which are defined in Equation 3a and 3b (Tassier 2013):

$$\bar{s} = \frac{\kappa}{\alpha\gamma} \text{ (a)} \qquad \bar{i} = 1 - \frac{\kappa}{\alpha\gamma} \text{ (b)} \qquad (3)$$

This looks at the flow of the model: numbers in either category will never be realistically constant, and will be always changing by a factor of $\frac{\kappa}{\alpha\gamma}$, where κ represents the percentage of population that recovers in each period t. The two equations seem to be fairly simple to understand even at glance; as the number of contacts of an infected person, and the probability of infection increase, the number of susceptible individuals decreases–this effect is given by $\bar{s}$. Similarly, if recovery time increase (therefore decreasing the value of κ) the number of susceptible individuals will also decrease, increasing the number of infected individuals– we can observe this in $\bar{i}$. $\bar{s}$ *and* $\bar{i}$ represent the point in which no more people will enter or exit the susceptible and infected stage, bringing the epidemic to a halt (Tassier 2013). The steady state provides us with a measure of action; if we understand at which level S and I will be constant, we can then enact a containment plan. Grasping the work behind these functions might be hard at a mathematical level, so Figure 12 represents a simple SI Model computed on Excel[59]. The point where the two curves flatten out represent the steady state of the epidemic–in a simple SI model, κ is not present, therefore the system reaches steady state when all the subjects in the population have been infected.

[58] I have oversimplified purposely the SIS Model to try not to delve too much into math, however we can define with more accuracy even the epidemic threshold, reproduction numbers and the flow of births, deaths, and migration that are kept as constant in these equations. However, while extremely pertinent to the research, it would risk complicating and digressing from the core analysis of this paper. An exemplary explanation to all of the models described can be found in Troy Tassier's book "The Economics of Epidemiology" published in 2013. The book served me well in understanding econometrics and computational modelling.

[59] The model is adapted from the functions and data bank suggested by https://www.shodor.org/succeed/curriculum/apprenticeship/Modeling/Excel/LessonPlan2/

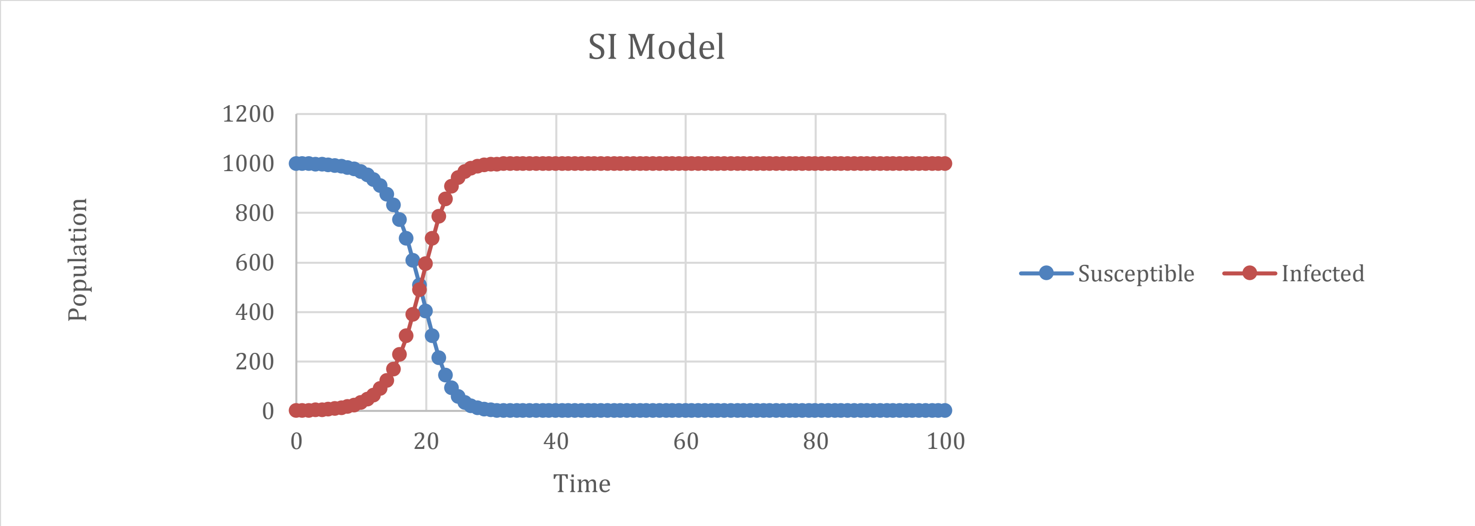


Figure 12- simple SI Model with a population of 1000 subjects, infection rate (α) = 0,12 and t= 100

Source: self-made graph on Excel with online database, Lionello 2017

Notice how in the time period 20 the two curves cross, representing the point of epidemic threshold. Observe also how the infection rate is relatively low at 0,12 which causes the initial stall of the epidemic in period 0 to 20. With such a low α, the system is compensated with a high γ at 0,004 (which might sound small, but in a population of 1000 people it amounts to 35 interactions per individual), explaining the steep take off–once enough people are infected, then the epidemic spreads fast. From a public health perspective, it is important to act before the time period t=20 and before 500 individuals are infected, and this can be achieved through vaccinations–we can deduct from the model, though, that not the whole population need to be vaccinated, in fact barely half of it does. This has critical public health implications, which can greatly reduce costs of vaccination campaigns: if officials act before t= 20, then epidemic threshold might never be reached and the epidemic may never spread to the whole population. This is also known as *herd immunity*, a concept that explains to us that "complete immunization" of a group of people may be reached without actively immunizing all (Tassier 2013)–networks prove to be of high value in this situation. Immunization is costly, and properly allocating resources is important at the sprout of epidemics; by looking at this simple computer model we can derive how impactful it could be to act quickly. Epidemic modelling, from what I have explained above, proves to be an important instrument for utility analysis, critical for economic enquiry. If we were to take the utility of any individual to be U_j, j representing a state between susceptible, infected, and recovered, equation 4 represents an economic value function, which describes the various costs and benefits of being in any given state throughout the epidemic.[60] (Tassier 2013)

$$V_t = U_s - \pi C_i \quad (4)$$

[60] We make the assumption that $U_s = U_r > U_i$ and also that recovery is direct, with no continuous symptoms that persist. Also, we will assume that there are no benefits to being infected (such as knowing that being infected will give you immunization and peace of mind).

The value of being susceptible (V_s) is equal to the Utility of being susceptible (U_s) minus the probability of being infected (π) and the costs of being infected (C_i)[61]. It is logical to assume that being infected will have some costs, like treatment and doctor's visits, but also costs of not being at work and therefore not being paid. The value function, then, is a calculation of the trade-offs between the utility of being ill and being susceptible, the latter representing the possibility of being productive and able to gain a wage. By considering the value function of an epidemic, we understand the real costs of falling ill, valuing then also the costs of prevention. If, for example, the probability of catching the common flu in any given season in New York city were to be very high (as they typically are, at around .7) and the costs of catching it were to be 10 days of forgone work and not being paid (taking a rough average of $30 per hour in the city of New York, with a 9 to 5 job, and assuming only monetary utility costs)[62] then the value of being susceptible would be of $720[63]; as long as vaccinating an individual costs less than that (averaging at $16,46[64] seasonally for a single shot) it will be much more convenient to get vaccinated. For as reasonable as this sounds, this is not how we usually think of our vaccines, and most people prefer to take the chance of getting sick believing that value to be particularly low–cost-benefit analysis is not how we usually work through health issues. The value function is a particularly important tool in economics, and allows individual and public prevention decisions, as well as providing a strong incentive–if I were to tell you that your wellbeing is worth $720, you wouldn't think twice in paying $16 to get vaccinated. At the same time, public officials considering the high costs of vaccine campaigns, might decide how many individuals to vaccinate for free based on the individual calculations of anyone deciding whether to get vaccinated or not: the implications of a value function are many.

Economic analysis goes much more into singular detail in epidemics, but these would be far from the discussion of this chapter. The small introduction to the topic of epidemics' economics will prove to be sufficient for the rest of the analysis, which will focus more on a descriptive, rather than mathematical approach to the relationship of economic changes and infectious diseases.

ECONOMY AND EPIDEMICS: FOUR EXAMPLES THROUGHOUT HISTORY

1347 PLAGUE AND HIGH MIDDLE AGES ECONOMY

Historians believe that the high middle ages represent the first real demographic growth observed in the world, "Historical demographers suggest that the number of inhabitants in the 10th century was not so different from that of 5 centuries before and that between the 10th century and 1300, European population

[61] $C_i = U_s - U_i$
[62] https://labor.ny.gov/stats/ceshourearn2.asp
[63] a simple mathematical computation: (30*8)10=2400=U_s, $\pi = .70$, $C_i = 2400 - 0$ $(assuming\ that\ monetary\ utlity\ is\ 0\ when\ ill)$ $V_s = 2400 - (.7)(2400) = 720$
[64] Costs for a vaccine for Influenza age 18 years and older https://www.cdc.gov/vaccines/programs/vfc/awardees/vaccine-management/price-list/index.html

doubled". (Malanima 2010) Sign of one of the most important economic rebirths of Europe after the dark times of the Middle Ages, 1300s Europe had seen great social and technological improvements, as well as new continental interconnectivity. The 12th Century saw the birth of the first commercial agreements, with the creation of the Hanseatic League which allowed a free trade between almost all the biggest ports in Europe of the time. Moreover, the favorable weather conditions allowed very high yields in crops, allowing better nutrition and good trade. The 11th and 12th century were definitely periods of great economic expansion, with strong cultural movements associated with it. (Clark 2003) Figure 13 shows an estimated real wage for carpenters with the annexed approximated population growth experienced in Europe from 1200 to 1500. Historians give much credits to improvements in technology and advancements in commerce, but why do wages seem to be dropping? Clark suggested that this is just an apparent effect of the big demographic changes of the period.

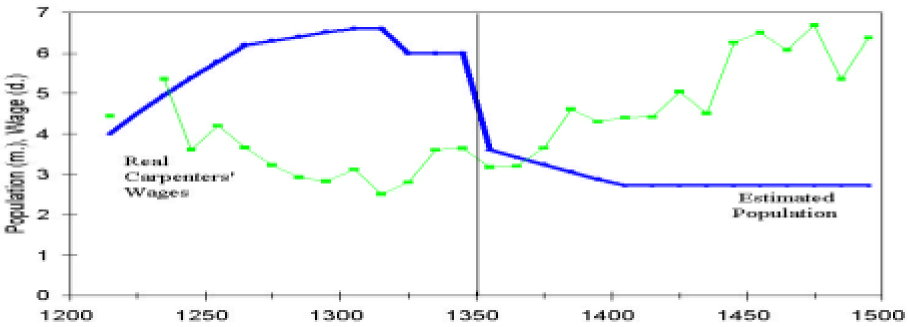


Figure 12- Carpenter's real wages and estimated population 1200-1500

Source: Clark, 2003 "Microbes and markets: was the black death an economic Revolution?"

This is the significant feature of the century, which was characterized first by high birth rates and low mortality, then the opposite (2003). Most of the later economic success experienced all throughout Europe is largely credited to the advancements that were initiated in the High Middle Ages. (Pamuk 2007) the late 1200s saw the first urbanization of the bigger cities in Europe, and perhaps the elongated economic expansion of the continent was part of the reason it crumbled under the Black Death; unrestricted growth, while beneficial for the overall prosperity of the continent, left Europe susceptible and off-guard–managing over double the population proved to be hard. The Bubonic Plague is a great SIR Model: with very high infectivity, and quick removal periods (usually the disease developed over the period of 10 to 15 days, and almost no one survived contagion) it was devastating and swift, and spread through the continent largely thanks to the social growth that preceded it. The effects of the Plague after 1351, the last big wave, are complex. Some, like Clark, claim that the effects were more apparent than realistic, as progress in the Middle Ages had always been relatively slow for the previous 3 centuries as well. Only demography had seriously accelerated, making the stagnation of the period after the Black Plague almost regular if put in context of the whole historical era (2003). Other economic historians suggest that the Black Plague was perhaps part of the biggest economic revolution in Europe because of its demographic shock that contained the previous demographic boom, "modern economic growth and the Black Death are the two events that led to the most significant changes in wages and incomes during the last millennium". (Pamuk 2007) Effects remain speculated upon, mainly because all that economists can rely on are approximated measurements–real wages, value on land, and rents–which are hard to quantify consistently throughout more than a decade. Regardless, rents per hectare as estimated by Clarks never fully recovered to pre-plague levels, signifying a sure economic stagnation, which might have contributed to the growth in wellbeing in the coming centuries. (2003)

1918 INFLUENZA AND POST-WAR ECONOMIC GROWTH

The Industrialization of the United States and of Europe is perhaps one of the most significant economic growth periods in modern history. The 1800s brought innovation in technology, rapid expansion of cities, and growth in population–germ theory was discovered in the late 19th Century, greatly improving the private sanitation and overall hygiene of cities and citizens. People were now living for much longer than before–we see the first symptoms of the big demographic transition of the world with rising birth rates and lower fertility rates. The process of growth experienced by our modern society (a tremendously complex machine, with a vast number of moving parts) began in the Industrialization, often cited by economists and historians as a period of economic transformation with the appearance of new transportation, automation, and a deeply connected global society. Industrialization in the Western world was the first, major factor that increased overall wellbeing, increasing for the first time GDP per capita substantially. Figure 13 shows the remarkable increase in personal wealth experienced in 1800. It is impossible to miss the staggering difference between the earlier periods, which puts the industrial Revolution of the 19th century as the single most significant growth in wellbeing in modern history.[65]

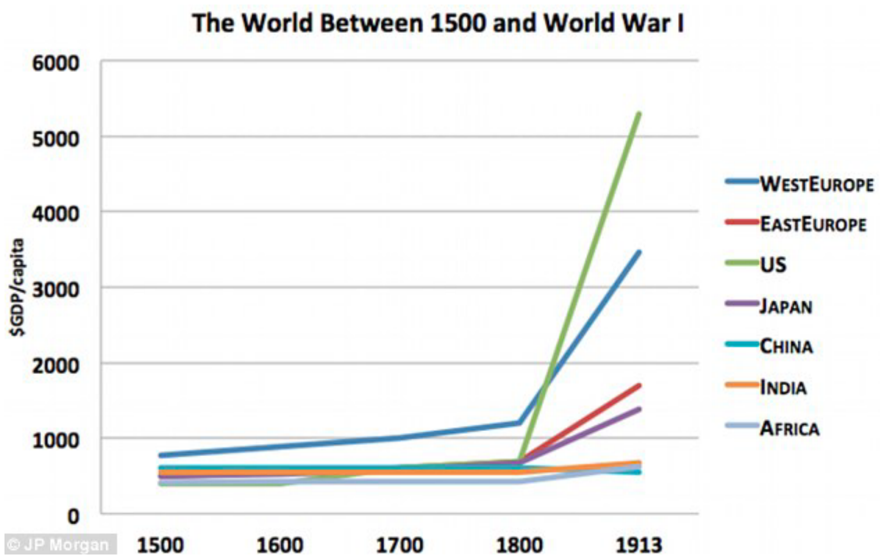


Figure 13- GDP per Capita Growth 1500-to WWI

Source: JP Morgan

[65] http://www.dailymail.co.uk/news/article-2163610/Fascinating-new-graph-shows-economic-history-world-Jesus.html

The early 20th Century, a product of the fast and constant growth of the previous period, also saw the break out of the first major war, which showed the new world society for the first time as a politically interconnected body. The above graph allows us to see that most of the actors of the First World War entered the conflict at the high tide of the economic ramp of the 1800s. the Western world experienced a societal revolution, and the break out of the Spanish Influenza is a sign of this unparalleled growth. The first modern global pandemic infected one quarter of the United States population and killed over 600 thousand people in the North American continent. (Bell and Lewis 2005) Also modeled as an SIR, the influenza of 1918 was trivial because of its high virulence and low survival rates in the working age cohorts ranging from 19 to 44. The demographic effects because of this were severe, "The only other demographic crisis of a similar order of magnitude to the influenza epidemic is the tremendous increase in mortality experienced by the working-age population in the countries of the former Soviet Union in the early 1990s." (Brainerd & Siegler 2002) The epidemic is in fact often portrayed with its "w-shaped" mortality rates, with big dips in the younger and older generations and a high peak in the middle, figure 14 portrays this high mortality in three main age groups: toddlers with less than a year, senior citizens, and the 19-44 age group.

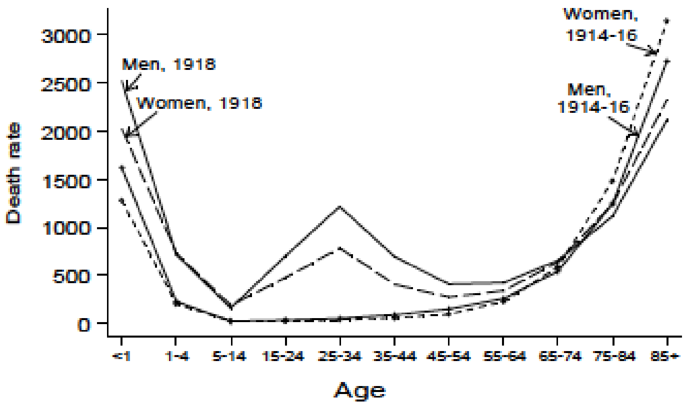


Figure 14-mortality rates per age structure of the 1918 influenza

Source: Brainerd and Siegler 2002 "The Economic Effects of the 1918 Influenza Epidemic"

Its virulence in this specific age cohort is unclear, but evidence suggests that it might have been because of the high quantity of younger people at the beginning of the 20th Century–the changing demographic structure of the world at the end of the Industrialization yielded a much younger world population, which suffered the biggest consequences in the epidemic. The economic effects have been deeply studied, and remain ambiguous. Brainerd and Siegler (2003) tried to assess the economic impact of the disease by plotting per-capita income before and after the flu waves, registering two interesting effects: a rise in per-capita income right after the pandemic in the United States, but a Great Depression less than 10 years after that.[66] An economic stagnation also took over the United States throughout the 1919, a proof of the missing labor force killed off by the flu and the war. Maureen and Lewis (2005) arrive at the following conclusions:

[66] The authors derive these effects with caution and uncertainty as data are sometimes inconsistent and deriving long-term effects is always difficult, however they do find a certain correlation.

> the higher the death rate due to influenza and pneumonia in 1918-19, the greater the proportional increase in real per capita income between 1919-21 and 1930. One explanation is that the heavy, but short-lived concentration of deaths among the most productive age groups in 1918-19 caused an immediate reduction in real per capita income, a shock from which the level of the latter progressively recovered over the years that followed, and so resumed its earlier long-term path. The larger the shock, the stronger was the transient element representing the recovery.

Keeping in mind the utility functions discussed earlier in the chapter, we can understand how the total utility of the world population fell short through and in the period immediate after the outbreak. Epidemic modelling can help us come to terms with the speed and difficulty in the containment of the Spanish Flu; clustered cities made contacts frequent, multiplied by a high probability of contracting a disease, the epidemic reached its threshold likely before it was even discovered. The longer incubation period, which rendered the disease more lethal, allowed infective individuals to infect more susceptible citizens before dying, "If people die from an infectious disease it is better that they die fast for the purpose of ending the epidemic" (Tassier 2013) might seem like a sinister phrase, but it is terribly realistic; epidemic modeling tells us that the faster an individual is removed (or recovers) from a pathogen, the better it will be for the population as a whole–this was not the case of the 1918 flu, which swept rather quickly through the world because of it took a long time for detection. Of course, the public response to the flu was a failure, and part of the reason why it took the world over 3 phases to terminate the pandemic. Poor communication of the United States, which initially recognized the disease as "a common flu", allowed soldiers to go to Europe and spread the pathogen. (Marueen and Lewis 2005) Public health was put to the test with the 1918 Influenza, unfortunately miserably: it took far too long to single out the pathogen and offer a cure, and the poor global relationships caused by WWI made fighting the disease a complicated geopolitical task.

1957 FLU AND THE GOLDEN AGE OF ECONOMIC GROWTH

World War II brought, especially to the Western society, unusual prosperity. The most significant changes from the second global war were the technological innovations that it produced–from micro waves to house fridges and the TV, the world saw a revolution in its way of life. We see in the period a significant growth in cities all of the world, with the rise of "the suburbs" trend–living farther away from the industrialized city centers, urban expansion soared in the years immediately after the war: "In the second half of the twentieth century, the lives of Europeans were transformed almost beyond recognition. In 1950, many of the continent's residents heated their homes with coal, cooled their food with ice, and lacked even rudimentary forms of indoor plumbing"[67] (Eichengreen 2007). Geopolitical balances, too, saw some major reconfiguration, as the five "winners" of the world created the first global alliance for peace and shaped what would become modern

[67] http://www.nytimes.com/2007/03/25/books/chapters/0325-1st-eich.html

global politics. GDP per capita in the European continent tripled in the whole of the 20th century, as working-hours, leisure time, and overall quality of life significantly increased: the modern commodity life defiant of our time was slowly taking shape. (Eichengreen 2007) the 20th Century is often dubbed as the golden age of economic development, which offset what would later become the “developed” and “underdeveloped” world, dividing countries as “borrowers” and “lenders”, and establishing the Western cultural hegemony of Liberal Democracies. Rapid technological change, war reparations and capital stock reconstruction all helped the surprisingly quick convergence of the European economy to the American counterpart. Post WWII saw the emergence of worker’s right and unions, better trade contracts and the development of savings; Bergeaud, Cette, and Lecat (2015) recently plotted a detailed growth of GDP per capita in the 20th Century for Continental Europe, Japan, the United States and the United Kingdom[68] reporting an annual 2% growth from the 1890 to 2013 on average. They recognize “The second industrial revolution, which corresponds mainly to the diffusion of a massive use of electricity and of the internal combustion engine, to the development of chemistry with petrol chemistry and pharmaceuticals, and to the development of communication and information innovations” as the biggest peak in production and overall life improvement in modern history. Figure 15 is the modeled growth of the represented countries in their survey; note the peaks for GDP per capita growth around the period of the first half of the 20th century, right at the end of the war. It is interesting to also observe the effects around the time of the Asian Flu pandemic in 1957, which seems to have no visible effect on the continuous growth, peaking approximately in 1966. This is peculiar, but should sound familiar by now–the effects in the short-run of epidemics on economic growth are non-existent, but it should come to no surprise that less than 5 years later Japan started its decline of after almost 20 years of continuous growth. This is because GDP per capita will suffer the effects of the loss of the work force when it goes back to normal levels of production. Demographic shocks tend to have a long adaptation period, and the medium-run is a much better observatory for economic significance.

[68] The UK is often portrayed as independent of European Union because of its pioneering in Industrialization, it would skew results too much if considered with the rest of Europe

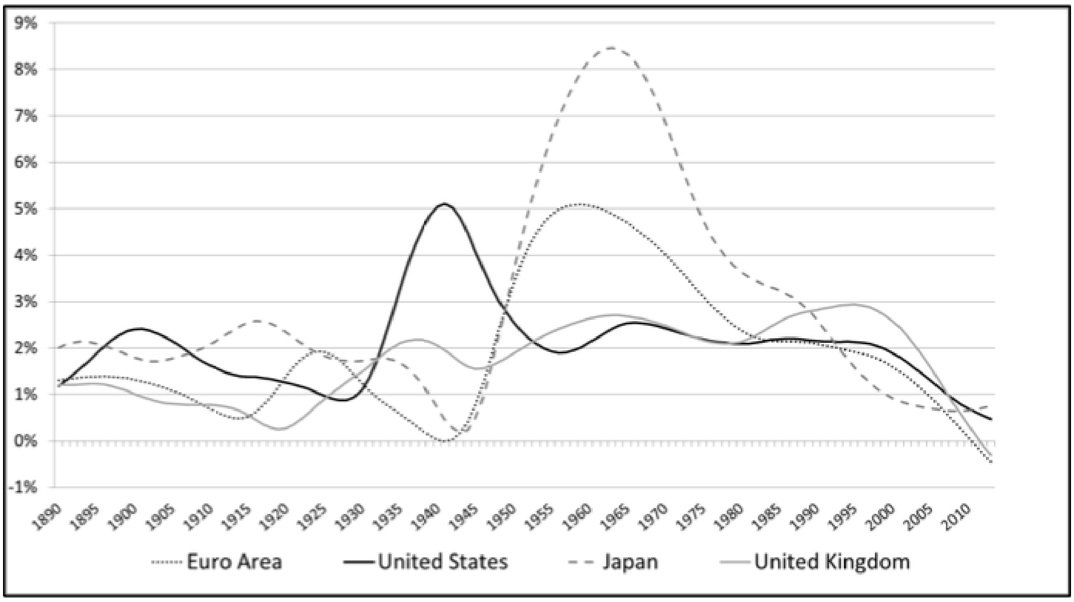


Figure 15- GDP per capita growth in % from 1890 to 2013 for Europe, US, Japan, and the UK

Source: Bergeaud, Cette, and Lecat 2015 "GDP per capita in advanced countries over the 20th Century"

The 1957 Asian flu was in fact much more detrimental to Asia than to the Western World, however we do see some economic deceleration in Europe as well around the 60s right after the breakout of the pandemic. It was not, although, particularly deadly in the US, killing approximately 80,000 people–a fraction considering the 600,000 of the Spanish Influenza. (Potter 2001) Europe and North America had stabilized their growth in the previous Industrial Revolution, so the second wellbeing growth wave was less hectic and more structured–urbanization was bounded to cities that were much better prepared, and technological innovation paved the way for the economic revolution of the 40s. The same could not be said about Asia, which experienced little of the benefits of the 1800s Industrial Revolution and saw after the Second World War its first major growth in wellbeing. It came although at a complicated time: no reparations were payed to the Asian countries like the ones to Europe, and two atomic bombs were dropped on its biggest economy–Japan. Moreover, the devastating famines that ruptured the Chinese society during the Mao dictatorship–an epidemic that would deserve an analysis for itself–hindered greatly the development of the Asian economy in a period of great global prosperity. For this reason, growth in the 40s in Asia paralleled that of the Western World at the end of the 19th Century, and the parallel Influenza pandemic are an interesting case to analyze. The Asian situation was, then, critical: on the verge of a massive growth sprout, but unprepared and underequipped to truly exploit this opportunity. It is often argued that the breakout of the flu in 1957 was a key factor in the offset of the economies of the West and the East, staggering growth at a fundamental time in economic development for Asia (Bergeaud, Cette, and Lecat 2015). Unlike the previous influenza pandemic, the Asian flu kept the typical "U-shaped" mortality, affecting mostly the younger and older generations in society. This dropped investments and was one of the causes of the economic deceleration of the Asian economy of the mid 60s (Bergeaud, Cette, and Lecat 2015). With 4 million worldwide deaths[69], its low morbidity was largely due to a

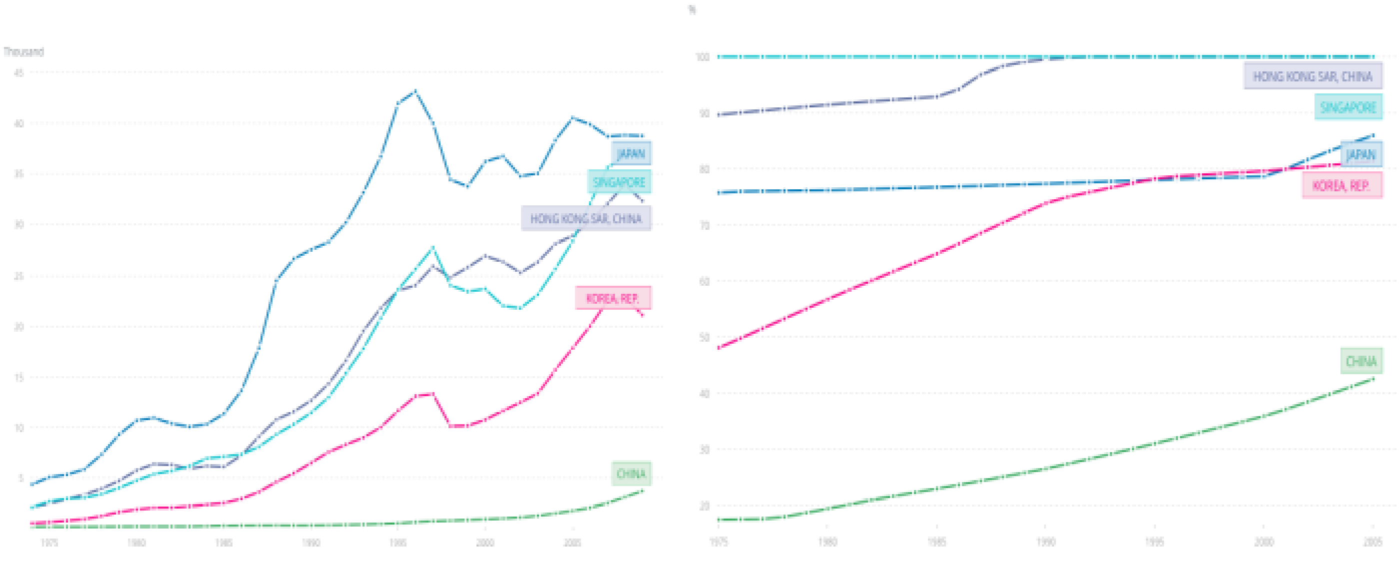
[69] https://www.britannica.com/event/Asian-flu-of-1957

good public health response by the newly established World Health Organization (WHO), which quickly identified the virus strain and provided a vaccination. The Asian flu proves to be an optimal example of international organization's efforts to stop a pandemic, and a lesson learned from the Spanish flu less than half a decade earlier. Technological innovation and global cooperation enacted a containment plan that reduced contagion by immunizing quickly the susceptible population, making the response to the Asian Flu the first modern epidemiological response to a health crisis.

2009 SARS AND THE NEW MILLIENUM

The turn of the latest millennium characterized the capitalist society of today. However, the economic development we will discuss for this period focuses much more on the Asian economy, where the 2009 SARS epidemic had the most serious economic effects. 2000 was "The Year of the Dragon" according to Chinese astrology, and an accurate description of the Asian economy of the 21st Century. Most manufacturing jobs, because of low production costs and plenty primary resources had started their swift movement in China (Nakaso 2015), while the industry soared, the Asian population also rose, having more than 2/7th of the total global population in its geographic area. Asia had set its path to becoming the leading world economy in the beginning of the century, and would soon lead the world into modernization of automation and mass production. GDP per capita in all the Asian continent rose steadily in the late 20th century, and life dramatically improved–cities expanded enormously and was followed by quick urbanization (Nakaso 2015). Compared to the previous 70 years, there were massive reductions in overall poverty and an increase in skilled labor. Educational investments also steadily rose, and Asia saw the intellectual revolution that swept through the Western world in the previous two centuries take over its culture in less than 50 years. Truly a dragon, the Asian economy rocketed to competitive levels after a crushing dictatorship and deep political fissures. It is only right to note that this development came to a cost: political economy in Asia grew on a much more centralized basis, and democratic values were withheld in order to favor an instantaneous recovery and colossal rebirth of the area. Most Asiatic countries opted for one party systems, which guaranteed citizens significant improvements in life standards at the cost of their liberal political rights. Figure 16 shows the real growth of the biggest Asian economies measure as GDP per capita and percentage of people living in urban areas. Notice the steady growth reached around the year 2000 in GDP per capita, defined by the Asian positon of "factory of the world", increasing "global trade volumes dramatically with trade liberalization and direct investment growth" (Nakaso 2015). The mixture of low-cost highly-skilled labor force provided by the Asian economy created an alluring prospect for the emerging businesses of the west, increasing the capital international investment flow noticeably– this allowed for a constant urbanization of Asian cities.

The fear remained that Asia would develop upon an unsustainable class, which was partially true–while development was quick and GDP per capita rose steadily, Asia still saw some major problems managing poverty–wages did rise, but still remained relatively low for a long time.



(a) (b)

Figure 16- (a) GDP per capita Growth of 5 major Asian economies 1975-2005; (b) Percentage of people living in urbanized areas of 5 major Asian economies 1975-2005

Source: worldbank.org

This in part explains the effect that the SARS epidemic of 2009 had not only on the economy, but on the population as well. The epidemic was not particularly violent, and affected the Asian society in three waves: first by infecting manual livestock workers which had little access to healthcare, then the communities infected shortly after that, and finally the doctors in the moment of treatment.[70] The tightly packed megacities of China made every sneeze a potential threat, and virtually unavoidable. The 2009 SARS epidemic can be modeled as a SEIR because of its stacked development and for its long times in the exposed category, which hit different parts of the population at different times. The low morbidity of SARS was due to the efficient public health response from the international community, which provided with extreme effectiveness immunization and a containment plan to the disease. The origin of the pathogen was quickly identified and a vaccine was provided to the "hotspots" of the epidemic: hospitals. It was recognized that the high infection of health workers was creating a vicious cycle of contagion, so the first response was to immunize those working in hospitals. China and Singapore initially hid the break-out of the epidemic, undermining the virulence and claiming international action was non-necessary, afraid of losing the wave of international tourism and investment; Bell and Lewis (2005) estimate that those fears were well-established: "In Taiwan, nearly a million people were quarantined in mid-May, and the inhabitants of many large cities in East Asia responded to the threat of infection by staying at home voluntarily. Removing the related effects of the Iraq war, SARS

[70] https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-3-19

cost the region nearly $15 billion, or 0.5 percent of GDP" concluding that SARS developed to be an "occupational hazard" scaring workers to not move from their home. The effects were felt in all branches of the economy, from the financial sector to the blue-collar class; the absence of workers from their job preoccupied investors, which quickly backed out of plans–premiums on financial instruments for China-related (Eurobonds) declined from 140 in April of 2009 to a mere 40 in August of the same year (Bell and Lewis 2005). The fear of catching the disease anywhere in the city made citizens avoid social contact, and those effects manifested themselves in a 50% reduction in restaurant sales in Japan and Hong Kong. The whole of Asia lost between 20-70% of tourism flows in the period of the epidemic (Bell and Lewis 2005). The effect of SARS prove to be interesting from an economic point of view, as it clearly shows the deep connection between the two fields of social studies. While not violent and surely short-lived, SARS had long-lasting economic effects which showed the Asian continent its fragility and dependency on the international market.

CONCLUSIONS: ARE ECONOMICS AND EPIDEMICS RELATED?

With this concluding chapter, I tried to analyze in more detail the epidemics mentioned in the previous chapters to try to come to terms with the real effect of epidemics on economics. I have made some stylistic choices, namely to analyze 4 epidemics, two of which affected more the west, and two which affected more the Asian countries–this was done because of the different velocities at which the two areas of the world developed. It is with no doubt that we can assess that epidemics largely impact economics, but the relationship between the business cycle and the spread of infectious diseases is rather interesting. Since economic expansion also expands populations, epidemics–which as we have seen seem to happen shortly after big economic growth periods–seem to act like natural "checks and balances". All the epidemics described above contributed to some kind of later natural improvements, making their outbreak of importance for development as well as containment, proving the world that fast and uncontrolled economic development is as dangerous as beneficial to a country. Regardless, the interconnectivity of the two fields makes epidemiologic modelling of outermost importance for economists and epidemiologists alike. The possibility to analytically approach the spread of an infectious disease allows for efficient action in order to counter it. This last chapter should in fact serve mostly as a proof of the importance of rapid health response, which relies on proper economic resources' allocation. Both economists and epidemiologists will find common ground in comprehending the reality of finite resources, and in both fields a trade-off is always necessary–this proves to be much easier said than done. Finally, the chapter should serve as a lesson of prevention; economics can tell us that it is expensive to vaccinate the whole population, but the costs are much higher in trying to contain it and eradicate it, the SARS example tried to prove that the economics of prevention should make-up most of the spending and planning involved in epidemiology. Today, a lot is done but perhaps not enough. A word should be discussed on the purposeful choice of not including the AIDS epidemic in this research, which has outperformed in duration, mortality, and social-economic effects arguably all the mentioned epidemics. This was because the effects of AIDS/HIV are extremely complex, and we have yet to observe them. The detrimental costs to the African economies, which still struggle to estimate the number of infected individuals and to provide anti-retroviral drugs are starting to come up now with the demographic transition of the continent. Without doubt, the pandemic has contributed greatly to the hindering of the economic development of Africa, but opinions still remain divided on whether these effects will be long-lasting or not. Regardless, the field of the AIDS/HIV pandemic is rich in content, and I felt as my short contribution would have been too simplistic and inaccurate–a whole other work should be done solely on the topic. I also avoided the most recent Ebola epidemic, which on the contrary has very little literature on the economic effects of the infectious disease and had small historical context. The idea of this research was to observe the historical development of the relationship between two the two sciences, and analyzing a 2014 outbreak seemed out of context.

CONCLUDING REMARKS: HEALTH IN AN AGE OF GLOBALIZATION

From this analysis, it may seem that pandemics are a thing of the past–nothing could be farther from the truth. As our society progresses, inevitably so do the things that affect our health; the purpose of taking into consideration economics, the most anthropocentric sciences of all, is precisely to highlight the central role of humans in the development and spread of infectious diseases. From the previous chapters, a common trend should have emerged: the outbreak of any of the epidemics was always subsequent to some kind of societal disorganization and inaction. The consequences of excess growth and uncontrolled development have been historically detrimental, and have seemed to always be rebalanced by the breakout of epidemics. While we are more prosperous, healthier, and over all better off today than ever, the most fundamental problems are still far from being eradicated. While we might not be ravaged by some threatening pandemic, the challenges to our wellbeing today are perhaps much more complicated and consolidated in our society. We might provide cheap vaccines and potent drugs that can save us from life-threatening infections, but 20 million people, including 1.4 million children are suffering from lack of basic nutrition[71]. This, in a world that produces enough food to properly feed 10 million people in the United States alone[72]–indifference seems to be a ravaging epidemic for itself. "Americans throw away almost as much food as they eat because of a "cult of perfection", deepening hunger and poverty, and inflicting a heavy toll on the environment" explains Suzannne Goldberg in her 2016 report on humans' consumption, explaining that we waste 1.6 billion tons of food per year, "enough to cover 60% of London and all of the 5 New York boroughs, Jersey, and Newark". The key to our failure is unsustainability, which directly undermines the right of life to a more than a seventh of the world population–this has been true for the fight against infectious diseases too. The importance of food security is inarguable for our health, and it is ludicrous that we live in a society with so much excess where the majority struggles for a loaf of bread (Deaton 2013). This of course has detrimental effects on a myriad of aspects, but first and foremost on the environment around us–our way of production has completely changed our planet, and has exposed us to problems that were unseen before. Lack of water, for one, impacts our proper development and our hygiene–to this day, 663 million people live without access to safe water to drink, and over 2.4 billion lack basic sanitation standards.[73] I have shown how poor hygiene has been perhaps the number one cause in all the worst epidemics in history, and yet we allow this inevitably to happen. The biggest burden stands on the western society, which has for so long appeased the problem by narrow-mindedly dismissing any consequence from overconsumption and overproduction. We lack the empathic connection to repercussions if

[71] https://www.nytimes.com/2017/02/22/world/africa/why-20-million-people-are-on-brink-of-famine-in-a-world-of-plenty.html?_r=0

[72] https://www.theguardian.com/environment/2016/jul/13/us-food-waste-ugly-fruit-vegetables-perfect

[73] The water crisis has been often called an epidemic of the 21st century https://water.org/our-impact/water-crisis/

these last do not happen to us or to anyone nextdoor, making our society blindly unaware of the problem of changing climate and unsustainable development. (Jamieson 2012) Climate change is the single, most threatening pandemic of our time, and while it might seem far from being a health hazard, the direct consequences of rising temperatures are inherently on our health.

Climate change is a problem and a cause of inequality, something our generation will have to face with much more resilience. For as wealthier and better we are now, we are also more economically divided than ever (Deaton 2013). The social fissure of unequal opportunities expands itself to lack of access to a better health– people in Western Africa struggle more than us to obtain the life-saving therapy for malaria, although they account for more than 90% of the annual deaths from the parasite.[74] Wealth is the primal indicator of health, and we do not have to look at extreme cases like malaria to see how much inequality affects how healthy we are: in American society the infamous "longevity gap" between the poorest and richest 10% is of a staggering 14 years for men and 13 years for women[75]. The difference is chilling, and the reasons of the gap are many, but one is prevailing: Social Security is more accessible to richer people than poorer ones. Access to proper health care and cures is, intuitively, imperial to our wellbeing. The problem is undoubtedly also tied to eating habits, which diverge greatly from the bottom to the top–food is expensive, and healthy food even more. Highly caloric diets, full of added sugars and fats expose the less wealthy to a cohort of diseases (from diabetes to cardiovascular failure) that are expensive to treat and not very forgiving (Deaton 2013). The eradication of poverty is a public health mission as much as an economic development one, because an improvement on the overall wealth of the world is the key to a better health.

The lack of information on basic hygiene practices, the way diseases are spread, and proper waste disposal are a vital tassel to the fight against infectious diseases. "Diseases of poverty", a truly unsettling name, describes a cohort of infectious diseases that primarily affect poorer people; these are truly basic infections like diarrhea and tapeworm, which could easily be eradicated by providing proper sanitary education. Even the AIDS/HIV epidemic could be greatly contained in countries like Africa with proper sexual education standards–unfortunately, education is not filling the cultural void that could truly contain the problem. Locally too, the recent fight against vaccines[76] has contributed to a staggering rise in cases of measles (a disease virtually eradicated in the mid 90s) because of lack of education on the importance of vaccination.[77]All of these can be derived directly from our lack of action–the most detrimental disease of all.

I have described throughout this research our lack of commitment in the past, but I like to think positively in seeing a remarkable advancement in our society in wanting to create a more equal world. While I might sound pessimist and far too critical, I say this with a sense of purpose of wanting to change the future, a path that is certainly long, but already established by many great minds before me. In this research, I have done an

[74] http://www.who.int/gho/malaria/epidemic/deaths/en/
[75] https://www.brookings.edu/research/what-growing-life-expectancy-gaps-mean-for-the-promise-of-social-security/#recent/
[76] https://fivethirtyeight.com/features/facts-alone-wont-convince-people-to-vaccinate-their-kids/
[77] https://www.cdc.gov/measles/cases-outbreaks.html

historical analysis of the problems that our development has brought to our society to try to learn how to lead from behind–our past is after us, and we must not dismiss it but learn from it. It is important, with these last remarks, that we understand the deep interconnection of the system in which we live in, where economics and epidemics are only one of the countless interweaved disciplines that affect the advancement of our wellbeing. If one thing must transpire from this research, is that the work to be done is plenty, but that today, more than ever, we all understand that we need to change. The challenges of the future in our society might not present themselves all in the form of deadly viruses and bacteria: epidemiologists, economists, and social scientists alike must shift from the limelight the importance of our wellbeing to try to understand that the biggest threat is always the weakest link. If nothing will be done to improve those parts of the world that will suffer the most from future diseases, the direct repercussions will be on us. The health challenge of the 21st Century is to eradicate those problems that, in the past, have shown to be detrimental and fatally important to the spread of a pathogen: lack of hygiene, inequality, poverty, and inaction. My generation, and the ones to come, must understand the significance of this change in mindset in order to advance in the future.

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Riepilogo esecutivo

INTRODUZIONE: ECONOMIA E SALUTE

L'economia e l'epidemiologia sono scienze descrittive che potrebbero sembrare diverse, ma sono in realtà molto simili. Nella seguente ricerca, utilizzerò gli strumenti che entrambe le scienze forniscono in un contesto storico per spiegare lo sviluppo sociale ed economico del nostro mondo oggi. I rapporti di salute e di economia vanno ben oltre le loro caratteristiche descrittive comuni e possono essere utilizzate per descrivere l'un l'altro. Molta discussione nella letteratura è dedicata alla comprensione di come i cambiamenti economici e la diffusione di una malattia infettiva si influenzano realmente. Bhargava, Jamison, Lau e Murray (2001), ad esempio, hanno modellato i veri effetti economici della salute sulla crescita economica e hanno scoperto che il tasso di sopravvivenza per adulti ha influenzato notevolmente la crescita economica, ma soprattutto nei paesi a basso reddito; gli effetti sono molto meno evidenti nei paesi sviluppati. Infatti, rimane discusso se le epidemie siano in realtà dannose per lo sviluppo economico dei paesi. Alcuni, come Pamuk (2007) e Clark (2003), guardano gli effetti demografici che le pandemie hanno sulla nostra società e osservano una "rivoluzione" nel lungo termine dei cambiamenti nella struttura della popolazione, osservando una tendenza generale di crescita nei decenni successivi di un'epidemia. Le critiche a questo approccio, come quelle di Deaton (2003), sostengono che questi sono solo effetti apparenti, in quanto inevitabilmente quelli che soffrono di più dalle epidemie sono i meno ricchi, quindi apparentemente diminuendo i livelli di povertà, ma i reali effetti vanno analizzati sulla forza lavoro e le uscite di un paese. Indipendentemente da ciò, è ovvio che molto più è a lavoro nel rapporto tra economia e epidemie, ed è importante calcolare l'importanza delle epidemie quando si analizza il meccanismo tra salute e evoluzione della società.

Ho deciso di concentrarmi di più sulle crisi sanitarie, piuttosto che sulla salute nel suo complesso, per due motivi principali. Innanzitutto, le crisi sanitarie si verificano in punti definiti della storia e consentono quindi una valutazione molto più dettagliata dell'effetto sui cicli economici quando analizzate. In secondo luogo, le crisi sanitarie sono generalmente gateway a miglioramenti, per cui dimostrano di essere un ottimo punto di partenza per un’analisi dell’avanzamento, non solo nel settore medico, ma anche a livello sociale e politico - lo vedremo ulteriormente. Tuttavia, le epidemie non hanno un effetto determinato sull'economia ed è difficile disegnare una linea conclusiva sull'intero argomento; Per questa ragione, la mia analisi sarà su tre aspetti principali che sono, inevitabilmente, in constante cambiamento con il tempo, lo sviluppo e la crescita. Ho individuato tre principali caratteristiche sociali che favoriscono la diffusione di una malattia infettiva: i cambiamenti nella popolazione, i cambiamenti nell'interconnettività delle persone e i cambiamenti economici. Con queste tre variabili, analizzerò innanzitutto il loro significato singolarmente, spiegando poi il loro rapporto con l'epidemiologia per infine osservare le loro interazioni applicate in alcuni casi specifici, per cercare di dimostrare il loro effetto sullo sviluppo di un'infezione e l'avanzamento del nostro benessere. È senza dubbio che le epidemie sono un fenomeno sociale quanto naturale, e vorrei concentrare gran parte dell'attenzione del lavoro su questo argomento - piuttosto che affrontare l'argomento in modo analitico, ho cercato di esporre la ricerca da una prospettiva sociale. Le epidemie hanno cambiato paesi, hanno modificato le società e ci hanno inevitabilmente incoraggiati a progredire. A differenza dei disastri naturali, i danni epidemici sono molto più sottili e richiedono uno sviluppo più lungo; Per questo motivo, sono in gran parte analizzati periodi che vanno da un intervallo di tempo da 5 a 20 anni per cercare di valutare gli effetti economici di una malattia. Questa scelta stilistica è perché, come dimostrerò, le epidemie potrebbero sembrare avere effetti quasi positivi sulla ricchezza personale durante o subito dopo la loro diffusione: una prevenzione che ho cercato di controllare con questo stallo temporale. Dovrei anche indicare che questa non è una valutazione rigorosamente economica, visto che già molto è stato fatto a riguardo da ricercatori ben più qualificati di me–un'analisi del genere avrebbe reso quindi il mio lavoro ripetitivo e poco originale. Invece ho cercato di fondere diversi settori delle scienze sociali per mettere in un unico lavoro l'essenza di tre macro aree di ricerca, cercando di giungere a alcune conclusioni comuni.

Gran parte dell'attenzione sul significato del rapporto tra economia e epidemiologia è sui costi della sanità pubblica, come è giusto che sia. Per questa ragione, parlerò anche ampiamente delle risposte, delle spese e dei contributi della sanità pubblica - spesso troppo sottovalutati - al miglioramento del nostro benessere. Una famosa ricerca di Angus Deaton e Daniel Kahneman (2010) discute il fatto che, anche se la ricchezza inevitabilmente rende più facile per essere più felice, non esiste una correlazione diretta tra i due campi, e infatti il valore del denaro "ci rende più felici" è Fissato a circa 75.000 dollari. La felicità è essenziale per i nostri benessere, gli economisti comportamentali ei medici saranno d'accordo su questo fatto, ma se il denaro infatti non compra "la felicità" allora perché sembra che le persone più ricche siano sicuramente più sane? In questa ricerca cercherò di sottolineare il fatto che una minore accessibilità alla cura e all'igiene adeguata, inevitabilmente legata alla ricchezza, tendono ad sovrappeso all'importanza della felicità nella nostra equazione sanitaria personale e come la minore salute renda inevitabilmente meno felici: è un ciclo vizioso. Mentre potrebbe sembrare talvolta grottesco, il contesto della mia ricerca è positivo: come una fenice dalle sue ceneri, la nostra società ha visto la sua rinascita da pandemie devastanti e la mia analisi spera di evidenziare la nostra forza nonostante i nostri fallimenti. Spero di aver creato qualcosa di significativo e non troppo ridondante.

DEMOGRAFIA E SALUTE

"La battaglia è finita", dice Paul Ehrlich aprendo il suo libro "La bomba della popolazione", "Negli anni 70, centinaia di milioni di persone stanno per morire di fame " (xi). Ehrlich naturalmente si riferiva alla relazione infinitamente complessa tra economia e demografia, un problema risorto negli anni '70 che affligge economisti e matematici da oltre 3 secoli. Le ideologie malthusiane dello sviluppo economico mondiale in relazione alla crescita della popolazione erano la credenza primaria in demografia all'epoca: la popolazione era cresciuta esponenzialmente dalla Seconda Guerra Mondiale, una percentuale senza precedenti nella storia dell'umanità. (Bloom et al., 2001) Ancora oggi, tre decenni dopo il libro di Ehrlich, e quasi tre secoli dalla teoria della crescita della popolazione di Malthus, la situazione sembra simile. Con oltre sette miliardi di persone al mondo (Bloom et al., 2001) e la popolazione in Asia e nei paesi in via di sviluppo ancora in crescita, le proiezioni migliori suggeriscono un aumento di circa 2 miliardi di persone in meno di 30 anni. Mentre le logiche di crescita malthusiane sono state oggi generalmente viste come erroneamente pessimistiche, alcuni aspetti delle sue osservazioni potrebbero fornirci un utile punto di partenza per un'analisi importante: il problema dello spazio. Quando parla della popolazione del mondo, Malthus ha visto un problema di allocazione delle risorse e spazio fisico. Ai livelli di produzione di allora, con un numero di nascita esorbitante- molto più alto del numero di decessi - lo spazio per la produzione di cibo sufficiente per nutrire tutta la popolazione del mondo sembravano mancare. La teoria malthusiana della crescita, naturalmente, non poteva tener conto dello straordinario sviluppo economico dell'America Latina e dell'Asia che ha raggiunto la maturità economica negli anni '80. Inoltre, non ha potuto prevedere la transizione demografica che l'Europa e gran parte del mondo dell'Occidente ha avuto dall'inizio degli anni ‘80. Tuttavia, pur lontano dai problemi dei mezzi di produzione, è difficile respingere il problema dello spazio che Malthus osservò nel XVIII secolo. Una popolazione in crescita significa inevitabilmente meno spazio.

I cambiamenti demografici non rientrano semplicemente nei tassi di fertilità e mortalità e la popolazione del mondo dovrebbe essere vista come una grande macchina con vari componenti. I cambiamenti più importanti sono tre:

- Quelli strutturali, cioè i livelli di dipendenza dei non lavoratori con la parte di società attiva nell'economia.
- Quelli di eguaglianza, cioè le differenze in benessere e prosperità che cambiano continuamente con il crescere della popolazione.
- Quelli ambientali, cioè il cambiamento dell'ambiente in cui viviamo, l'urbanizzazione, e il sempre più ravvicinato contatto con tutti.

Questi tre meccanismi a loro modo rendono la nostra popolazione continuamente più esposta a malattie infettive e suscettibile a cambi improvvisi. Le popolazioni diventano inevitabilmente più anziane, rendendoci tutti più suscettibili a malattie non solo infettive, ma anche croniche. Questo processo di invecchiamento continuo ha un effetto decisamente negativo sul nostro benessere, ma anche sulla nostra economia, creando una società sempre meno produttiva.

"Salute è sinonimo di ricchezza" è un meccanismo molto studiato nel campo dell'economia, ed una crescita della popolazione rende parte della popolazione inevitabilmente meno ricca. Queste disparità creano delle diseguaglianze nelle provvisioni sanitarie pubbliche che mettono a repentaglio la parte più suscettibile della società.

La sovrappopolazione, in particolare, crea società più connesse e più legate una all'altra, di conseguenza anche più "infettive": più siamo, più contatti sociali avremo e più le malattie riusciranno a trasmettersi nelle nostre comunità. Possiamo osservare questo meccanismo attraverso vari eventi storici, dove la crescita della popolazione ha avuto effetti sulla nostra intreconettività ed ha favorito il contagio della nostra popolazione. Il primo esempio è la Peste Bubbonica del 1347, che ha contagiato tutta l'Europa in meno di 4 anni, uccidendo quasi 1 quarto della popolazione totale del mondo, che ha "sfruttato" le nuove tratte marittime del XIV secolo per contagiare tutto il continente. L'influenza spagnola del 1918, una delle epidemie più devastanti della storia, ha girato tutto il mondo grazie ai veloci metodi di trasporto nati dalla seconda guerra mondiale, arrivando fino alla punta dell'Sud Africa dalla sua nascita negli Stati Uniti in meno di 3 anni. La SARS del 2009 ha usufruito egualmente delle città sovrappopolate dell'Asia del XXI secolo, rendendo una comune polmonite acuta una pericolosa epidemia.

I NETWORK E LA LORO IMPORTANZA NELLE EPIDEMIE

La scienza dei network è estremamente complessa, con implicazioni che vanno dalla fisica alla sociologia. Per questo, la mia ricerca cerca solamente di introdurli nel contesto epidemiologico, evitando di divagare in spiegazioni fin troppo tecniche e fuori dalla mia portata. I network, molto semplicemente, sono un modello grafico che rappresentano la relazione tra due attori diversi, e sono fondamentali nella ricerca epidemiologica per capire l'azione pubblica da intraprendere nella risposta ad una malattia infettiva. Analizzare le relazioni sociali, però, è al quanto problematico: ci troviamo a dover categorizzare tra relazioni strette e formali, entrambi di estrema importanza per il contagio di una malattia, l'analisi diventerebbe eterna se dovessimo stare a dissezionare ogni contatto sociale che porta ad un contagio, ed ogni soggetto diventerebbe un potenziale super-conduttore per la contaminazione. Quindi, in epidemiologia gli attori nei network sono solitamente dei luoghi e le connessioni i soggetti infetti; in questo modo, siamo in grado di mantenere sempre stabili i parametri di analisi, per poi agire sempre sugli stessi attori nel caso necessario. Quindi, per esempio, si parla di aeroporti e città quando si va ad analizzare un punto centrale di un'economia, al posto di individui che contraggono la malattia.

La definizione dei network è data in base alla loro connettività e quando parliamo di attori, definiamo la loro "centralità" in un network per capire la loro importanza (ovvero, quanto sono connessi). I network, nel corso della storia crescono–questo è dato dal fatto che il mondo è sempre, inevitabilmente, più popolato e le città continuano a crescere. È però difficile riuscire a tracciare la crescita storia dei network sociali, fondamentalmente perché ciò che disfinisce una relazione sociale è una caratterista difficile da quantificare (come facciamo a sapere se le nostre relazioni oggi sono migliori o peggiori di quelle dei nostri antenati? Come facciamo a sapere se siamo più o meno connessi?) quindi è necessario trovare delle misure alternative per definire la crescita dei network nella storia. Con l'avanzare del tempo progredisce anche la tecnologia ed il trasporto; queste due misure, che in qualche modo ci "aiutano" ad essere più connessi tra di noi, risultano essere delle buone metriche per definire il livello di connettività di ogni secolo. Per esempio, se confrontassimo la tecnologia di comunicazione nel 1347 quando è scoppiata la Peste con il secolo storico prima, noteremmo dei netti miglioramenti. Lo stesso vale per il confronto tra il 1347 ed il 1918, dove il trasporto pubblico ed il modo in cui comunichiamo ha reso la distanza tra le persone molto minore. Da questo possiamo trarre che i network, con l'avanzare del tempo, si espandono e noi diventiamo sempre più interconnessi. La connotazione negativa è chiara nel caso della SARS del 2009, che ci ha messo una frazione del tempo che ci mise la peste o l'influenza Spagnola ad attraversare il globo ed infettare gente in America dalla Cina. l'interconnetività è dunque direttamente correlata con i cambiamenti demografici, che a loro volta sono un punto focale per lo sviluppo e la diffusione di un patogeno nella società.

Un articolo recente del New York Times intitolato "chi è più popolare vive più a lungo" spiegava come, un gruppo di biologi, ha scoperto che il contatto sociale attiva dei geni umani che migliorano il nostro sistema immunitario. Un meccanismo primitivo, i ricercatori spiegano come, per motivi di autodifesa da possibili infetti nella propria comunità, stare in comunità provvedeva un modo per creare anticorpi. Studiando soggetti per lunghi periodi che si autodefinivano più o meno "popolari" (definito non solo in base alle relazioni amichevoli, ma a quelle familiari e a quanto tempo si passava in genere fuori casa settimanalmente) hanno scoperto che essere popolari incide sulla longevità della vita e sul miglioramento del proprio sistema immunitario in più del 90% dei casi. Una scoperta strabiliante, che fa rivalutare effettivamente il valore dell'essere in un mondo sempre più connesso: ci rende più suscettibili alle malattie infettiva, ma allo stesso tempo potrebbe renderci più forti.

ECONOMIA ED EPIDEMIE

Il seguente capitolo analizzerà quattro periodi di crescita economica globale nella storia. Legato a questo, introdurremo quattro grandi epidemie che hanno seguito queste crescite nella prosperità. Tenendo presente le dinamiche discusse nei capitoli precedenti, mi concentro più su una spiegazione analitica piuttosto che spiegare l'intero processo di cambiamenti demografici, il cambiamento dei networks e l'espansione economica. Comunque, è importante innanzitutto introdurre alcune nozioni epidemiologiche all'analisi economica. Le epidemie possono essere analizzate attraverso il loro impatto sul mercato del lavoro, gli effetti sulla demografia e la crescita economica a lungo termine; è importante quindi introdurre alcuni degli strumenti economici per questo capitolo per capire al meglio la relazione econometrica tra le due discipline. I modelli epidemiologici ci permettono di vedere non solo lo sviluppo di un'epidemia nel tempo, ma ci offre anche un modo concreto per capire come contenere e gestire la diffusione di un agente patogeno.

I modelli epidemiologici tentano di descrivere i possibili scenari di diffusione di una malattia infettiva. Per fare questo, i modelli tracciano le proprietà fondamentali delle epidemie e dei loro attori e definiscono l'inizio di una malattia in termini di probabilità e di equazioni matematiche. I soggetti di un modello epidemico sono differenziati in base al loro stato epidemiologico, che afferma il loro rapporto con l'epidemia e il loro ruolo nella diffusione della malattia. Le categorie usate sono:

- Suscettibile

- Infetto
- Infettivo
- Rimosso
- Esposto

È importante notare che non tutte le epidemie hanno le stesse fasi, e lo stato epidemiologico di un paziente è definito dalla biologia della malattia. Da queste fasi possiamo trarre un modello categoriale che definisce le fasi che un individuo attraversa in un'epidemia, definendo poi il ciclo semplificato di un'epidemia dalla relazione tra patogeno e paziente, le più comuni sono:

- Semplice Epidemia o SI (Suscettibile-infetto).
- Suscettibile-Infetto-Suscettibile (SIS) dove il soggetto non guarisce dopo che è stato esposto alla malattia.
- Suscettibile-Infetto-Rimosso (SIR) dove il soggetto, una volta esposto, o muore o guadagna immunità dal patogeno.
- Suscettibile-Esposto-Infetto-Rimosso (SEIR).

Questi possono sembrare modelli semplicistici, ed infatti lo sono: non riescono a spiegare i complessi processi economici, sociali e demografici che vanno dietro al movimento delle persone tra queste diverse fasi - ma questo è in parte il loro uso analitico. Dato che le epidemie incorporano un ampio spettro di fattori, può risultare difficile e in realtà impossibile osservare tutti i fattori e controllare tutte le variabili. Eliminandoli dall'analisi, siamo in grado di lavorare con la logistica e dare all'epidemia una formula probabilistica semplice di contatto e due stati di base dell'epidemia: infetti o sani. Può sembrare strano, ma con questi modelli semplici possiamo trarre una soglia epidemica, o il numero di individui necessari per una malattia diventare epidemica, e da questa tutta una serie di calcoli che ci permettono di formulare un sistema base di risposta. Per comprendere meglio questo aspetto econometrico dell'epidemiologia possiamo osservare l'equazione 1, che descrive il meccanismo di diffusione di una semplice epidemia (o modello SI):

$$I_t = (1 + \gamma\alpha)^t I_0 \tag{1}$$

Qui, γ rappresenta il numero di contatti di un singolo individuo infetto, mentre α rappresenta la probabilità di contatto tra una persona suscettibile e una persona infetta che determina la trasmissione della malattia effettiva. Quindi, il prodotto caratterizza il numero di contatti riusciti che un paziente ha che trasmette con successo il patogeno. Se "I" rappresenta gli individui infetti, allora intuitivo "I" sottoscritto 0 è il numero iniziale e l'indice "I" sottoscritto “t” il numero di individui infetti in qualsiasi periodo. L'analisi economica va molto più in dettaglio singolare nelle epidemie, ma queste sarebbero ben lontane dalla discussione di questo capitolo. Questa introduzione al tema dell'economia delle epidemie risulterà sufficiente per il resto dell'analisi, che si concentrerà più su un approccio descrittivo, piuttosto che matematico, sul rapporto tra cambiamenti economici e malattie infettive.

Gli storici credono che l'alto medioevo rappresenti la prima vera crescita demografica osservata nel mondo: "I demografi storici suggeriscono che il numero degli abitanti del X secolo non era così diverso da quello di 5 secoli prima e che tra il X secolo e il 1300, La popolazione europea è raddoppiata" (Malanima 2010).

Il XII Secolo ha visto la nascita dei primi accordi commerciali, con la creazione della Lega Anseatica che consentiva un libero scambio tra quasi tutti i più grandi porti d'Europa del tempo. Inoltre, le condizioni meteorologiche favorevoli hanno reso molto elevati i rendimenti nelle colture, permettendo una migliore alimentazione e un buon commercio. L'undicesimo e il dodicesimo secolo erano sicuramente periodi di grande espansione economica, accompagnati da forti movimenti culturali. Gli effetti della Peste dopo il 1351, l'ultima grande ondata, sono complessi. Alcuni, come Clark, sostengono che gli effetti sono più evidenti che realistici, poiché il progresso del Medioevo era sempre stato relativamente lento anche nei precedenti tre secoli. Solo la demografia ha accelerato seriamente, rendendo quasi stagnato il periodo dopo la peste nera se inserito nel contesto dell'intera epoca storica (2003). Indipendentemente, gli affitti per ettaro come stimato da Clarks non si sono mai completamente ripresi a livelli pre-peste, il che significa una stagnazione economica, che avrebbe potuto contribuire alla crescita del benessere nei secoli a venire. (2003)

La seconda guerra mondiale ha portato, in particolare alla società occidentale, una prosperità insolita. I cambiamenti più significativi della seconda guerra mondiale erano le innovazioni tecnologiche che ha prodotto –frigoriferi e TV, il mondo ha visto una rivoluzione nel suo modo di vivere. Vediamo in questo periodo una crescita significativa delle città in tutto il mondo, con l'aumento della "tendenza dei sobborghi" più lontani dai centri urbani industrializzati, l'espansione urbana è infatti salita negli anni immediatamente successivi alla guerra. L'influenza asiatica del 1957 è stata infatti molto più dannosa per l'Asia che per il mondo occidentale, tuttavia vediamo una decelerazione economica in Europa anche negli anni '60 subito dopo la pandemia. Non è stata particolarmente letale negli Stati Uniti, uccidendo circa 80.000 persone - una frazione se consideriamo i 600.000 dell'influenza spagnola.

È arrivata anche in un momento complicato: nessuna riparazione è stata pagata ai paesi asiatici come quelli in Europa dopo la Seconda Guerra Mondiale, e due bombe atomiche sono state sganciate sull'economia più grande della zona- il Giappone. Inoltre, la devastante fame che hanno rovinato la società cinese durante la dittatura del Mao - un'epidemia che meriterebbe un'analisi per sé - ha ostacolato notevolmente lo sviluppo dell'economia asiatica in un periodo di grande prosperità mondiale. Per questa ragione, la crescita negli anni '40 in Asia è paragonata a quella del mondo occidentale alla fine del XIX secolo e le epidemie speculari sono un caso interessante da analizzare.

La situazione asiatica, quindi, era critica: all'orlo di un grosso periodo di crescita, ma impreparata e inabilitata per sfruttare veramente questa opportunità. Si sostiene che l'influenza del 1957 è stata un fattore chiave nell'offset delle economie dell'Occidente e dell'Est.

Il cambio dell'ultimo millennio ha caratterizzato la società capitalista di oggi. Tuttavia, lo sviluppo economico che discuteremo per questo periodo si concentra molto più sull'economia asiatica, dove l'epidemia SARS del 2009 ha avuto gli effetti economici più gravi. Il 2000 è stato "L'Anno del Drago" secondo l'astrologia cinese e una descrizione accurata dell'economia asiatica del XXI secolo. Gli investimenti educativi sono aumentati costantemente nella prima metà del secolo, e l'Asia ha visto la rivoluzione intellettuale che ha attraversato il mondo occidentale nei due secoli in meno di 50 anni. Veramente un drago, l'economia asiatica ha raggiunto livelli concorrenziali dopo una dittatura schiacciante e divisioni politiche profonde. È giusto notare che questo sviluppo è stato ad un costo: l'economia politica in Asia è cresciuta su una base molto più centralizzata, dove i valori democratici sono stati tolti per favorire una ripresa immediata e una rinascita colossale dell'area. La maggior parte dei paesi asiatici hanno optato per un sistema di dittatura politica, che ha garantito ai cittadini miglioramenti significativi degli standard di vita a costo dei loro diritti politici. L'epidemia non è stata particolarmente violenta e ha colpito la società asiatica in tre onde: prima infettando i lavoratori di bestiame che avevano scarso accesso all'assistenza sanitaria, poi le comunità poco dopo, e infine i medici nel momento del trattamento. Le megacity della Cina hanno reso ogni starnuto una minaccia potenziale e praticamente inevitabile. L'epidemia SARS del 2009 può essere modellata come SEIR a causa del suo sviluppo impilato e per i suoi lunghi tempi nella categoria esposta, che ha colpito diverse parti della popolazione in tempi diversi. La bassa morbilità della SARS è dovuta all'efficace risposta della sanità pubblica della comunità internazionale, che ha fornito un'efficacia risposta di immunizzazione e un piano di contenimento della malattia. L'origine del patogeno è stata rapidamente identificata e un vaccino è stato fornito agli "hotspot" dell'epidemia: gli ospedali. È stato riconosciuto che l'alta infezione degli operatori sanitari stava creando un pericoloso ciclo di contagio, quindi la prima risposta è stata quella di immunizzare coloro che lavoravano negli ospedali. Gli effetti sono stati sentiti in tutti i rami dell'economia, dal settore finanziario alla classe lavorativa; L'assenza di lavoratori crea instabilità, preoccupando gli investitori, che rapidamente si tirati indietro da investimenti nella regione - i premi sugli strumenti finanziari per i collegamenti connessi alla Cina (eurobond) sono diminuiti da 140 nell'aprile del 2009 a soli 40 in agosto dello stesso anno (Bell e Lewis 2005). La paura di prendere la malattia in qualsiasi parte della città ha recluso i cittadini dal contatto sociale, e questi effetti si sono manifestati in una riduzione del 50% delle vendite di ristoranti in Giappone e Hong Kong. L'intera Asia ha perso tra il 20 e il 70% dei flussi turistici nel periodo dell'epidemia (Bell e Lewis 2005). L'effetto della SARS risulta interessante dal punto di vista economico, poiché dimostra chiaramente la profonda connessione tra i due campi di studi sociali. Pur non violenta e sicuramente di breve durata, la SARS ha avuto effetti economici a lungo termine che hanno mostrato al continente asiatico la sua fragilità e dipendenza dal mercato internazionale.

CONLCUSIONE

Da questa analisi, può sembrare che le pandemie siano una cosa del passato - niente potrebbe essere più lontano dalla verità. Mentre la nostra società progredisce, inevitabilmente lo fanno anche le cose che influenzano la nostra salute; Lo scopo di prendere in considerazione l'economia, le scienze più antropocentrica di tutti, è proprio quello di evidenziare il ruolo centrale degli esseri umani nello sviluppo e nella diffusione delle malattie infettive. Dai capitoli precedenti, dovrebbe essere emersa una tendenza comune: lo scoppio di una qualsiasi delle epidemie è sempre stato seguito da una qualche forma di disorganizzazione e inazione da parte della società. Le conseguenze dell'eccesso di crescita e dello sviluppo incontrollato sono state storicamente dannose e sembrano essere sempre riequilibrate dall'apparsa di un'epidemia. Anche se siamo più ricchi, sani e felici di sempre, i problemi più fondamentali sono ancora lontani dall'essere eradicati. Le sfide al nostro benessere oggi sono forse molto più complicate e consolidate nella nostra società. Possiamo fornire vaccini a basso costo e farmaci che ci possono salvare da infezioni pericolose per la vita, ma 20 milioni di persone, tra cui 1,4 milioni di bambini soffrono di mancanza di nutrizione. Questo naturalmente ha effetti dannosi su una miriade di aspetti, ma in primo luogo sull'ambiente che ci circonda. Il nostro modo di produrre ha completamente cambiato il nostro pianeta e ci ha esposto a problemi che non sono stati visti prima. La mancanza d'acqua, influenza il nostro sviluppo e la nostra igiene, e ad fino ad oggi, 663 milioni di persone vivono senza accesso ad acqua potabile e oltre 2,4 miliardi non dispongono di standard sanitari basilari. Ci manca la connessione empatica alle ripercussioni se queste ultime non accadono a noi, rendendo la nostra società ciecamente ignara del problema del cambiamento climatico e dello sviluppo insostenibile. Il cambiamento climatico è la singola e più pericolosa pandemia del nostro tempo e, anche se potrebbe sembrare lontano dall'essere un pericolo per la salute, le conseguenze dirette delle temperature in aumento sono intrinsecamente sulla nostra salute. Il cambiamento climatico è un problema e una causa di disuguaglianza, qualcosa che la nostra generazione dovrà affrontare con una maggiore resilienza. Per quanto siamo più ricchi e migliori, siamo anche più economicamente divisi che mai. La frattura sociale delle disuguaglianze sociale si espande alla mancanza di accesso a una parte della popolazione che ne necessita di più: in Africa occidentale, è tutt'oggi molto più difficile ottenere le medicine contr la malaria anche se rappresentano più del 90% delle morti annuali dal parassita . La ricchezza è l'indicatore primario della salute e non dobbiamo guardare casi estremi come la malaria per vedere che la diseguaglianza influenza la nostra salute: nella società americana il "gap di longevità" tra il 10% più povero e ricco è di14 anni per gli uomini e 13 anni per le donne, una cifra sconcertante. Le sfide del futuro nella nostra società potrebbero non presentarsi tutte sotto forma di virus e batteri mortali: gli epidemiologi, gli economisti e gli scienziati sociali devono smetterla di focalizzarsi sull'importanza del nostro benessere per cercare di comprendere che la minaccia più grande è sempre il legame più debole. Se non si farà nulla per migliorare quelle parti del mondo che soffriranno di più dalle malattie future, le ripercussioni dirette saranno su di noi. La sfida sanitaria del ventunesimo secolo è quello di eliminare quei problemi che in passato hanno dimostrato di essere dannosi e fatalmente importanti per la diffusione di un patogeno: mancanza di igiene, disuguaglianza, povertà e inazione. La mia generazione, e quelli che devono venire, devono capire il significato di questo cambiamento nel modo di pensare per avanzare in futuro.