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Pandemics, Capital Allocation and Structural Change

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Pandemics, Capital Allocation and Structural Change

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Abstract

The economic impact of pandemics is commonly studied using theoretical models that assume constant returns to scale and no factor movements. This article argues that a new economic geography model with increasing returns to scale and capital mobility better explains the effects of pandemics in modern economies. Our model predicts that pandemics shape where investments are made, leading to long-term impacts on economic development. To test this, we examine the consequences of the Great Influenza Pandemic on credit allocation and structural transformation in Spain from 1915 to 1929. Our research shows that credit growth was lower in regions with high mortality. Quantitatively, a one standard deviation increase in flu-driven mortality decreases credit (per capita) by 13.6%. We also document that this flu-driven reallocation of credit resulted in an increase in relative urban GDP in low mortality rate regions. A one standard deviation increase in flu-driven credit raises relative urban GDP by 9.5%.

Keywords: pandemics, capital mobility, economic geography, structural change

JEL Codes: E32, N10, N30, N90, O11

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1 Introduction

The unpredictable outbreak of pandemics can profoundly impact the economy, disrupting long-term economic growth. Consequently, economic historians and economists have shown significant interest in studying their effects. The recent global COVID-19 pandemic has further heightened this interest, emphasising the urgent need for a deeper understanding of such crises and their economic implications. (Arthi and Parman, 2021, Basco et al., 2021a; Callegari and Feder, 2022, Doran, 2023).

The commonly held perception about pandemics is that they can have a positive economic impact on individual welfare in the medium and long term. According to a modeling approach that assumes constant returns to scale (in both Malthusian and Neoclassical versions), pandemics reduce labor supply while leaving the amount of capital (land) unchanged. This implies that the remaining population have access to more capital per worker, leading to higher real wages and low asset returns for several decades until the economy returns to its steady state (Jorda et al., 2022). Pandemics have also been associated with positive long-run effects at the aggregate level by changing the equilibrium steady-state output per capita. For example Voth and Voigtlander (2013) argued that the Black Death's population shock led to a new steady state in Western Europe with higher per capita income, driven by increased manufacturing and urbanization.

This traditional and benevolent view on pandemics may not apply in modern economies. Two salient differences between modern economies and pre-industrialized economies are that (i) capital is substantially more mobile due to financial market developments (Demirguc-Kunt and Levine, 2004), and (ii) increasing returns to scale are more relevant due to the structure of the economy, which is more based on manufacturing and services than agriculture (Krugman and Venables, 1995). This paper investigates how pandemics affect modern economies when capital can freely move across locations.

In particular, we want to answer the following questions: What are the economic consequences of pandemics on economies with capital mobility and increasing returns? To what extent do pandemics prompt significant reallocation of capital across regions? Furthermore, if this reallocation of capital occurs, where is it being directed? Lastly, we want to understand whether modern pandemics adversely affect long-term economic growth or can lead to positive income growth in the long run. This thorough analysis will offer new insights into the complex relationship between pandemics and capital dynamics.

To theoretically illustrate why modern pandemics may have very different economic effects, we consider a stylized core-periphery model à la Krugman (1991),which incorporates capital mobility. More specifically, we build upon the analytically solvable core-periphery model of Forslid and Ottaviano (2003) to derive our empirical predictions. Under certain trade cost restrictions, we show that a heterogeneous shock in labor supply disrupts the symmetric equilibrium and leads to a core-periphery equilibrium in which all capital and manufacturing resources are concentrated in the region which experiences a less negative labor supply shock. The underlying logic of the model is that capital and labor are complementary inputs, and there are increasing returns to scale in manufacturing. The core comprises regions with lower mortality rates, while regions with higher mortality rates become the periphery. Due to these increasing returns to scale, GDP experiences permanent growth in the core regions and the overall economy while the periphery stagnates.[1]

Our empirical analysis focuses on understanding the long-term economic effects of exogenous mortality shocks caused by the influenza virus in different regions of Spain during the Great Influenza Pandemic. Spain is an ideal case for studying the economic consequences of this pandemic. It experienced the highest mortality rate among Western European countries, with 12.85 deaths per thousand inhabitants (Basco et al., 2021a). In addition, there were significant variations in pandemic-induced mortality rates among Spanish regions (Basco et al., 2024), which enables us to exploit them in our empirical exercises. Importantly, as extensively discussed in Basco et al. (2024), these differences were exogenous to the provinces' economic characteristics and only marginally related to climatic conditions during the pandemic. Also, the economic impact of the pandemic can be better identified because the country was less affected by World War I, having remained neutral. This neutrality minimized the influence of military spending and other war-related factors on its economy. Finally, the country's economy aligns well with the fundamental assumptions of the new economic geography model. Despite variations in economic and industrial development across regions, considerable evidence supports the presence of agglomeration economies in the country during the early 20th century (Rosés, 2003, Pons et al., 2007, Martinez-Galarraga, 2012).

To empirically test the predictions of the model, we exploit the heterogeneous distribution of flu-driven mortality across across regions in Spain. Our measure of flu-driven mortality is the excess mortality rate computed and explained in Basco et al. (2021a). We document that this measure of excess mortality is uncorrelated to regional GDP per capita or measures related to economic development (literacy rate) or urbanization (density). Our empirical strategy is based on the standard difference-in-differences analytic framework. In a further analytical step, we use instrumental variable (IV) regressions to examine whether the flu-

[1]It is important to notice that this result cannot be explained using a Malthusian framework, which assumes that capital is not mobile and that adjustments occur solely due to population growth. In contrast, the movement of capital from regions with high mortality rates to those with low mortality rates is consistent with the Solow model, which allows for capital mobility citebarro. However, this Solow model predicts only temporary effects on income rather than permanent ones, as capital remains mobile until the long-run equilibrium is restored.

driven reallocation of credit resources can lead to structural transformation in the economy.

We uncover permanent economic growth effects of the Great Influenza Pandemic. We proceed in two steps. First, we document that an increase in influenza-related mortality was associated with less urban credit per capita, particularly in high-risk, mobile credit. Given the absence of data on capital investment per province, we employ high-risk credit as an investment proxy. Quantitatively, an increase of one standard deviation in flu-driven mortality results in a 13.6 per cent decline in credit over 1915-1929. As a robustness exercise, we show that this shift in credit was not caused by any easing of credit conditions (proxied by the loan-to-value ratio), which remained unchanged. Additionally, the pandemic had no significant impact on rural credit, which is consistent with our narrative that this reallocation of capital was related to the urbanization process.

In our second set of results, we examine whether this flu-driven reallocation of credit was indeed related to the structural transformation predicted by the model. We find evidence consistent with this prediction. Quantitatively, one standard deviation increase in flu-driven credit raises relative urban GDP by 9.5 per cent over 1915-1929. We also document that this effect is driven by the regions with the lowest flu-driven mortality rates. Consistent with the model's predictions, we also show that relative urban inflation declined due to this reallocation of capital.

In summary, our empirical findings paint a picture consistent with the effects of pandemics in modern economies being shaped by agglomeration forces and capital mobility. Our narrative is that capital reallocation towards the regions with low flu-driven mortality was conducive to structural transformation. In particular, we provide suggestive evidence that housing drives this structural transformation. Indeed, the credit boom enabled developers to increase the supply of housing, which led to a rise in relative urban GDP. Even though the results are regional, they could be extrapolated at the country level. Countries with higher mortality shocks may experience capital outflows in a globalized world with capital mobility, leading to long-run aggregate output declines. Therefore, pandemic shocks can increase spatial economic inequality.

Related Literature. Our paper contributes to different strands of the literature. First and foremost, it is related to the literature that examines how pandemics impact economic growth and inequality. Recent research tends to adopt a positive perspective, asserting that pandemics may spur economic growth. For example, Alfani (2022) and Scheidel (2017) highlight pandemics' enduring effects in diminishing wealth inequality. Jorda et al. (2022) examine long-term patterns of growth and inequality following pandemics, arguing that pandemics lead to decreased asset returns and to an increase in real wages and real output per capita. Broadberry (2013) offers a historical view of the Black Death, emphasizing its significant favorable influence on wages, prices, and demographic changes in medieval Europe. Moreover, Voth and Voigtlander (2013) argue that demographic changes, mainly stemming from the Black Death, played a key role in alleviating subsistence constraints on wages in Europe. Alfani and Percoco (2019) present data that challenges this positive perspective on the long-run consequences of pandemics. The epidemics that affected Italy in the 17th century resulted in lasting decreases in real wages. Despite the population staying lower than pre-plague levels for over two centuries, there was a significant decline in skills, as well as in capital and technology. Our results suggest that modern pandemics may negatively affect inequality as capital reallocates towards regions with lower mortality rates. In addition, the presence of economies of scale implies that pandemics have long-run effects.

Many research studies offer relevant insights into the economic consequences of the 1918 Great Influenza pandemic. Barro et al. (2022) examines the macroeconomic impacts, asserting that the pandemic led to severe drops in GDP and heightened economic uncertainty. Beach et al. (2022) points out that the 1918 pandemic led to an economic contraction potentially triggered by a negative labor supply shock resulting from the deaths of many prime-aged workers. Correia et al. (2022) argue that while the 1918 pandemic generally harmed the economy, health interventions promoting strong health measures did not necessarily exacerbate economic downturns. Velde (2022) uses high-frequency data to assess the U.S. economy, uncovering substantial declines in industrial production and interruptions in economic activity. Carillo and Jappelli (2022) analyzed the long-term effects on regional economic development in Italy, revealing significant negative consequences. Galletta and Giommoni (2022) explore the pandemic's effects on income inequality in Italy, determining that it worsened existing disparities. Basco et al. (2021a, 2024) illuminate the complex nature of the pandemic and its differing mortality and income impacts across various social classes and regions. Together, these studies underscore the diverse economic disruptions brought about by the 1918 pandemic and offer essential lessons for current responses to pandemics. Nevertheless, these analyzes overlook the pandemic's effects on capital markets. Our contribution to this literature is to highlight that the Spanish Flu pandemic drove structural transformation and urbanization in Spain leading to long-run income differences across regions.

Our study also relates to the literature on the economic impacts of credit expansion. Jordà et al. (2013) uses long-run data for several developed economies to document that credit availability shapes economic activity and show that excess borrowing causes deeper financial recessions. Salient recent contributions have focused on the build-up of the mortgage debt and housing boom, and the ensuing Great Recession. Financial crises caused by housing bubbles have more harmful and persistent effects (Jordà et al., 2015), which is not unexpected given that housing is the most important asset throughout history (Jorda et al., 2019). Our results are consistent with the view that an increase in credit supply (capital inflows) were responsible for the credit boom and urbanization process that followed the Spanish Flu pandemic. This narrative is consistent with Mian and Sufi (2009) who argue that the increase in credit supply was the main responsible for the large U.S. mortgage boom in the late 2000s. Similarly, Basco (2014) theoretically argues that financial globalization can lead to large capital inflows in financially developed (or less financially constrained) economies, and it can be conducive to credit mortgage and house prices booms. He empirically applied it to the US housing market between 1983 and 2007. Adelino et al. (2016) emphasize that credit demand also played a role during the build-up of the U.S. mortgage debt boom driven by unrealistic expectations of house price appreciations. In our setting, this latter channel seems less relevant since mortgage credit, as we argue later, increased housing supply and reduced house prices.

Our emphasis on shifting economic activity from agriculture to non-agriculture aligns with new economic geography theories, particularly those of Krugman (1991) and Krugman and Venables (1995). While existing research has investigated the factors influencing economic activity distribution across U.S. states and counties—such as studies by Kim (1995), Glaeser and Ellison (1999), Beeson et al. (2001), Rappaport and Sachs (2003), and Glaeser (2008)—the focus on structural transformation has often been lacking. The work of Caselli and Coleman (2001) closely parallels our analysis as it explores structural transformation and income convergence between Southern and Northern U.S. states. Additionally, Desmet and Rossi-Hansberg (2009) investigate differences in employment growth patterns in manufacturing versus service sectors in U.S. counties, linking these trends to technological diffusion and sector age. However, neither of these studies addresses the correlation between structural transformation and urbanization, which our relatively small space unit's data is ideally positioned to analyze.

Our research relates to the macroeconomic discussion on structural transformation. The model presented here departs from the two primary explanations for structural transformation in the existing macroeconomic literature. The first explanation highlights that productivity growth in agriculture outpaces that in non-agricultural sectors, alongside inelastic demand across sectors, as noted by Baumol (1967), Ngai and Pissarides (2007), and Rogerson (2008). The second explanation involves that the significance of agriculture in consumer preferences diminishes as real income rises, as referenced in Echevarria (1997), Gollin et al. (2002), Matsuyama (2019), Comin et al. (2021). Instead, we focus on how population shocks, such as pandemics, may spur structural transformation in the presence of capital mobility and increasing returns in manufacturing.

2 Historical Background

2.1 Overview of the Pandemic

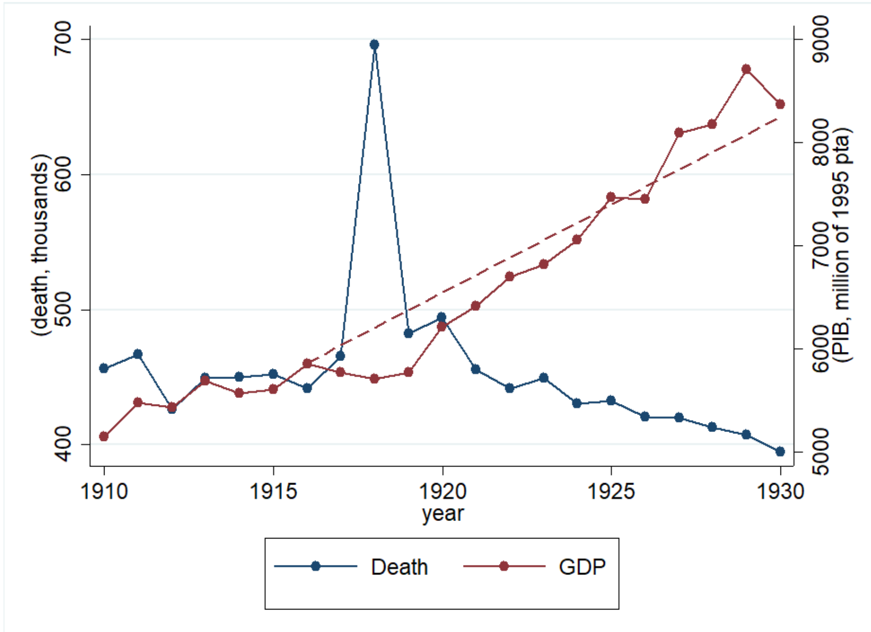
The Great Influenza pandemic between 1918 and 1920 was one of the deadliest pandemics in recorded history. It is among the top five deadliest pandemics ever documented and the most lethal in the last two centuries. A variant of the influenza virus, which is transmitted by air, caused the pandemic. The exact death toll of the pandemic is unknown, but estimates indicate that it caused around 58.5 million deaths (Cirillo and Taleb, 2020), equivalent to 283 million people today. However, some estimates suggest that the actual death toll could be as high as 100 million (Johnson and Mueller, 2002), which would be equivalent to over 330 million people today. The Great Influenza claimed between 2.5 and 5 lives per thousand.

The Spanish Flu was particularly deadly in Spain. According to Johnson and Mueller (2002), the death rate per thousand was 12.3 in Spain. This contrasts with the significantly lower rates in France (7.3) and Portugal (9.8), which are Spain's neighboring countries. Despite the high mortality rates in Spain, the characteristics of the pandemic were similar to those of other Western countries (Basco et al., 2022). The pandemic occurred in three consecutive waves: the initial wave in the summer of 1918, followed by the deadliest autumn wave, and a milder wave during the winter of 1918-1919. Mortality rates varied by sex and age, with women experiencing higher rates than men. Furthermore, age-specific mortality rates showed significant variations, with infants, younger adults (aged 15-34 years), and individuals over 60 years of age being the most affected. The high mortality rates among young adults resulted in a substantial decrease in the workforce and a reduced formation of new families in the years that followed (Basco et al., 2022).

2.2 Economic development before and after the pandemic

Before the Great Influenza Pandemic, the Spanish economy lagged behind other Western countries and experienced only modest growth (Prados de la Escosura, 2017). During World War I, GDP rose until 1916 but then declined before rebounding in 1919 and 1920 (Prados de la Escosura, 2017). In contrast to previous decades, the Spanish economy experienced a significant transformation during the 1920s (see Figure 1). This period was marked by rapid growth in output, investment, and Total Factor Productivity (TFP) (Prados de la Escosura and Rosés, 2009). This impressive growth was accompanied by substantial structural changes, including migration from rural areas and urban development (Prados de la Escosura and Rosés, 2009). A notable indicator of these changes was that, for the first time in Spanish history, the primary sector employed less than half of the workforce by 1930 (Nicolau, 2005).

Figure 1: Evolution of GDP per capita in Spain



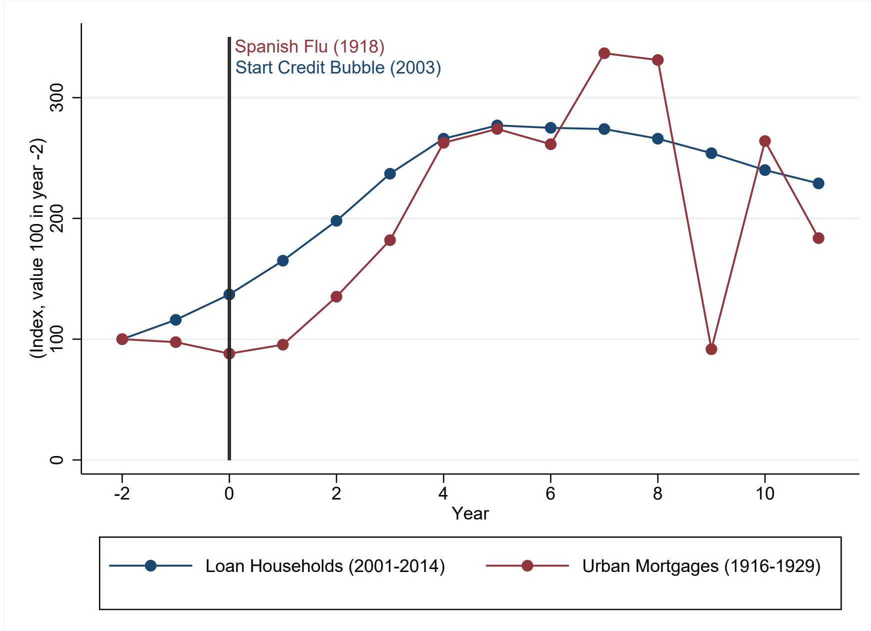
Source: INE Historical Database and Prados de la Escosura (2017).

2.3 Foreign capital inflows and the expansion of credit

The 1920s marked a significant shift in the external sector of the Spanish economy. Unlike in previous decades, Spain began attracting considerable foreign investment (Prados de la Escosura, 2009 and Prados de la Escosura and Rosés, 2009). The exact causes of this capital influx are poorly understood, but it likely resulted from Spain's neutrality during the war and higher interest rates in the country. In addition, foreign investors were drawn to the potential for Spain to join the gold standard. However, this influx of foreign capital declined sharply in 1927, and it did not come back to previous levels when other countries raised their interest rates, and Spain did not finally adopt the gold standard (Martín-Aceña et al., 2012, Martínez-Ruiz and Nogues-Marco, 2014).

The Bank of Spain did not implement comprehensive measures to thoroughly sterilize the influx of foreign capital that flowed into the country (Martín-Aceña, 2017, Martín-Aceña et al., 2012). A portion of this foreign investment increased the Bank of Spain's gold reserves, enhancing the country's financial stability. However, a significant percentage of these capital inflows was actively injected into the Spanish economy, notably by expanding credit availability (Jorge-Sotelo, 2022). This led to a notable surge in mortgage lending. Specifically, the mortgage credit growth exceeded that of Spain's most significant economic boom from 2003 to 2007, which ultimately culminated in the onset of the Great Recession

Figure 2: Evolution of Credit in Spain



Source: Loans granted to households are obtained from the ECB Dataset (https://data.ecb.europa.eu). Urban Mortgage Data come from Land Registry Statistics of Spain (*Registro de la Propiedad*). As argued in, for example, Basco et al. (2021b), the consensus is that the credit boom prior to the Great Recession in Spain started in 2003.

(Basco et al., 2022). This is represented in Figure 2, which shows the evolution of credit during both episodes. For ease of exposition, we represent both indexes with value 100 two years before the peak of the Spanish Flu (1918) and the onset of the recent mortgage credit bubble in Spain (2003). There exists a consensus that 2003 marks the start of the credit boom (see, among others, Basco et al., 2021b) which led to the onset of the Great Recession. Interestingly, the first index (from 1916 to 1929) mirrors the evolution of foreign capital inflow, including the abrupt halt in 1927.

2.4 Financial Markets

The Spanish financial markets in the 1920s were well-integrated but still exhibited several non-fully modern characteristics. Property rights and debt enforcement were well-established, and in 1921, the Bank of Spain transitioned to a central bank (Martín-Aceña, 2017). This institution also implemented an efficient transfer system that facilitated the free movement of capital between Spanish regions (Nogues-Marco et al., 2019). In addition, Spain had four fully operational stock exchanges in Madrid, Barcelona, Bilbao, and Valencia. There were also numerous private banks with regional branches, each specializing in different types of business. However, the presence of the banking system was uneven across the country, and many Spaniards did not use banking services daily (Martín-Aceña, 2011).

The most important form of long-term credit contract was mortgages, which were backed by tangible assets such as land and buildings. Like other continental European countries, Spain implemented a system of double registration. Initially, the parties signed the credit contract under the supervision of a notary, but then, a copy of the document was enlisted in the Public Property registry (*Registro de la Propiedad*). Although this contract was secure, it was relatively expensive because of the fees and government taxation (Arruñada, 2003). Unfortunately, we do not have enough evidence on the relative involvement of banks and other financial institutions in this market. However, contemporaries insisted that most lending transactions were peer-to-peer and not backed by financial institutions. Unlike current practices, families rarely purchase their homes with mortgages (Carmona et al., 2017). Therefore, the most common use of mortgages was business credit for relatively asset-rich investors.

In our research, we have observed that Spanish official sources make a noteworthy distinction between two categories of mortgages, primarily based on the interest rate applied to them. These sources classify mortgages into two groups: those with an interest rate of 6 per cent yearly or lower and those with an interest rate exceeding 6 per cent yearly. During this period in Spain, the 6 per cent threshold was significant as it represented the official interest rate often imposed by the government on various forms of debt and regulated financial transactions. This rate was typical in government-related lending and similar to the rates charged by the Bank of Spain for money-market arrangements (Jorge-Sotelo, 2022).

Mortgage interest rates above 6 per cent are typically associated with riskier business ventures and varying credit activity across different provinces. Borrowers obtaining these higher-rate mortgages were likely engaged in financial transactions that involved a greater degree of uncertainty. Furthermore, evidence supports this observation, as these higher-interest mortgages were often unevenly distributed throughout the country and were rarely used in transactions involving rural land. Instead, they concentrated primarily on regions with higher financial activity and economic development levels. This pattern highlights a clear connection between mortgage interest rates and the economic landscape of different Spanish regions. In addition, this geographical disparity underscores the risks associated with such financial products and their stronger appeal in more economically vibrant areas.

3 Theoretical Motivation

This section explains how the economic effects of pandemics depend on the assumptions about capital mobility and technology. First, we postulate reasonable assumptions about modern pandemics. Then, we explain the empirical predictions given these assumptions.

The standard assumption in the literature examining the effects of pandemics is that capital is not mobile. This is the case for the extensive and critical literature on the Black Death and the most recent work on the Spanish Flu. This is a fair assumption for pre-modern pandemics, in which labor and land were the main factor of production, and capital markets had limited development. However, in modern economies, this assumption seems less plausible. Capital was more important than land and was mobile both within and between countries at the beginning of the 20th century. This, at least, was the case in Spain during the Spanish Flu, as discussed in the previous section.

Most of the economic growth models used to examine the effects of pandemics assume constant returns to scale and feature production functions in which capital and labor are complements. For example, the textbook versions of both the Malthusian and the Solow models without capital mobility imply that real wages increase with the pandemic because the capital-labor ratio increases. In contrast, if capital is perfectly mobile in the Solow model, real wages would not change because capital would adjust so that the capital-labor ratio is the same in all regions (Barro et al., 1995).[2] In this case, there would be capital reallocation from the high-mortality regions towards the regions with less mortality. Regardless of the assumption on capital mobility, unless we depart from the standard assumptions, there would be no long-term effects.[3]

The Spanish economy boomed in the 1920s after the Spanish Flu and it was a moment of structural change and urbanization. In addition, Basco et al. (2021a) document that, within Spain, real wages actually fell in the regions with higher flu-driven mortality. Thus, this evidence would seem at odd with a Solow or Malthusian interpretation of pandemics. As a plausible alternative, we consider the increasing returns model of Krugman (1991) with capital mobility. This model has the advantage of being able to generate long-run effects.

To illustrate the potential long-run effects of pandemics, we adapt, in the appendix (Section B), the Forslid and Ottaviano (2003) version of Krugman (1991). We make two main assumptions. First, there are two factors of production: capital (mobile between regions), and labor (cannot move).[4] Second, there is an homogeneous agricultural good (only uses

[2] Land is the factor of production in the Malthusian Model, which is not mobile by nature.

[3] There could be long-run effects if, for example, there is some correlation between pandemics and institutions. See Basco et al., 2022 and references within for a discussion.

[4] We assume that labor cannot move to emphasize the effect of capital mobility. Empirically, we do not have yearly data on migrations within Spain and, thus, we cannot formally test the potential complementary

labor) and a differentiated manufacturing good, which features increasing returns to scale and uses capital.

Under some parametric assumptions on the trade cost of the manufacturing good, we derive the following results.[5] Before the pandemic, we obtain a symmetric equilibrium in which agricultural and manufacturing production is equally split between the two regions. After the pandemic, there is symmetry breaking. There is agglomeration with all capital and manufacturing production in the regions with less flu-driven mortality. Real wages are also higher in the low-mortality region. The intuition for these results is that capital agglomerates to the region with more population since returns to capital are higher in the larger market. In addition, since there are increasing returns to scale and capital is needed for manufacturing, manufacturing prices are also lower in the less flu-driven mortality region.

We next summarize the empirical predictions of pandemics according to a core-periphery model with capital mobility.

Empirical Predictions

1. Regions with more flu-driven mortality experience a relative decline in productive capital.
2. Regions that receive relatively more capital, due to flu-driven mortality, experience a relative increase in urban/rural production ratio and lower manufacturing prices.

It is beyond the scope of this paper to identify the mechanism through which pandemics may have long-run effects. We chose the core-periphery model with capital mobility as a natural way to illustrate this potential long-run effect of pandemics. An extensive theoretical literature on structural transformation does not rely on increasing returns and could deliver similar results. For example, a growing literature using non-homothetic preferences to explain structural change (see, for example, Matsuyama, 2019 or Comin et al., 2021). One advantage of our theoretical choice is that disaggregated production and credit data (as opposed to consumption) are available, which allow us to examine our proposed mechanism.[6] We also

or substitution effect of labor mobility. As a robustness exercise, we use long-run migration data. These data suggest that flu-driven migration has a similar, albeit quantitatively smaller, effect than capital reallocation on structural change. Moreover, flu-driven mortality does not explain flu-driven capital reallocation.

[5] As it is standard in core-periphery model, we need to assume that trade costs are intermediate to have unique solution. In the appendix, Section B, we derive the thresholds of these trade costs.

[6] Basco and Mestieri (2019) consider a dynamic model with trade in intermediate goods, which would also deliver the same results on capital re-allocation as the core-periphery model. However, from an empirical point of view, it is hard to justify the importance of trade in intermediate goods in the early 20th century.

want to emphasize that the first prediction holds in any model in which capital and labor are complements. Section 5 formally tests our empirical predictions for the Spanish Flu in Spain.

4 Data

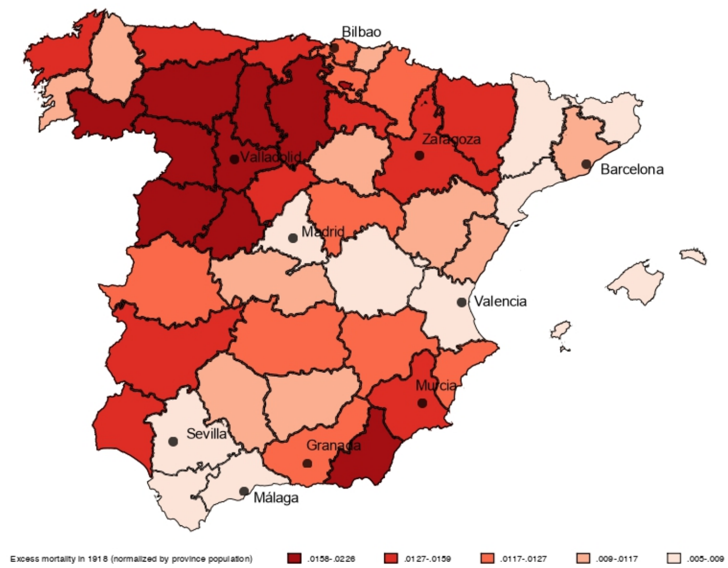
To empirically test the theoretical predictions described above, we need disaggregated data on flu-driven mortality and economic activity in Spain during the Spanish Flu. Next, we briefly explain and describe these data.

4.1 Measure of Flu-Driven Mortality

We use the excess mortality rate created in Basco et al. (2021a) to measure the flu-driven mortality rate. It is defined as the deviation of the actual number of deaths from the predicted linear trend (normalized by population size) for each province in 1918. This is the cleanest and most comparable proxy of flu-driven mortality. This variable only requires information on an objective measure: the number of deaths in a given year and province (the official disaggregation of regions in Spain). These data come from the Spanish government, which compiled national aggregate statistics (*Movimiento de la población de España*) employing direct information gathered by the provincial registers. An alternative approach exists, which is to use death certificates to identify flu-related deaths. As argued by Basco et al. (2024), we disregard this approach even though data on causes of death is available in Spain's Vital Statistics. The use of official causes of death is fraught with reporting problems. During the pandemic, flu-testing technologies did not exist. Therefore, the cause of death was established by the external symptoms of the sick patient. To address this reporting problem, the literature typically identifies all deaths related to pulmonary illnesses as influenza-related. In any event, as discussed Basco et al. (2024), both measures give very similar numbers at the country level.

Figure 3 plots the excess mortality rate in the different regions (provinces) in Spain. The map also indicates the 10 largest capitals of the province at the time of the pandemic. The average value is 12.6 (per thousand) and the standard deviation is 3.9%. This heterogeneity across regions can also be seen in the figure. We will use this dispersion to identify the economic effects of flu-driven mortality. Table 10 shows that excess mortality in 1918 was not correlated to the standard control variables used in the literature (GDP, literacy rate, density, and atmospheric pressure). Only atmospheric pressure is mildly correlated (significant at 10 percent) with excess mortality. This finding was discussed at length in Basco et al.

Figure 3: Excess Mortality in Spain



Source: Excess mortality rate at the regional level computed in Basco et al. (2021a). Includes the 10 largest capitals of provinces (1910). Death data obtained from INE Base Histórica and Census Data.

(2022). Thus, we argue that this mortality shock is exogenous and not explained by economic fundamentals.

4.2 Economic Activity Data

Data on our dependent variable come from different sources. The original mortgage data comes from Land Registry Statistics of Spain (*Registro de la Propiedad*). This official data already disaggregate for different interest rates (below and above 6%). This database has been used before and checked against historical evidence (see Carmona et al. (2017) for more details). Real urban and rural prices at the regional level come from Carmona et al. (2017). The same basket of goods from Roses and Sanchez-Alonso (2004) is employed for all locations. Urban prices correspond to provincial capitals. The basket was computed as an unweighted average of provincial consumption. The underground prices are obtained from official sources, mainly publications from the Spanish Ministry of Labor.

Real annual GDP at the province level in Spain was derived from the nominal estimates computed in Rosés et al. (2010). The original nominal decadal series was extended to yearly observations using the same methodology and sources. The corresponding urban and rural price indices deflated each of the two components of the regional GDP. Provincial population data has been obtained directly from the Spanish population censuses. Yearly population figures are calculated using the same method employed by González-Val and Silvestre (2020), which combines natural population growth rates with migration figures.

Table 1 presents the summary statistics on economic activity pre- and after-Spanish Flu. As can be readily observed, following the Spanish Flu, there is a credit boom particularly affecting risky urban mortgages. Additionally, there is an increase in relative urban GDP and, if anything, a decline in relative urban prices. In the following sections, we will empirically investigate whether these average changes are due to the differences in flu-driven mortality across regions.

Table 1: Summary Statistics

	Pre-Pandemic (1915-1918) Mean	Post-Pandemic (1919-1929) Mean	Overall (1915-1929) Mean	Overall (1915-1929) St. Dev.
Mortgage Credit				
Urban (>6%)	0,44	1,72	1,38	3,31
Urban (<6%)	2,67	3,88	3,56	8,09
Rural	3,82	4,64	4,42	9,26
Loan-to-Value Ratio	0,65	0,70	0,69	0,44
GDP				
Urban/Rural	2,58	2,95	2,85	5,08
IPC				
Urban/Rural	0,98	0,97	0,97	0,06
No. Observations	192	528	720	720

Notes: Mortgage credit (real value per capita). These data are obtained from Registry Statistics of Spain (*Registro de la Propiedad*). Prices comes from Carmona et al. (2017). Real annual GDP was computed in Rosés et al. (2010).

5 Empirical Analysis

In this section, we discuss the empirical strategy and present the main results. Subsection 5.1 introduces our empirical model. Subsection 5.2 details our findings on the effects of the Spanish Flu on capital reallocation. Subsection 5.3 explores the potential of this flu-driven reallocation to induce structural transformation. Lastly, subsection 5.4 investigates possible mechanisms and alternative explanations for our findings.

5.1 Identification Strategy

One of the main reasons that could explain why the effects of modern pandemics differ from those of old pandemics, such as the Black Death, is that credit (in contrast to land) is mobile and could react to the pandemic. Before examining the potential long-run effect on urbanization and structural change, we want to analyze this potential flu-driven reallocation of capital. To perform this exercise, we consider the following diff-in-diff strategy,

$$Y_{ct} = \alpha + \beta * D_{post1917} * Flu_c + \delta_c + \delta_t + \epsilon_{ct}, \quad (1)$$

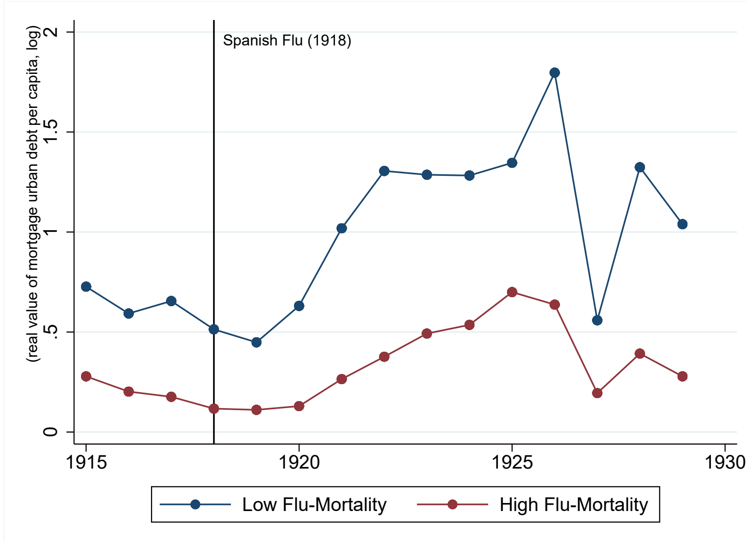
where Y_{ct} is log of mortgage credit per capita in region c and year t, $D_{post1917}$ is a dummy variable equal to 1 if year>1917 and 0 otherwise, Flu_c is flu-driven mortality in region c as described in Section 4 and computed in Basco et al. (2021a). δ_c and δ_t are province and year fixed effects, respectively. Including year fixed effects is justified because there could be aggregate shocks at the country level, distorting our results. We also add province fixed effects because some province characteristics correlated with our measure of flu-mortality could contaminate our results. We checked that the parallel trend assumption is not violated for our main dependent variables (Table 11 in Appendix). Thus, we can interpret our coefficients as causal effects.

A negative coefficient β implies that regions with less flu-driven mortality experienced a larger increase in mortgage credit compared to pre-flu regions. As we explained in our theoretical motivation, a negative β is expected if capital mobility exists, and capital and labor are complements in the region's aggregate production function.

We consider different time horizons to capture potential agglomeration (or dynamic) effects. Specifically, we examine three periods: (i) a short-run effect (1915-1921), (ii) a mid-run effect (1915-1925), and (iii) a longer-run effect (1915-1929). We hesitate to label this last period as "long-run"; however, we choose not to extend the analysis beyond the 1920s because Spain underwent dramatic institutional changes in the 1930s (including the replacement of the monarchy system with a republic in 1931, and the Civil War, 1936-1939), which would challenge our identification strategy. In any event, if there were agglomeration forces, we would expect that differences among similar pre-shock regions would increase over time. In other words, the coefficient β should become larger, in absolute terms, as we expand the time horizon.

Figure 4 provides suggestive evidence on the effect of the mortality shock on capital reallocation. It illustrates the evolution of the average value of credit per capita in the first (blue line) and fourth (red line) quartile of the flu-driven mortality distribution. We observe that the trends look quite parallel before the outbreak of the Spanish Flu (1918), but they start to significantly diverge afterwards. Credit per capita increases considerably more in the low flu-driven mortality region. In the Appendix, we test and confirm the pre-shock parallel trend assumption (see Table 11). Next, we examine the causal effect of flu-driven mortality

Figure 4: Flu-Driven Reallocation of Capital - Suggestive Evidence



Notes: The blue (red) line represents the evolution of average urban mortgage credit per capita among the regions in first (forth) quartile of the flu-driven mortality distribution between 1915 and 1929. The vertical line in 1918 represents the year of the Spanish Flu. Sources are described in Section 4.

on credit by running equation 1.

5.2 Pandemics and Capital Reallocation

Table 2 presents the estimates of equation 1 for three different time horizons. Consistent with theoretical predictions, the coefficient of interest is negative across all three-time horizons. This indicates that capital and labor are complements, and capital tends to move towards regions with lower flu-driven mortality. More interestingly, the magnitude and statistical significance of the effect increases over time. Indeed, in the very short run (1915-1921), the coefficient is small and not statistically significant (column 1). In contrast, we document much larger and significant effects for both the medium run (1915-1925) and longer run horizons (1915-1929).

Quantitatively, the coefficient for the medium run (1915-1925) implies that one standard deviation decline in flu-driven mortality results into a 12 percent (30.77*3.9%) increase in urban mortgage per capita. The analogous exercise for the longer-run horizon delivers an increase of 13.6 percent (34.90*3.9%). Thus, these findings seem supportive of (i) capital mobility, (ii) capital-labor complementarity and (iii) agglomeration forces.

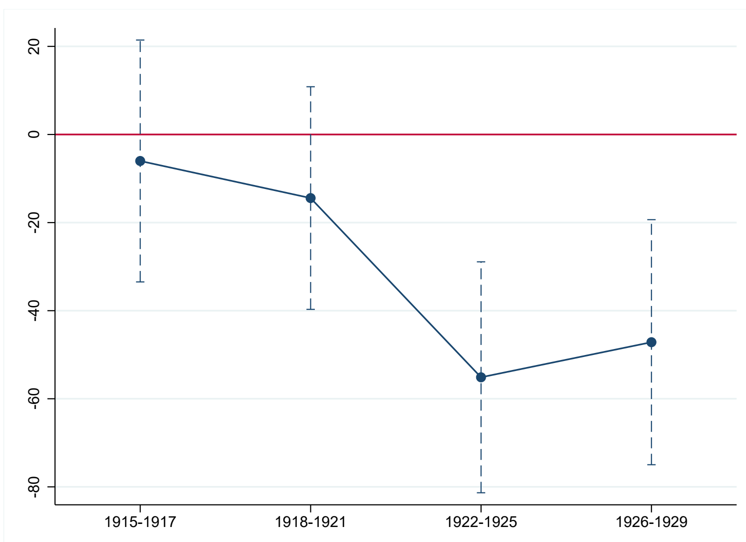
Figure 5 illustrates the dynamic effect of the Spanish Flu on capital reallocation. To obtain this figure, we replace the $D_{post1917}$ in equation 1 for three dummies, $D_{1918-1921}$, $D_{1922-1925}$ and $D_{post1925}$. We also include a pre-flu dummy, $D_{1915-1917}$, as a complementary pre-shock

Table 2: Value of urban mortgage per capita (1915-1929)

	(1) 1915-1921	(2) 1915-1925	(3) 1915-1929
$Flu * D_{post17}$	-10.42	-30.77***	-34.90***
	(7.49)	(8.04)	(8.00)
Year FE	Y	Y	Y
Country FE	Y	Y	Y
Number Obs.	336	576	720
F-stat	1.94	14.64***	19.04***

Notes: Column headings indicate the sample period. Dependent variable is value of urban mortgages with an interest rate above 6% (in real terms, per capita). Flu is excess mortality rate. Sources are described in section 4. D_{post17} is a dummy equal to 1 for years after 1917. We transform the dependent variable using an inverse hyperbolic sine to retain observations with zeros. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Figure 5: Dynamic Effect on Capital Reallocation



Notes: Each dot represents the point estimates of the four dumies: $D_{1915-1917}$, $D_{1918-1921}$, $D_{1922-1925}$ and $D_{post1925}$. Dotted lines are the 95 percent confidence intervals. The dependent variable is urban mortage credit with an interest rate above 6% (in real terms, per capita).

analysis. The message is the same as the one comparing the three columns in Table 2. It took time to observe significant effects on capital reallocation, but these effects build up over time. Also, risky urban mortgages (per capita) were not statistically different across regions before the Spanish Flu.

5.2.1 Robustness Checks

We next provide several robustness checks on our findings, which support our narrative that the Spanish Flu caused a reallocation of capital towards the regions with lower mortality.

Rural Credit In our theoretical motivation, the region with lower flu-driven mortality should accumulate more productive capital, which could foster urbanization. Therefore, we should not observe the same effect on rural mortgage debt. Column 1 of Table 3 reproduces the estimates of running 1 using the value of rural mortgages. The coefficient is positive but not significantly different from zero. Thus, in line with our narrative, we do not observe the same reallocation of capital for rural credit.

Low-Risk Credit One particularity of our database is that we also have information on the interest rates of credit granted. In particular, we know if they were below or above 6%, the legal benchmark for credit set by the Spanish government (for example, this benchmark was used to calculate the interest resulting from tax debts). According to our theoretical motivation, productive capital (or risky capital) should be more responsive to flu-driven mortality since we relate these mortgages to urbanization and risky projects. Column 2 of Table 3 reports the coefficient of interest when using the values of urban mortgages with an interest rate below 6%. The coefficient is negative and statistically significant. As expected, the magnitude of this coefficient (-26.66) is smaller than its counterpart in column 3 of Table 2 (-34.90). This evidence suggests that the effects were exacerbated for risky credit.

Loan-to-value According to our narrative, the capital reallocation towards regions with lower flu-driven mortality was unrelated to changes in the financial conditions of these areas. A plausible alternative could be that regions less affected by the Spanish Flu seized this opportunity to increase capital inflows by relaxing their financial standards. We test this alternative by running equation 1 using the loan-to-value ratio of urban mortgages. Column 3 in Table 3 reports the estimates. The coefficient is not statistically different from zero; thus, we can rule out this possibility.

5.3 Pandemic-driven Capital Reallocation and Structural Change

We next turn to the question of whether this flu-driven capital reallocation could explain the urbanization and industrialization process that took place in Spain in the 1920s. To conduct this analysis, we consider a two-stage difference-in-differences specification. In the first stage, we predict the change in credit induced by the Spanish Flu, which is akin to our first set of

Table 3: Robustness Checks

	(1) Rural	(2) Low-Risk	(3) Loan-to-Value
$Flu * D_{post17}$	-3.98	-26.66***	-3.74
	(6.44)	(9.40)	(5.40)
Year FE	Y	Y	Y
Prov. FE	Y	Y	Y
Number Obs.	720	720	720
F-stat	0.38	8.04***	0.48

Notes: Dependent variable in column 1 is value of rural mortgages with an interest rate above 6% (real terms, per capita). Dependent variable in column 2 is value of urban mortgages with an interest rate below 6% (real terms, per capita). Dependent variable in column 3 is the ratio between value of loan and value of the mortgage. *Flu* is excess mortality rate. Sources are described in section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

results. In the second stage, we use the pandemic-induced reallocation of capital to explain the potential change in the evolution of urban and rural GDP and urban and rural inflation. Note that this exercise can be interpreted as examining the effect of exogenous credit shocks using the Spanish Flu as an instrument. In particular, the second stage is the following,

$$Y_{ct} = \alpha + \beta * D_{post1917} * Credit_{ct} + \delta_c + \delta_t + \epsilon_{ct}, \tag{2}$$

where Y_{ct} is log of urban/rural real GDP (urban/rural inflation) in region c and year t, $D_{post1917}$ is a dummy variable equal to 1 if year>1917 and 0 otherwise. The coefficient β inform us on the effect of the change in credit after the Spanish Flu on the shift in urban/rural GDP (inflation).

5.3.1 The Effects on Relative Urban Production

Table 4 presents the OLS coefficients from directly estimating equation 2 for the three different time horizons. The coefficient of credit is positive and significant across all time horizons. This indicates that regions that received more credit after the Spanish flu experienced increased relative urban real GDP. A key shortcoming of this specification is that it does not connect the change in credit after the Spanish Flu to the flu-driven mortality. This is why, in our preferred specification, we opt for a two-stage least squares (or IV approach) and utilize flu-driven mortality to explain the change in credit following the Spanish Flu.

Table 4: Effect of Capital Reallocation on Urban/Rural GDP: OLS Specification

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * D_{post1917}$	0.088***	0.063***	0.053***
	(0.024)	(0.016)	(0.016)
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	336	528	720
F-stat	13.13***	15.63***	10.35***

Notes: Column heading indicates sample period. Dependent variable is ratio of urban to rural GDP (in real terms). Sources are described in section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 5 reports the estimates of the two-stage least squares specifications. The bottom panel reports the first stage. As it was expected, given our results on flu-driven capital reallocation, we find that the coefficient is negative and statistically significant. In addition, all the F-statistics are above 10. Turning to the coefficients of credit, we find that they are positive and statistically significant. The magnitude of these 2SLS coefficients is larger than the OLS coefficients reported above, which seems consistent with the presence of attenuation bias in the previous OLS specification. We also note that the coefficient of credit does not seem to significantly vary over time. We do not have a priori reason for why the effect of capital-induced change on urban/rural GDP should vary across time. In any event, consistent with our previous results, we can see in the coefficients of the first stage that the effect of the flu-driven mortality on capital accumulation does increase over time. Quantitatively, according to our longer-run specification (column 3), a one standard deviation increase in credit raises relative urban GDP by 9.5% over the 1915-1929 period.

Heterogeneous Effects Across Mortality Distribution We next investigate which part of the flu-driven mortality distribution is responsible for the effects on relative urban GDP. To perform this exercise, we divide the sample into three groups according to flu-driven mortality and create a dummy for each of these groups. Then, we interact our previous specification with this dummy. Table 6 reproduces these results. As can be seen, the first tercile drives the results. That is, consistent with our theoretical motivation, the regions with the lowest mortality rates were the ones that received more credit and were able to increase their relative urban GDP relatively more.

Table 5: Effect of Capital Reallocation on Urban/Rural GDP: 2SLS Specification

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * D_{post1917}$	0.161***	0.131***	0.112**
	(0.049)	(0.037)	(0.041)
$Flu * D_{post1917}$	-78.70***	-99.05***	-103.17***
	(15.02)	(16.58))	(17.71)
F-stat	27.45***	35.69***	33.95***
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	336	528	720

Notes: Column heading indicates sample period. Bottom panel reports the first stage of the 2SLS regression along with the F-stat. The top panel reports the coefficients of the second stage. Dependent variable is ratio of urban to rural GDP (in real terms). Flu is excess mortality rate. Sources are described in section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effect regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

5.3.2 The Effects on Relative Urban Inflation

One of the distinctive features of a core-periphery model with capital mobility is that capital reallocation should be conducive to reducing relative urban prices. That is, as explained in Section 3 and derived analytically in the appendix, if there are increasing returns, capital agglomeration will cause a reduction in manufacturing prices. To empirically examine this effect, we consider the same 2SLS specification discussed above and use relative urban inflation as the dependent variable.[7]

Table 7 presents the coefficients from the first and second stages. There are two differences compared to the specification with relative urban production. First, we use inflation (first differences) instead of levels, which reduces the sample size. Second, we include lagged inflation as a control variable to account for inflation inertia. The coefficients from the first stage exhibit the expected negative sign. A small caveat is that F-statistics are slightly below 10 (9.60 in our preferred specification, column 3). Turning to the coefficients of the second stage, we find that all of them are negative and statistically significant. Quantitatively, the estimates in our preferred specification (longer-run period, column 3) imply that a one standard deviation increase in credit reduces relative urban inflation by 5.1%.

[7] For ease of exposition, we relegate the OLS specification to the Appendix (Table 12). Consistent with the empirical predictions, the coefficients on credit are negative and statistically significant.

Table 6: Urban/Rural GDP: Across Flu-Driven Mortality Distribution

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * Low * D_{post1917}$	0.171***	0.130***	0.145***
	(0.053)	(0.038)	(0.050)
$Credit * Mid * D_{post1917}$	0.009	0.026	0.103
	(0.144)	(0.072)	(0.088)
$Credit * High * D_{post1917}$	0.239	0.116	0.285
	(0.394)	(0.166)	(0.210)
S-W1 F-stat	14.22***	16.41***	21.37***
S-W2 F-stat	24.63***	28.37***	24.63***
S-W3 F-stat	19.52***	25.74***	24.46***
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	336	528	720

Notes: Column heading indicates sample period. Low, Middle and High are dummy for the provinces in the Q1, Q2-Q3 and Q4 of the flu-driven mortality distribution, respectively. In the first-stage, $Credit * Low * D_{post1917}$ is instrumented by $Flu * Low * D_{post1917}$. Analogous for Middle and High. For ease of exposition, we only report the coefficients of the second stage of the 2SLS regression. S-W1, SW-2. SW-3 correspond to the Sanderson-Windmeijer multivariate F test of excluded instruments for each of the three instrumented interaction terms. The table reports fixed effect regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Effect of Capital Reallocation on Urban/Rural Inflation: 2SLS Specification

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * D_{post1917}$	-0.092***	-0.065***	-0.060***
	(0.034)	(0.024)	(0.022)
$InflationLag$	-0.39***	-0.34***	-0.34***
	(0.068)	(0.050)	(0.048)
$Flu * D_{post1917}$	-79.13***	-99.59***	-103.79***
	(28.54)	(32.58)	(33.50)
F-stat	7.69***	9.34***	9.60***
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	240	432	624

Notes: Column heading indicates sample period. Bottom panel reports the first stage of the 2SLS regression along with the F-stat. The top panel reports the coefficients of the second stage. Dependent variable is ratio of urban to rural inflation. *Credit* is value of mortgage credit above 6% (in real terms, per capita). Sources are described in section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

5.4 Mechanisms and Alternative Theories

In this section, we provide suggestive evidence on a potential mechanism behind the effects of the flu-driven capital reallocation of credit. First, we argue that building houses could be the channel through which capital reallocation increased relative urban GDP. Second, we provide suggestive evidence that labor mobility could be a complementary reason why pandemics could have long-run economic effects.

5.4.1 Capital Reallocation and Housing

The prime suspect of the effects of flu-driven capital reallocation is housing (or urbanization). Table 13 in the appendix shows, using the same diff-in-diff strategy as equation 1 that the Spanish Flu was conducive to a relative increase in house prices. This fact was documented earlier in Basco et al. (2021a). There may be different reasons why house prices increase relatively more in regions with higher mortality. One explanation is that capital became scarcer in hit regions, which relatively reduced housing supply and, thus, raised prices. In other words, credit was used to build houses rather than buy them. This reasoning seems counterfactual from today's perspective, but it fits the Spanish economy in the 1920s, when housing supply was elastic and institutional constraints to housing construction were limited (Carmona et al., 2017).[8]

Table 16 in the appendix shows additional support to this interpretation. It reports the correlation between mortgages per capita (our credit proxy) and real house prices. After considering region and year fixed effects, we uncover a negative correlation between both variables (significant except for the short-run 1915-21), which suggests that mortgages (credit) increased the housing supply. To sum up, capital reallocation could affect relative urban GDP through housing.

Table 8 provides additional suggestive evidence consistent with this narrative. Column 1 reports the baseline 2SLS estimates of the effect of flu-driven capital reallocation on relative urban GDP. Column 2 reports the estimates for those regions in which the increase in the supply of housing between 1920 and 1930 was above the median. As can be seen, among these regions, the effect of capital reallocation on relative urban GDP is twice as large as the baseline specification. Column 3 considers a proxy for pre-flu housing demand. It reports the effect of credit for regions with a share of occupied housing units above the median in 1920. Note that the coefficients in columns 2 and 3 are very similar. In conclusion, our interpretation is that the Spanish Flu was instrumental in starting the urbanization process in Spain and helped to allocate productive capital to the regions with less flu-driven mortality.

5.4.2 Flu-Driven Labor Mobility and Urbanization

In this paper, we focus on flu-driven capital reallocation. However, workers could also react to the Spanish Flu. According to a Malthusian or Solow interpretation, wages increase in regions with larger mortality and, thus, if anything, workers should want to migrate to these regions. In contrast, in a core-periphery model, there are gains from agglomeration, and workers should want to leave regions with high mortality. We could relabel capital as skilled workers, as in Forslid and Ottaviano (2003), and we would obtain that skilled work (the ones who can move) migrate towards regions with less mortality.

It is beyond the scope of this paper to examine the effect of pandemics and labor mobility. Moreover, data limitations would prevent us from performing this analysis. Indeed, we do not have annual data on internal migrations at the provincial level for the period of interest. The only available data come from the Census, which provides information for the years 1910, 1920, and 1930. Given this information, we consider two migration shocks. First, a short-run

[8]Table 14 and 15 in the appendix provide evidence that the flu-driven capital reallocation were conducive to lower house prices. They report the analogous OLS and 2SLS specification used by examining the effect on relative urban GDP, respectively. All coefficients on credit are negative and statisticalll significant.

Table 8: Suggestive Evidence on Mechanism: Housing

	(1) All Sample	(2) Construction	(3) Internal Demand
$Credit * D_{post1917}$	0.112***	0.227***	0.214***
	(0.041)	(0.048)	(0.045)
$Flu * D_{post1917}$	-103.17***	-196.77***	-192.21***
	(17.71)	(33.32)	(34.62)
F-stat	33.95***	34.87***	30.82***
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	720	360	360

Notes: Column 1 reports all sample (for ease of exposition). Column 2 constraints the sample to the regions in which the increase in housing supply between 1920 and 1930 were above the median (Carmona et al. (2017)). Column 3 considers the regions with a share of occupied housing unit above the median in 1920 (Carmona et al., 2017). Bottom panel reports the first stage of the 2SLS regression along with the F-stat. Top panel reports the coefficients of the second stage. Dependent variable is ratio of urban to rural GDP (in real terms). *Credit* is value of mortgage credit above 6% (in real terms, per capita). *Flu* is excess mortality rate. Sources are described in Section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

change, which we obtain by calculating the difference in net migration between 1920 and 1910. Second, a long-run change, which we obtain by calculating the difference between 1930 and 1910. None of the shocks is perfect. Although workers may hesitate to move and our first estimate may downwardly bias the effects, we prefer this estimate because it is more likely to be influenced by the Spanish Flu. The second one is more likely to be affected by the interaction with the response of capital; that is, labor may follow capital. Paluzie et al. (2009) and González-Val and Silvestre (2020) provide evidence that migrants in Spain moved towards cities and, hence, more urbanized regions during the period analyzed in this paper.

Table 9 reports the estimates of replacing the credit variable in our 2SLS specification, equation 2, for this migration shock. The coefficients of the first stage are negative and statistically significant. This indicates that, consistent with the core-periphery narrative, regions with less flu-related mortality received an inflow of workers. Other factors may be driving this migration, such as young workers being afraid of another pandemic. However, we want to emphasize that this is at odds with a Malthusian/Solow interpretation. The coefficient of the migration shock for urban GDP is positive and statistically significant. Quantitatively, a one standard deviation increase in flu-driven labor mobility increases GDP by 6.4% (0.020*3.18). While we cannot credibly perform a horse race between capital and labor mobility, we note that this effect is smaller than the 9.5% increase in relative urban GDP implied in the analogous exercise for capital, as shown in column 3 of Table 5. Column 3 reports the results for relative urban inflation, where the coefficient is negative and statistically significant. This evidence also supports a core-periphery model featuring economies of scale. Quantitatively, a one standard deviation increase in flu-driven migration reduces inflation by 3.5%, which is also quantitatively smaller than the analogous exercise for capital (5.1%). Columns 2 and 4 report the estimates of the long-run migration shock. The magnitudes of the coefficients are very similar. However, the standard deviation of the net migration shock is larger (4.16 vs. 3.18), which implies that the quantitative effects are, as expected, larger. In particular, relative urban GDP would increase by 9.1% (0.022*4.16) and inflation would decrease by 5.0% (0.012*4.16).

To conclude, our measures of flu-driven labor mobility are imperfect, but they support our narrative that a core-periphery model with factor mobility seems more adequate to examine modern pandemics. Even though we cannot credibly disentangle the flu-driven capital and labor mobility, both factors migrate from regions with high mortality rates and were conducive to the industrial and structural changes observed in regions with low mortality rates in the 1920s. Thus, we see this flu-driven labor mobility as complementary to our core-periphery narrative rather than an alternative hypothesis.

Table 9: Complementary Channel: Population Mobility

	(1) GDP	(2) GDP	(3) Inflation	(4) Inflation
$MigrationShock * D_{post1917}$	0.020***	0.022***	-0.011***	-0.012***
	(0.007)	(0.008)	(0.004)	(0.004)
Inflation Lag			-0.290***	-0.251***
			(0.048)	(0.061)
$Flu * D_{post1917}$	-567.21***	-530.73***	-562.51***	-520.40***
	(105.18)	(90.23)	(217.98)	(188.82)
F-stat	29.08**	34.60***	6.66**	7.60***
Year FE	Y	Y	Y	Y
Prov FE	Y	Y	Y	Y
No Obs	720	720	624	624

Notes: Column headings indicate the outcome variable. In column 1 and 3, the migration shock is defined as the change in net migration between 1920 and 1910. In columns 2 and 4, the shock is defined as change between 1930 and 1910. Bottom panel reports the first stage of the 2SLS regression along with the F-stat. The top panel reports the coefficients of the second stage. Migration is obtained from Silvestre (2005). *Flu* is excess mortality rate. Sources are described in Section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

6 Concluding Remarks

Pandemics are rare yet recurrent events. The conventional view, mainly based on a Malthusian framework, emphasizes that pandemics may exert positive long-run effects on income per capita. We argue that the effects will differ significantly in modern economies, which feature capital mobility and increasing returns to scale. To illustrate this point, we adapted the analytically solvable Forslid and Ottaviano (2003) version of the core-periphery model of Krugman and Venables (1995). We demonstrated that a population shock will disrupt the symmetry across regions, resulting in capital and manufacturing concentrating in the region with the lowest mortality shock.

We empirically examined these empirical predictions regarding the Spanish Flu in Spain from 1915 to 1929. We demonstrated that capital was reallocated towards regions with lower flu-driven mortality, which was conducive to structural transformation. Quantitatively, we find that a one standard deviation increase in flu-driven credit raises relative urban GDP by 9.5%. We provide suggestive evidence that housing was an essential mechanism through which this flu-driven capital reallocation spurred structural transformation in 1920s Spain.

Our evidence on the effects of modern pandemics has important policy implications. Pandemics profoundly affect regional dynamics. We show that pandemic shocks in poorer regions exacerbate existing economic disparities. Capital shifts from areas with higher mortality rates to those less impacted by these shocks have led to widening gaps in income and employment. To address these disparities, governments can implement targeted interventions. One potential strategy is to provide financial subsidies to poorer areas with higher mortality rates due to the pandemic. By doing so, the aim is to bolster these affected regions and facilitate capital investments that can stimulate growth and development. The goal is to encourage a more equitable distribution of investments and support, mitigating the adverse effects on the hardest-hit areas. However, a significant challenge for this approach lies in the principle of economies of scale. Concentrating capital in regions with the highest mortality rates may sometimes lead to less nationally efficient outcomes and may deter urbanization and growth in the less affected zones. This suggests a complex balance between addressing spatial inequality and fostering economic efficiency that policymakers must carefully navigate. Integrating these considerations into policy frameworks will be essential for effectively tackling the impact of pandemics on regional disparities.

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A Additional Tables

Table 10: Determinants of Flu-Driven Mortality

	(1) 1915	(2) 1916	(3) 1917
$Atm.Pressure_{1918}$	-0.695*	-0.698*	-0.697*
	(0.360)	(0.360)	(0.359)
GDP_t	-0.781	-0.562	-0.799
	(1.69)	(1.41)	(1.55)
$Literacy_{1910}$	0.204	0.205	0.204
	(0.344)	(0.344)	(0.344)
$Density_{1910}$	-0.195	-0.202	-0.189
	(0.176)	(0.177)	(0.176)
$Constant$	0.020***	0.020***	0.020***
	(0.005)	(0.005)	(0.005)
F-stat	4.19***	4.21**	4.16***
No Obs	48	48	48

Notes: Column heading indicates the year of the only time-variant independent variable, GDP. Dependent variable is excess mortality rate computed in Basco et al. (2021a) . $Atm.Pressure_{1918}$ is a daily average of atmospheric pressure during September and October of 1918. Data obtained from Goerlich (2012). Gross Domestic Product (GDP) per capita, in real terms, from Rosés et al. (2010). Literacy rates are defined as the share of people aged over 10 who could write and read. Data from Nunez (1992). Population density is thousands of people by square-km in 1910. Data from Carmona et al. (2017). The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 11: Testing Pre-Shock Parallel Trends

	(1) Credit	(2) Relative GDP	(3) House Price
$Flu * Year$	6.23	4.62	-0.89
	(5.86)	(3.92)	(0.57)
Year FE	Y	Y	Y
Country FE	Y	Y	Y
Number Obs.	144	144	144
F-stat	1.13	1.22	2.49

Notes: Column headings indicate the dependent variable. Column 1 is value of urban mortgages with an interest rate above 6% (in real terms, per capita). Column 3 is (log) real house prices (hedonic adjusted). *Flu* is excess mortality rate. Sources are described in Section 4. We cannot perform the same regression for inflation for insufficient data. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 12: Effect of Capital Reallocation on Urban/Rural Inflation: OLS Specification

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * D_{post1917}$	-0.043***	-0.017**	-0.012**
	(0.016)	(0.007)	(0.005)
$InflationLag$	-0.37***	-0.33***	-0.32***
	(0.068)	(0.055)	(0.056)
F-stat	18.70***	19.54***	18.94***
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	240	432	624

Notes: Column heading indicates sample period. Dependent variable is ratio of urban to rural inflation. Sources are described in section 4. D_{post17} is a dummy equal to 1 for years after 1917. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 13: Effect of the Spanish Flu on Real House Prices

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Flu * D_{post17}$	1.91**	2.77***	2.70***
	(0.78)	(0.71)	(0.70)
Year FE	Y	Y	Y
Prov. FE	Y	Y	Y
Number Obs.	336	528	720
F-stat	5.91**	15.18***	14.84***

Notes: Column heading indicates the sample period. Dependent variable is (log) real house prices (hedonic adjusted) from Carmona et al. (2017). The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 14: Effect of Capital Reallocation on Housing Prices: OLS Specification

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * D_{post1917}$	-0.010**	-0.013***	-0.009***
	(0.005)	(0.003)	(0.002)
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	336	528	720
F-stat	4.23**	22.09***	14.90***

Notes: Column heading indicates the sample period. Dependent variable is (log) real house prices (hedonic adjusted) from Carmona et al. (2017). The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 15: Effect of Capital Reallocation on Real House Prices: 2SLS Specification

	(1) 1915-21	(2) 1915-25	(3) 1915-29
$Credit * D_{post1917}$	-0.024**	-0.028***	-0.026***
	(0.012)	(0.009)	(0.052)
$Flu * D_{post1917}$	-78.70**	-99.05***	-103.17**
	(15.02)	(16.58)	(17.71)
F-stat	27.45***	35.69***	33.95***
Year FE	Y	Y	Y
Prov FE	Y	Y	Y
No Obs	336	528	720

Notes: Column heading indicates the sample period. Dependent variable is (log) real house prices (hedonic adjusted) from Carmona et al. (2017). The bottom panel reports the first stage of the 2SLS regression along with the F-stat. The top panel reports the second stage. The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 16: Correlation between Real House Prices and Mortgage Credit

	(1) 1915-21	(2) 1915-25	(3) 1915-29
Mortgage per capita	-0.011*	-0.015**	-0.010**
	(0.006)	(0.003)	(0.002)
Year FE	Y	Y	Y
Prov. FE	Y	Y	Y
Number Obs.	336	528	720
F-stat	3.72*	28.93***	15.90***

Notes: Column heading indicates the sample period. Dependent variable is (log) real house prices (hedonic adjusted). Data from Carmona et al. (2017). Mortgage per capita is real value of urban mortgage with an interest rate above 6%. Data from Registry Statistics of Spain (*Registro de la Propiedad*). Prices comes from Carmona et al. (2017). The table reports fixed effects regressions weighted by population. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

B A Core-Periphery Model with Capital Mobility

The goal of this section is to show how an increase in flu-related mortality can be conducive to capital agglomeration and industrialization in the regions with lower flu-driven mortality. To do that, we adapt the Forslid and Ottaviano (2003) version of the core-periphery model of Krugman (1991) to examine the long-run effects of Spanish Flu. In this section, we explain the model and describe the main results. All derivations are relegated to Online Appendix C.

Our economy consists of two regions, $i = 1, 2$. There are two sectors: agriculture (A) and manufacturing (X). Agricultural good is homogeneous and the manufacturing good is differentiated. There are two factors of production: capital and labor. In particular, K_i and L_i denote the stock of capital and labor in region i, respectively. Capital can move across regions, whereas workers can not. The main departure from Forslid and Ottaviano (2003) is to think of the mobile factor as capital. We make this assumption to emphasize the importance of capital flows across regions in modern pandemics. This is in stark contrast to the typical Malthusian economy where capital (land) is assumed to be fixed in each region. In addition, it is consistent with the fact that, capital (broadly defined) is generally more mobile than labor.

Agents in region i derive utility from agricultural and manufacturing final goods,

$$U_i = C_{X_i}^{\mu} C_{A_i}^{1-\mu}, \tag{B.1}$$

$$C_{X_i} = \left(\int_{s \in N} c_{x_i}(s)^{\frac{\sigma-1}{\sigma}} ds \right)^{\frac{\sigma}{\sigma-1}}, \tag{B.2}$$

where C_{X_i} is the consumption of the differentiated manufacturing good, C_{A_i} is the consumption of the homogeneous agricultural good and μ is the exogenous share of manufacturing in the utility function. $c_{x_i}(s)$ is the consumption of each variety s and N is the amount of varieties in the country. Note that we use the standard Dixit and Stiglitz (1977) love-for-variety utility function for varieties. Following the literature, we assume that the elasticity of substitution between varieties, σ, is larger than one. The budget constraint of the representative consumer in region i is as follows,

$$\int_{s \in n_i} p_{ii(s)} c_{x_{ii}}(s) ds + \int_{s \in n_j} p_{ji(s)} c_{x_{ji}}(s) ds + p_i^A C_{A_i} = Y_i = R_i K_i + W_i L_i, \tag{B.3}$$

where $p_{ji(s)}$ is the price in region i of variety s produced in country j and n_i is the number of varieties produced in region i.

The production function of the agricultural good is,

$$Q_{A_i} = L_{A_i}, \tag{B.4}$$

where L_{A_i} is the number of workers employed in the agricultural sector in region i. We assume that the agricultural good is freely traded at zero cost. Given the production technology, it means that wages are equalized across regions. We choose as numeraire the agricultural good. Thus, P_i^A=W_i=1 for i=1, 2.

We assume that in the manufacturing sector there are increasing returns and monopolistic competition à la Krugman (1979). In particular, to produce each variety, a fixed cost equal to α units of capital needs to be incurred. This fixed cost can be thought of, for example, machinery or R&D-investment. Once this fixed cost has been paid, the marginal cost is β workers. Thus, the Total Cost (TC) to produce $q_{x_i}(s)$ units of variety s in region i is

$$TC_i(s) = \alpha R_i + \beta q_{x_i}(s) W_i. \tag{B.5}$$

Varieties are traded across regions but at a cost. There are iceberg transportation costs, which imply that τ>1 units need to be shipped for one unit to arrive. The profits of producer of variety s in region i are,

$$\pi(s) = p_{ii(s)} q_{x_{ii}}(s) + p_{ij(s)} q_{x_{ij}}(s) - \beta q_{x_{ii}}(s) - \tau \beta q_{x_{ii}}(s) - \alpha R_i, \tag{B.6}$$

where we have already used the numeraire. Note that the marginal cost of selling varieties abroad is higher. Firms face a downward slopping demand curve and, thus, they would have profits. However, there is free entry which implies that profits are zero in equilibrium. In particular, the returns to capital are such that profits of variety producers are zero.

Lastly, we turn to the problem of capital owners. Following Krugman (1991), we assume that agents are short-sighted and, thus, they choose to switch regions if the current welfare is higher in the other region. Let us define k as the share of capital in region 1, $k = K_1/K$. It then follows that,

$$\frac{dk}{dt} = \begin{cases} W(h,\tau) & \text{if } 0 < k < 1 \\ min\{0, W(h,\tau)\} & \text{if } k = 1 \\ max\{0, W(h,\tau)\} & \text{if } k = 0 \end{cases} \tag{B.7}$$

where $W(h,\tau)$= $\left(\frac{R_1}{P_1^\mu} - \frac{R_2}{P_2^\mu}\right) \mu^\mu (1-\mu)^{(1-\mu)}$ is the indirect utility function.

Definition *Given endowment of labor in the two regions (L_1 and L_2), and trade* *costs τ, an steady-state equilibrium is a set of manufacturing price indices P_i, rental rates R_i, number of varieties n_i, production in both sectors Q_{x_i}, output Y_i for all regions i, and an allocation of capital in each region k, such that (i) consumers maximize utility (B.1) given budget constraint (B.3) in each region, (ii) firms maximize profits (B.7) in each region, (iii) profits (B.6) are zero (iv) capital owners do not want to change location, dk/dt=0 in (B.7), and (v) all markets clear.*

The purpose of this model is to illustrate how flu-driven mortality can change the allocation of capital and be conducive to agglomeration and industrialization in one region. Without loss of generality, we assume that the relative population in region 2 is $L_2 = \gamma L_1$. To make our analysis cleaner, we assume that before the pandemic the labor endowment was the same in both regions (i.e., $\gamma = 1$). In contrast, after the pandemic the relative population in region 1 declines (i.e., $\gamma > 1$). In addition, we assume that trade costs are intermediate, $\underline{\tau} < \tau < \bar{\tau}(\gamma)$. [9] We refer the reader to Forslid and Ottaviano (2003) for the different equilibria associated to different trade costs. Given these assumptions, we derive the following results.

Proposition 1 *Given intermediate trade costs, $\underline{\tau} < \tau < \bar{\tau}(\gamma)$, and regions differing only on the relative population, $L_2 = \gamma L_1$, it follows that*

1. *Before the Spanish Flu ($\gamma = 1$), the only equilibrium is the symmetric equilibrium in which production, prices and allocation of capital are the same in both regions.*
2. *After the Spanish Flu ($\gamma > 1$), there exists an agglomeration equilibrium in which production and prices are lower in the region with lower flu-driven mortality (region 2) and all capital is located in this region. Income per capita increases (decreases) in the region with lower (higher) flu-driven mortality.*

Proof See Appendix.

The intuition for this result is as follows. As discussed in the seminal paper of Krugman (1991), ceteris paribus, low transportation costs are needed to break the symmetric equilibrium and have a core-periphery equilibrium. In our model, we consider that trade costs are high enough to rule out the agglomeration equilibrium in identical countries. However, we assume that trade costs are low enough to make the agglomeration possible when the relative size of the regions changes. Under this intermediate trade cost, an epsilon larger

[9] In the appendix, we derive the expressions determining the thresholds. As we show, $\underline{\tau} = \theta_{s_2}(\gamma = 1)^{1/(1-\sigma)}$ and $\bar{\tau}(\gamma) = \theta_{s_2}(\gamma)^{1/(1-\sigma)}$.

market leads the economy to a core-periphery equilibrium. The intuition is that by making one region relatively larger, it becomes more attractive to capital owners, who end up all in the same region. This is the reason why the heterogeneous flu-driven mortality can break the symmetric equilibrium in our model. The rest of the results are immediate once when we know that capital concentrates in the relatively larger market. First, since the price index of manufacturing is negatively related to the number of local firms (which require capital), it follows that the region with less-driven mortality will have lower prices. It also follows that manufacturing output will be larger in this region. Lastly, this reallocation has income effects because of the increasing returns. That is, income per capita increases in the region where capital flows into.

Empirical Predictions According to our theoretical motivation,

1. regions with more flu-driven mortality should experience a relative reduction in productive capital. Specially in riskier (more mobile) capital.
2. regions that receive relatively more capital, due to flu-driven mortality, should experience a relative increase in the ratio of urban/rural production and lower manufacturing prices.

C Online Appendix

In this appendix, we explain how we derive the results of the papers. As a reminder, in our economy, $L_2 = \gamma L_1$ and we are interested in the comparative statics on γ. Following the same steps as in Forslid and Ottaviano (2003), it can be shown that the determination of equilibria depends on the following equation, which is analogous to equation (30) in Forslid and Ottaviano (2003).

$$V(k,\theta) = \frac{(1+\gamma)\theta k + \left[1 - \frac{\mu}{\sigma} + \left(\gamma + \frac{\mu}{\sigma}\right)\theta^2\right](1-k)}{[h + \theta(1-h)]^{\mu/(1-\sigma)}} - \frac{(1+\gamma)\theta(1-k) + \left[\gamma\left(1-\frac{\mu}{\sigma}\right) + \left(1+\gamma\frac{\mu}{\sigma}\right)\theta^2\right]k}{[(1-k)+\theta k]^{\mu/(1-\sigma)}}, \tag{C.1}$$

where $\theta = \tau^{1-\sigma}$ and $k = K_1/K$.

As discussed in Forslid and Ottaviano (2003), the agglomeration in region 2 (k=0) is steady-state stable equilibrium when $V(0,\theta) < 0$. Analogously, agglomeration in region 1 (k=1) is steady-state equilibrium when $V(1,\theta) > 0$. Let us start with the possibility of agglomeration in region 2. In this case,

$$V(0,\theta) = \frac{1 - \frac{\mu}{\sigma} + \left(\gamma + \frac{\mu}{\sigma}\right)\theta^2}{\theta^{\mu/(1-\sigma)}} - (1+\gamma)\theta. \tag{C.2}$$

Agglomeration to region 2 is an equilibrium when $\theta > \theta_{s_2}(\gamma)$. $\theta_{s_2}(\gamma)$ is implicitly defined by

$$1 - \frac{\mu}{\sigma} + \left(\gamma + \frac{\mu}{\sigma}\right)\theta_{s_2}^2 = (1+\gamma)\theta_{s_2}^{1+\mu/(1-\sigma)}. \tag{C.3}$$

Lemma 1 $\theta_{s_2}(\gamma)$ is decreasing with γ.

Proof It follows from direct inspection of C.2. Note that $V(0,\theta)$ is decreasing in both γ and θ given that $\sigma > 1$ an $\mu < \frac{\sigma}{2\sigma-1}$.[10]

The interpretation of this result is that, given trade costs τ, an increase in the relative size of region 2, makes agglomeration in that region more likely. We now discuss the analogous result for agglomeration in region 1.

$$V(1,\theta) = (1+\gamma)\theta - \frac{\gamma\left(1-\frac{\mu}{\sigma}\right) + \left(1+\gamma\frac{\mu}{\sigma}\right)\theta^2}{\theta^{\mu/(1-\sigma)}}. \tag{C.4}$$

Agglomeration to region 1 is an equilibrium when $\theta > \theta_{s_1}(\gamma)$. $\theta_{s_1}(\gamma)$ is implicitly defined by

$$\gamma\left(1-\frac{\mu}{\sigma}\right) + \left(1+\gamma\frac{\mu}{\sigma}\right)\theta_{s_1}^2 = (1+\gamma)\theta_{s_1}^{1+\mu/(1-\sigma)}. \tag{C.5}$$

[10] These assumptions are standard in the literature. $\sigma > 1$ is for the elasticity of substitution between varieties. The constraint on μ is to make sure that agriculture is active in both regions.

Lemma 2 $\theta_{s_1}(\gamma)$ is increasing with γ.

Proof It follows from direct inspection of C.4. Note that $V(1,\theta)$ is increasing in θ and decreasing with γ given that $\sigma > 1$ an $\mu < \frac{\sigma}{2\sigma-1}$.

The interpretation of this result is that since region 1 is relatively smaller, given trade costs, it is more difficult to have agglomeration in this region.

Lemma 3 $\theta_{s_1}(\gamma = 1)$ is equal to $\theta_{s_2}(\gamma = 1)$.

Proof It follows from direct inspection of C.2 and C.4. Note that when $\gamma = 1$ $V(0,\theta)$=-$V(1,\theta)$.

It means that when the two regions are identical, agglomeration is as likely to happen in region 1 as in region 2. Lastly, we derive the results of the proposition, which we reproduce here for convenience.

Proposition 1 *Given intermediate trade costs,* $\underline{\tau}<\tau<\bar{\tau}(\gamma)$*, and regions differing only on the relative population,* $L_2 = \gamma L_1$*, it follows that*

1. *Before the Spanish Flu* ($\gamma = 1$) *the only equilibrium is the symmetric equilibrium in which production, prices and allocation of capital are the same in both regions.*
2. *After the Spanish Flu* ($\gamma > 1$)*, there exists an agglomeration equilibrium in which production and prices are lower in the region with lower flu-driven mortality (region 2) and all capital is located in this region. Income per capita increases (decreases) in the region with lower (higher) flu-driven mortality.*

Proof To have the symmetric equilibrium before changes in the relative population, we need $\theta < \theta_{s_2}(\gamma = 1)$. To have agglomeration only in region 2 with the Spanish Flu, we need $\theta > \theta_{s_2}(\gamma)$ and $\theta < \theta_{s_1}(\gamma)$. Given Lemma 1, Lemma 2 and Lemma 3, we know that $\theta_{s_2}(\gamma) < \theta_{s_2}(\gamma = 1) = \theta_{s_1}(\gamma = 1) < \theta_{s_1}(\gamma)$. Thus, Proposition 1 holds as long as $\theta_{s_2}(\gamma) < \theta < \theta_{s_2}(\gamma = 1)$. Since $\theta = \tau^{1-\sigma}$, it follows that $\underline{\tau} = \theta_{s_2}(\gamma = 1)^{1/(1-\sigma)}$ and $\bar{\tau}(\gamma) = \theta_{s_2}(\gamma)^{1/(1-\sigma)}$. The rest of the proposition is straightforward to show. Let's start with manufacturing prices. Given household and firm maximization, it can be readily checked that manufacturing price index is

$$P_i = \beta\frac{\sigma}{\sigma - 1}[n_i + \theta n_j]^{1-\sigma}. \tag{C.6}$$

Using the fact that labor is the fixed factor, it follows that the price before the flu P_i^{BF} in region i is,

$$P_1^{BF} = P_2^{BF} = \beta \frac{\sigma}{\sigma - 1} \left[(1+\theta) \frac{H}{2\alpha} \right]^{1-\sigma}. \tag{C.7}$$

That is, the price of manufacturing final good is the same in the two regions because they have the same number of varieties, $n_i = n_i = H/2\alpha$. In contrast, it changes after the flu, AF.

$$P_2^{AF} = \beta \frac{\sigma}{\sigma - 1} \left[\frac{H}{\alpha} \right]^{1-\sigma} < P_1^{AF} = \beta \frac{\sigma}{\sigma - 1} \left[\frac{\theta H}{\alpha} \right]^{1-\sigma}. \tag{C.8}$$

Manufacturing prices are lower in the region where capital is accumulated because there are more firms. Given that the agricultural good is homogeneous and all agents have the same consumption basket, it also implies that the consumption price index is lower in the region where there is more capital. Lastly, since there are no firms in region 1, manufacturing output is also larger in region 2.

It can also be shown that income inequality increases and income per capita falls in the region where capital leaves. By using that there are no profits in equlibrium, market clearing and the demand from consumers, it can be shown that return to capital is,[11]

$$R_i = \frac{\mu}{\sigma} \left[\frac{Y_i}{K_i + \theta K_j} + \frac{\theta Y_j}{\theta K_i + K_j} \right], \tag{C.9}$$

where $Y_i = L_i + R_i K_i$. Using our equilibria, it follows that income per capita in region i before the Spanish Flu is,

$$(Y_1/L_1)^{BF} = (Y_2/L_2)^{BF} = \frac{\sigma}{\sigma - \mu} > 1. \tag{C.10}$$

In contrast, after the Spanish Flu,

$$(Y_2/L_2)^{AF} = 1 + \frac{\mu}{\sigma - \mu} \frac{1+\gamma}{\gamma} > (Y_i/L_i)^{BF} > 1 = (Y_1/L_1)^{AF}. \tag{C.11}$$

The first inequality holds as long as $\mu > 0$. This sets of inequalities show that after the mortality shock income per capita increases in region 2 (where capital concentrates) and falls in region 1.

[11] This is analogous to equation 14 in Forslid and Ottaviano (2003).

D Data Online Appendix

Our primary data sources are the following,

- Anuario estadístico de España, several years, INE BASE.
- Anuario de los registros de la Propiedad y del Notariado, several years.
- Censo de población de España, 1900, 1910, 1920, 1930, INE BASE.
- Movimiento natural de la población española, several years, INE BASE.