# Long Run Health Impacts of Income Shocks: Wine and Phylloxera in 19th Century France[1]

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This paper provides estimates of the long-term effects on height and health of a large income shock experienced in early childhood. Phylloxera, an insect that attacks the roots of grape vines, destroyed 40 percent of French vineyards between 1863 and 1890, causing major income losses in wine-growing departments. Because the insects spread slowly from the southern coast of France to the rest of the country, phylloxera affected different regions in different years. We exploit the regional variation in the timing of this shock to identify its effects and examine the effects on the adult height, health, and life expectancy of children born in the years and regions affected by the phylloxera. The shock decreased long-run height, but it did not affect other dimensions of health, including life expectancy. We find that those born in affected regions were about 1.8 millimeters shorter than others at age 20. This estimate implies that children of wine-growing families born when the vines were affected in their regions were 0.6 to 0.9 centimeters shorter than others by age 20. This is a significant effect since average heights grew by only 2 centimeters in the entire 19th century. However, we find no other effects on health, including infant mortality, life expectancy, and morbidity by age 20. *JEL codes*: I12 O12, N32 *Keywords*: Military data; height; fetal origin.

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## 1. Introduction

Poor environmental conditions in-utero and during early childhood have been shown to have adverse consequences on later life outcomes, including life expectancy, height, cognitive ability, and productivity (Barker 1992).[6] Important influences include the disease environment (Almond 2006), the public health infrastructure (Almond and Chay 2005), food availability (see, e.g., Almond, et al. (2006) and Qian (2006) on the great Chinese famine, and Rosebloom, et al. (2001) and Ravelli, et al. (2001) on the Dutch famine of 1944–1945), and even the availability of certain seasonal nutrients (Doblhammer 2000).

At the same time, evidence from developing countries suggests, not surprisingly, that young children's nutritional status is affected by family income (see, e.g., Jensen 2000, and Duflo 2003). Taken together, these two facts suggest that, at least in poor countries, economic crises may have important long-term impacts on the welfare of the cohorts born during these periods.[7] Yet, except for the few papers on famines mentioned above, there is very little evidence establishing a direct link between economic events at birth and adult outcomes. This is perhaps not surprising since such an analysis requires good data on adult outcomes, coupled with information on economic conditions faced during early childhood. Longitudinal data is often not available over such long time periods, especially in poor countries, except for dramatic events such as famines. As a result, the few existing studies tend to be limited to cohort analyses. For example, Van Den Berg, Lindeboom and Portrait (2006) show that among cohorts born between 1812 and 1912 in the Netherlands, those born in slumps have lower life expectancy than those born in

[6] The idea that in-utero conditions affect long-run health is most commonly associated and referred to as the "fetal origin hypothesis," and associated with D.J.P. Barker (see e.g., Barker, 1992, 1994). For additional evidence see, among others, Strauss and Thomas (1995), Case and Paxson (2006), Berhman and Rozenzweig (2005), and references therein.

[7] In rich countries this effect may be compensated by the fact that pollutants diminish during economic slumps (Chay and Greenstone, 2003).

booms. However, a concern with using just time variation is that it might reflect other time-specific elements, such as the quality of public services, the relative price of different nutrients, or even conditions in adulthood. To fill this gap, this paper takes advantage of the phylloxera crisis in 19th century France, which, we will argue, generated a negative large income shock that affected different "departments" (regional areas roughly similar in size to U.S. counties) in France in different years, combined with the rich data on height and health that was collected by the French Military Administration.

Phylloxera, an insect that attacks the roots of vines, destroyed a significant portion of French vineyards in the second half of the 19th century. Between 1863, when it first appeared in southern France, and 1890, when vineyards were replanted with hybrid vines (French stems were grafted onto phylloxera-resistant American roots), phylloxera destroyed 40 percent of the French vineyards. Just before the crisis, about one sixth of the French agricultural income came from wine, mainly produced in a number of small, highly specialized wine-growing regions. For the inhabitants of these regions, the phylloxera crisis represented a major income shock. While there is no systematic data on departmental income in the period (or even agricultural income on a year to year basis), we estimate that the loss in department agricultural income during the crisis probably ranged between 16 and 22 percent in these regions, where 67 percent of the population was living in rural areas just before the crisis (and 57 percent was living directly from agriculture income). Because the insects spread slowly from the southern coast of France to the rest of the country, phylloxera affected different regions in different years. We exploit this regional variation in the timing of the shock to identify its effects, using a difference-in-differences strategy.

We examine the effect of this shock on the adult height, health, and life expectancy outcomes of children born in years when the phylloxera affected their region of birth, controlling for region and year of birth effects. The height and health data comes from the military, which measured all conscripts (who were 20 at the time of reporting) and reported the number of young men falling into a number of height categories at the department level. The statistics also reported the number of young men who had to be exempted for health reasons, and specified the grounds of exemption. This data is available for 83 departments, which are consistently defined over the period we consider.[8] In addition, we use data on female life expectancy at birth constructed from the censuses and reports of vital statistics.

In many ways, France in the late 19th century was a developing country: In 1876 female life expectancy was 43 years; infant mortality was 22 percent; and the average male height at the age of 20 was 1.65 meters, approximately the third percentile of the American population today. The phylloxera crisis therefore gives us the opportunity to study the impact of a large income shock to the family during childhood on long-term health outcomes in context of a developing economy. In addition, the crisis had a number of features that makes it easier to interpret the results. First, we will show that it was not accompanied by either important changes in migration patterns or by an increase in infant mortality. We therefore do not need to worry about sample selection in those who we observe in adulthood, unlike what seems to happen, for example, in the case of a famine. Second, the crisis did not result in a change in relative prices, which means that it did not spill over into areas that did not grow wine (even the price of wine did not increase very much, for reasons we will discuss below). As a result, we can identify regions that were completely unaffected. Finally, the progression of the epidemic was exogenous, as it was caused by the movement of the insects, which is something no one knew how to stop until the late 1880s.

We find that the phylloxera shock had a long-run impact on stature. We estimate that children born during a "phylloxera year" in wine-producing regions were 1.6 to 1.9 millimeters shorter than others. Our very rough estimates suggest that fall in department income in wine-producing regions during these years may have ranged between 10

[8] France lost Moselle, Bas-Rhin, and Haut-Rhin to Prussia in 1870, while retaining the Territoire de Belfort, a small part of Haut-Rhin. Moselle, Rhin-Bas, Haut-Rhin, and Belfort are excluded from the analysis.

percent and 15 percent.[9] These estimates are thus in line with the secular growth in height over the 19th century: height increased by 2 centimeters, when GDP was multiplied by 3, which implies a gain of 1.8 millimeters for a 10 percent increase in income.[10] If we assume that only wine-growing families were directly affected (which, as we discuss below, may not be a very good assumption, since we may expect market equilibrium effects in the department), we calculate that this drop in height corresponds to a decline in height of 0.6 to 0.9 centimeters for children born in families involved in wine production (workers or farm owners) in years where their region was affected. We do not find that children born just before, or just after, the phylloxera crisis were affected by it, which supports the Barker hypothesis of the importance of *in-utero* conditions for long-run physical development. However, we also do not find any long-term effect on other measures of health, including infant mortality, morbidity at the age of 20 (measured by the military as well) or life expectancy of women.

The remainder of this paper proceeds as follow: In the next section, we describe the historical context and the phylloxera crisis. In section 3, we briefly describe our data sources (a data appendix does so in more detail). In sections 4 and 5, we present the empirical strategy and the results. Section 6 concludes.

## 2. Wine Production and the Phylloxera Crisis

Wine represented an important share of agricultural production in 19th century France. In 1863, the year phylloxera first reached France, wine production represented about one sixth of the value of agricultural production in France, which made it the second most important product after wheat (table 1). Wine was produced in 79 out of 89 departments, but represented more than 15 percent of agricultural production in only 40 of them. We refer to these 40 departments below as the "wine-growing" departments.

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[9] We detail how we arrive at these numbers below, but we note that they are very approximative. They are useful merely as order of magnitude.

[10] We have no reliable estimate of the share of agriculture in department income at the time, but given that the share of the adult population working in agriculture was about 60 percent in these regions, it is reasonable to expect that the drop in department GDP was somewhere between 50 percent and two-third of the drop in agricultural income, so between 8 percent and 15 percent.

Phylloxera is an insect of the aphid family, which attacks the roots of grape vines, causing dry leaves, a reduced yield of fruit, and the eventual death of the plant. Indigenous to America, the insects arrived in France in the early 1860s, apparently having traveled in the wood used for packaging (though it is possible that it was actually in a shipment of American vines). By the 1860s, the pest had established itself in two areas of France. In the departments on the southern coast, near the mouth of the Rhône, wine growers first noticed the pest's effects in 1863, and there are many recorded reports of it in the years 1866–1867. In 1869 the pest also appeared on the west coast in the Bordeaux region. The maps in figures 1A to 1D show the progression of the invasion starting from these two points: From the south, the insects spread northward up the Rhône and outward along the coast. From the west, the insects moved southeast along the Dordogne and Garonne rivers and north to the Loire valley. By 1878, phylloxera had invaded all of southern France, and 25 of the departments where wine was an important agricultural production. It reached the suburbs of Paris around 1885.

During the first years of the crisis, no one understood why the vines were dying. As the phylloxera spread and the symptoms became well-known, it became clear that the disease posed a serious threat to wine growers, and two of the southern departments (Bouches-du-Rhône and Vaucluse) formed a commission to investigate the crisis. The commission found phylloxera insects on the roots of infected vines in 1868 and identified the insects as the cause of the dead vines. After experimenting with various ineffective treatments (such as flooding, or treatment with carbon bisulphide), they discovered the ultimate solution in the late 1880s. This solution required wine growers to graft European vines onto pest-resistant American roots. In 1888, a mission identified 431 types of American vines and the types of French soil they could grow in, paving the road to recovery starting in the early 1890s. Eventually, approximately four-fifths of the vineyards originally planted in European vines were replaced with grafted vines.

Figure 2 shows the time series of wine production in France from 1850 to 1908. The decline in the first few years reflects the mildew crisis, which affected the vines before the phylloxera. After a rapid recovery between 1855 and 1859, the production grew until 1877, by which time more than half of wine growing departments were touched by the phylloxera crisis. Note that aggregate wine production continued to increase until 1877 because it continued to increase quite rapidly in the non-affected regions. Wine production fell until 1890, when the progressive planting of the American vines started the recovery.

Table 2 shows the importance of the phylloxera crisis on wine production. Using data on wine production reported in Gallet (1957), we construct an indicator for whether the region was affected by phylloxera. Gallet (1957) indicates the year where the phylloxera aphids were first spotted in the regions. In most regions, however, for a few years after that, production continued to increase (or remained stable), until the aphid had spread. The number of years the aphid took to spread varies tremendously from one department to the next and cannot be captured by a single lag structure. Since we want to capture the fall in wine production due to the insect, we define the "pre-phylloxera" year as the year before the aphids were first spotted, and the indicator "attained by phylloxera" is equal to 1 between the first year the production is below its pre-production level and 1890 (since the grafting solution had been found by then).[11]

We then run a regression of area planted in vines, the log of wine production, and yield for the years 1852-1892 on year dummies, department dummies, and an indicator for whether or not the region was touched by the phylloxera in that year. Namely, we run the following specification:

$$y_{ij}=a\, P_{ij}+ k_i+d_j+u_{ij}$$

where $y_{ij}$ is the outcome variable (vine grown areas, wine yield, wine production, as well as wheat production) in department $i$ in year $j$, $P_{ij}$ is an indicator for phylloxera, $k_i$ and $d_j$ are department and year fixed effects, and $u_{ij}$ is an error term. The standard errors are corrected for auto-correlation by clustering at the department level.

[11] We experimented with other ways of defining the phylloxera attack as well, with results that are qualitatively similar (although the point estimates clearly depend on how strong the fall in production has to be before a department is considered to be "affected"). In particular, the results are unaffected if we use an average of several years before the start of the epidemics to define the pre-disease situation, rather than focusing on the last year.

We also run the same specification after controlling for department specific trends:

$$y_{ij}=a\ P_{ij}+\ k_i+t_{ij}+d_j+u_{ij},$$

where $t_{ij}$ is a department specific trend. The results are shown in table 2, panel B. The yield and the production declined dramatically: according to the specification that controls for a department specific trend, the production was 32 percent lower and the yield was 35 percent lower during phylloxera years.

To make up for the shortage of French wine, both the rules for wine imports into France and the making of "piquette" (press cake —the solids remaining after pressing the grape grain to extract the liquids that was then mixed with water and sugar) and raisin wines were relaxed. For example, while only 0.2 million hectoliters of wine were imported in 1860s, 10 million hectoliters were imported in the 1880s (for comparison, the production was 24 million hectoliters in 1879). Imports declined again in the late 1890s (Ordish, 1972). As can be seen in figure 1, this kept the price of wine from increasing at anywhere near the same rate as the decrease in production. Price movements thus did little to mitigate the importance of the output shock. Moreover, given the size of the crisis in the most affected regions, farmers could not systematically rely on credit to weather the crisis. In particular, Postel-Vinay (1989) describes in detail how in the Languedoc region the traditional system of credit collapsed during the phylloxera crisis (since both lenders and borrowers were often hurt by the crisis). All of this suggests that phylloxera was a large shock to the incomes of people in the wine-growing regions, and the possibility for smoothing it away was, at best, limited.[12]

[12] One question that arises is whether the drop in the wine production was entirely compensated by the increase in export and "piquette" production. It appears that total wine or wine substitute availability was indeed lower during phylloxera years (Ordish, 1972). The reduction in wine consumption may have had a direct effect on health. However, this will be reflected in our estimation, which is based on a differences-in-differences strategy, only to the extent that wine consumption dropped differentially in wine producing and non-wine producing regions. If it did (there is unfortunately no data that can help us answer this question), and in particular if wine consumption dropped more in wine producing regions than elsewhere, and if wine consumption during pregnancy is bad for child development, our estimates will be an underestimate of the true effect of income.

Unfortunately, yearly data on overall agricultural production or department "income" are not available except for a few departments (Auffret, Hau and Lévy-Leboyer, 1981) so we cannot provide a quantitative estimate of the fall in department "GDP" due to the phylloxera. However, there are reasons to think that there was no substitution toward other activities, so that the decline in wine production led to a corresponding decline in income in the affected departments. Table 2 shows that the area planted with vines did not decline during the crisis, both because many parcels of land that had been planted with vines would have been ill-suited to all other crops and also because most growers were expecting a recovery. As a result, the decrease in wine production was not compensated by a corresponding increase in other agricultural production: Columns 3 to 5, in the same table, show the results of regressing the production of wheat and the area cultivated on wheat on the phylloxera indicator, and shows no increase of wheat production compensating the decline in wine production. In the few departments in which the series on agricultural production have been constructed by Auffret, et al. (1981), the fall in overall agricultural production does appear to be proportional with the fall in wine production.

Given this evidence, we used the share of wine in agricultural production in 1862 and, using the total agricultural production as measured in the Agricultural survey of 1862 (Statistique de la France, 1868) as the starting point, we computed two estimates of the drop in agricultural income in wine-producing regions during the phylloxera period. In one estimate, we assume that the production of other crops did not increase (or decrease) in response to the drop in wine production, which is consistent with the historical evidence above. In the other, we assume that the surface area devoted to vine lost during the phylloxera was allocated to other crops during the crisis. With the first method, we estimate that the average loss in agricultural income in the wine producing region during the phylloxera period was 22 percent. With the second method we estimate that it was 16 percent.

The basis for computing the loss in total department income is even weaker. Before the crisis, 57 percent of the population was directly involved in agriculture in these regions (and 67 percent of the population was rural), with strong variation from department to department. For each department, we calculate an estimate of the regional income before the crisis, assuming the same relationship between the share of population in agriculture and the share of agriculture in the GDP as in the time-series at the national level for the 19th century (Lévy-Leboyer and Bourguignon, 1990; Marchand and Thélot, 1997). We then compute what the GDP of the department would have been if non-agricultural was not affected by the crisis. With the two assumptions above on how agricultural income evolved, we compute an estimate of the drop in income ranging from 10 percent to 15 percent. It is important to note that this is *not* a reliable estimate of the income loss. But it does help us scale the order of magnitude of the crisis, which will in turn be useful to give a sense of the magnitude of our estimates.

## 3. Data

In addition to the department level wine production data already described, we use several data sources in this paper (the data sets are described in more detail in the data appendix).

First, we assembled a complete department-level panel data set of height reported by the military. Height is widely recognized to be a good measure of general health, and countless studies have shown that it is correlated with other adult outcomes (see Case and Paxson (2006) and Strauss and Thomas (1995) for references to studies showing this in the context of the developing world and, among many others, Steckel (1995), Steckel and Floud (1997), and Fogel (2004) for historical evidence on this issue from countries that are now considered developed). France is a particularly good context to use military height data. Since the Loi Jourdan in 1798, young men had to report for military service in the year they turned 20 in the department where their father lived (all the young men reporting in one department in one year were called a "classe," or military class). The military measured all members of each classe, and, since 1836, published the data on height yearly in the form of the number of young men who fell into particular height categories (the number of categories varied from year to year). These documents also included, for each department and each year, the number of young men exempted and the grounds for exemption (in particular, if they were exempted for disease, the nature of the disease). Using this data, we estimated both parametrically and non parametrically the average height of the 20-year-olds in each department in each year, as well as the fraction of youth who were shorter than 1.56 meters, the threshold for exemption from military duty (see data appendix for the estimation methods).[13] We also computed the fraction of each military class exempted for health reasons, and created a consistent classification of the disease justifying the exemptions.

The nation-level aggregate data on French military conscripts has been used previously (see Aron, Dumont and Le Roy-Ladurie (1972), Van Merten (1990), Weir (1993), Weir (1997), and Heyberger (2005)). However, this paper is the first to assemble and exploit the data on mean height and proportion of those stunted for all departments and every year between 1872 and 1912.[14] The details of the data construction are presented in the appendix.

Moreover, we also conducted original archival work in three departments to collect military data at the level of the canton (the smallest administrative unit after the "commune," or village) in three wine-growing departments: Bouches du Rhône, Gard and Vaucluse. The precise height data was not stored at this level, but the canton level data tells us three things: The fraction of people not inducted into the military for reason of height (which is available only until the cohort conscripted in 1901, since the military did not reject anyone based on height after that year), the fraction rejected for reasons of "weakness," and the fraction put into an easier service for the same reason.

We only use the data for the years 1872 to 1912 in the analysis (corresponding to years of birth between 1852 and 1892), which span the phylloxera crisis, as well as the period before and the recovery, since this is the period for which the military data is the most

[13] Actually 1.56 meters was the highest threshold for exemption that was used—the threshold varied over time.

[14] With the exception of Postel-Vinay and Sahn (2006), which was written concurrently with this article and exploits the same data set. Weir (1993) constructed a panel of departments over a longer time period, but used only selected years.

representative of the height in the population. Starting in 1872, every young man had to report for military service. Starting in 1886, every man's height was published, even if they were subsequently exempted from the military service. Therefore, the data is representative of the entire population of conscripts from 1886 on; from 1872 to 1885, we are missing the height data for those exempted for poor health (15 percent) or other reasons (25 percent). We discuss in the appendix what we assume about the height of those exempted to construct estimates that are representative of the entire sample, and using a complete individual level dataset available for a sub-sample, we show that these assumptions appear to be valid. The data should therefore be representative of the entire population of young men who presented themselves to the military service examination in a given region.

This sample may be still endogenously selected if phylloxera led to changes in the composition of those who reported to the military conscription bureau in their region of birth, either because of death, migration, or avoidance of the military service. According to historians of the French military service (e.g., Woloch (1994)), the principle of universal military conscription was applied very thoroughly in France during this period. A son had to report in the canton where his father lived (even if the son had subsequently migrated) and the father was legally responsible if he did not. Avoidance and migration by the son are therefore not likely to be big issues. As a check, we computed the ratio between the number of youths aged 15 to 19 in each department in each census year, and the sum of the sizes of the military cohorts in the four corresponding years (for example, a youth aged 19 (resp. 17) in 1856 was a member in the class of 1857 (resp. 1859): The average is 99 percent and the standard deviation is low (table 1). Moreover, as we will show in table 8, this ratio does not appear to be affected by the phylloxera crisis.

The main potential sample selection problems that remain are therefore those of differential migration by the fathers and mortality between birth and age 20. We will show in the robustness section that neither of these seems to have been affected by the phylloxera infestation.

Finally, we use data on number of births and infant mortality (mortality before age 1), from the vital statistics data for each department and each year and two data series constructed by Bonneuil (1997) using various censuses and records of vital statistics: The first one gives the life expectancy of females born in every department every five years, from 1806 to 1901. The second gives the migration rates of females, both for the young (aged 20 to 29) and for the entire population.

## 4. Empirical Strategy

### 4.1 Department-level Regressions

Figures 3 and 4 illustrate the spirit of our identification strategy. Figure 3 shows mean height in each cohort of birth for wine-producing regions (where wine represents at least 15 percent of the agricultural production) and other regions. Wine-growing regions tend to be richer and, for most of the period, the 20-year-old males are taller in those regions than in others. However, as Figure 4 shows very clearly, the *difference* in average height between those born in wine-producing regions and those born in other regions fluctuates. The striking fact in this figure is how closely the general trend in the difference in mean height follows the general trend in wine production. Both grow until the end of the 1860s, decline in the next two decades, when the phylloxera progressively invades France, and increase again in the 1890s, when wine grafting allows production to rise again.

The basic idea of the identification strategy builds on this observation: It is a simple difference-in-differences approach where we ask whether children born in wine-producing departments in years where the wine production is lower due to the phylloxera, are shorter at age 20 than their counterparts born before or after, relative to those who are born in other regions in the same year. Likewise, we can ask whether they have worse health (which the military defines as lower life expectancy, lower long term fertility, etc.). The difference-in-differences estimates are obtained by estimating:

$$(1)\ y_{ij}=a\ PL_{ij}+k_i+d_j+u_{ij}$$

where $y_{ij}$ is the outcome variable (for example, height at age 20, life expectancy) in department $i$ in year $j$, $PL_{ij}$ is the production loss due to phylloxera in the wine-producing region, which is defined as the indicator that the region was affected by phylloxera (constructed as explained in section 2) multiplied by the loss in production in a given year $j$ ($production_{ij}$) relative to the production in the latest pre-phylloxera year ($preproduction_i$). Thus $PL_{ij} = P_{ij} * (Max(\frac{preproduction_i - production_{ij}}{preproduction_i}, 0)$ for departments in producing regions, and is set to 0 if the department was not a wine producing department.[15] $k_i$ and $d_j$ are department and year fixed effects, and $u_{ij}$ is an error term (following Bertrand, Duflo, and Mullainathan (2004), the standard errors are corrected for autocorrelation by clustering at the department level).

We also run the same specification after controlling for department-specific trends. If there is no mis-specification and no omitted time trend, the coefficient should be the same but the standard errors should be tighter.

$$(2)\ y_{ij}=a\ PL_{ij}+ k_i+t_{ij}+d_j+u_{ij}$$

We also define a binary instrument for whether a department is affected by the phylloxera in a given year. This is the interaction between the phylloxera dummy and an indicator for whether the loss in production was greater than 20 percent, and run a similar specification.

Finally, we interact this dummy with two measures of the role of wine in a region's economy. The first one is the area of vineyard per capita before the crisis (we use average area of vineyards over the years 1850 to 1869 taken from Gallet as our pre-crisis measure). An alternative continuous measure is the fraction of wine in agricultural production before the crisis, multiplied by the fraction of the population deriving a living from agriculture.[16]

[15] I.e. less than 15% of the agricultural income came from wine before the crisis.

[16] We will argue below that this appears to be a correct approximation of the fraction of people who lived in families involved in wine production.

Finally, in some specifications, we restrict the sample to those departments where wine represented at least 15 percent of the agricultural production before the crisis. All of these regions were affected by the phylloxera at one point or another, and in these specifications we therefore only exploit the timing of the crisis, not the comparison between regions that may otherwise be different.

All of these regressions consider the year of birth as the year of exposure. But one could easily imagine that the phylloxera affects the long-run height (or other measures) even if children are exposed to it later in their lives. We will thus run specifications where the shock variable is lagged by a number of years (so it captures children and adolescents during the crisis). For a specification check, we will also estimate the effect of being born just *after* the crisis.

### 4.2 Canton-Level Regressions: Gard, Vaucluse, Bouches-du-Rhône

With regressions run at the department level, one may worry that any relative decline of height during the phylloxera crisis is due to some other time varying factor correlated with the infestation. This concern is in part alleviated by controlling for department specific trends, but since we are considering a long time period, it is still conceivable that the trends have changed in ways that are different for regions and cohorts affected by phylloxera, but for reasons that have nothing to do with the disease. We therefore complement this analysis with an analysis performed at the level of the canton: We collected data on military conscripts at the canton level from the archives of three departments in southern France (Gard, Vaucluse, and Bouches du Rhône). Data on wine production is not available yearly at this fine a level, but the area of vineyards was collected for the 1866 agricultural enquiry, and is also available at the canton level in the archives. We will combine this measure of the importance of vine production before the crisis with the indicator for the fact that the department as a whole was hit by the disease as a proxy for the impact of phylloxera on wine-production.

The specification we use for these departments is as follows:

$$(3)\ y_{ijk}=a\ (P_{ij*}V_k)+ m_k+d_{ji}+u_{ijk},$$

where $V_k$ is the hectares of vineyards in 1866 in canton *k*, $P_{ij}$ is a dummy indicating whether department *i* is affected by the phylloxera in year *j*, $d_{ji}$ is a department time year fixed effect and $m_k$ is a canton fixed effect.[17] This specification only compares cantons within the same department, and it fully controls for department times year effects: It thus asks whether young men born in cantons where wine was more important before the crisis suffered more due to the crisis than those born in cantons where it was less important.

## 4. Results

### 4.1 Height

Table 3 shows the basic results on height at age 20 at the department level. In panel A, the independent variable is the fraction by which wine production dropped in the phylloxera period. The results are similar in magnitude with and without department trends, but more precise (and only significant) when we include department trends. The results that include trends indicate that, at age 20, those born in a region that would have lost all of its production to phylloxera would be 3.2 milimeters shorter, or are 0.72 percentage points more likely to be short. Those born in years where production was less than 80 percent of what it was pre-crisis are 1.9 millimeters smaller than others, on average. They are also 0.38 percentage points more likely to be shorter than 1.56 centimeters (panel B). The last panel of table 2 shows that these two sets of numbers are consistent: 56 percent of the production was lost in the years during which the regions were most affected by phylloxera, and the coefficient of the binary indicator of phylloxera is 59 percent of the coefficient of the "lost production" variable.

[17] In the working paper version we use instead the dummy for whether or not the department has lost at least 20 percent of its production, and the results are qualitatively similar. This changes the year for Bouches du Rhône, where the phylloxera was first spotted in 1863, but production did not significantly decline until 1876. This way of defining the affected dummy turns it "on" in 1867, which had slightly lower production than 1862.

While these numbers are small, they appear consistent with the times series evidence and with other estimates of the impact of income on height over the period. Heights increased by 2 centimeters during the century, when GDP roughly tripled, which implies about 1.8 millimiter gain per 10 percent of GDP. Using a time-series of cross sections of French departments over a period that includes ours, Weir (1993) finds an elasticity of height with respect to real wage of 1.5 millimeters per 10 percent of real wage. We argued above that the loss in agricultural income may have ranged between 16 percent and 22 percent in the wine-producing regions during the crisis. Under fairly strong assumptions, we estimate that this may have corresponded to a drop of 10 percent to 15 percent in the GDP in those regions during the crisis. Our estimates thus imply that a drop of 10 percent in a department's income decreased height by 1.06 millimeters to 1.3 millimeters (with the 15 percent estimate) or 1.5 to 1.9 milimeters (with the 10 percent estimate). While our estimates of the income drop due to phylloxera are to be taken with considerable care, they suggest that our numbers are in the same general range.

In panels C and D, we multiply the dummy for exposure to the phylloxera with the intensity of wine production in the area (hectares of vineyards per capita), first in the entire sample and, in order to check that the results are not driven solely by the contrast between wine-producing and non wine-producing regions, in the sample of departments where wine is at least 15 percent of agricultural production. We find that, in wine-producing regions, one more hectare of vine per capita increases the probability that a 20-year-old male born in years where production was at least 20 percent lower due to phylloxera is shorter by 3 percent and reduces his height by 1 centimeter. If, instead, we use data from all the regions, the effects are respectively 1.85 percent and 7 millimeters.

An interesting way to scale the effect of the phylloxera crisis would be to use the fraction of the population living in wine-producing households, or in households servicing the wine industry (oak barrel producers, for example). Note, however, that this would likely be an overestimate of the impact on the families involved in wine production: to the extent wine workers changed jobs in response to the crisis (moved to the local city, or competed with other agricultural workers for other kinds of job), other families in the department may also be affected, violating the exclusion restriction that the only way a person may be affected is because they are a wine-growing family (or a family related to that business). In the other direction, non-wine producing families could be positively affected by a drop in prices (through a reduction in demand from the wine-growing families hit by the crisis). For example, the price of wheat could decline if the demand of wheat dropped. However, the markets for grains and most commodities were well integrated at the time (Drame, Gonfalone and Miller, 1991). Therefore, this effect is likely to be common to all departments (rather than local) and can therefore be differenced out by our difference-in-differences strategy.

In any case, there is, unfortunately, no data source on the fraction of families involved in wine production or wine-related goods and services. To proxy for it, we use the product of the share of wine in agricultural income before the crisis (in 1862) and the share of the population living in households whose main occupation is agriculture (workers or landowners). This would be an overestimate of the fraction of population living in wine-producing households (or households involved in wine production, i.e., workers on vineyards)[18] if the output per worker was higher for wine than for other agricultural products. On the other hand, it is an underestimate of the total number of families related to wine production since it does not take into account those involved in businesses related to wine. Estimates based on the cross-department variation in output per worker and share of wine in agricultural production suggest, however, that the output per worker in wine and non-wine production is similar, so that the coefficient of this variable can then be interpreted as the effect of the crisis on families involved in wine production (wine growing households, or workers). We show this specification in panel E (for all regions) and F (for wine-producing regions only). The regressions indicate that a child born into a wine-producing family during the phylloxera crisis was 0.5 to 0.9 centimeters smaller by age 20 than he would otherwise have been. With all the caveats we discussed in mind, this is not a small effect, since heights in France grew only by 2 centimeters in the entire 19th century.

[18] Which would lead to an underestimate of the effect of the Phylloxera when we use this variable.

Table 4 shows the results of the specification at the canton level of the three wine-producing departments. The results can be directly compared to the results in panels C and D of table 2 since, as in that table, the explanatory variable is the number of hectares of vines divided by the population. One difference is that the data are only available for men born until 1881, and the other is that the threshold for being rejected is not 1.56 meters, but 1.54 meters. This specification also suggests a significant impact of the phylloxera on height: We find that the probability of being rejected for military service because of height was 1.5 percent higher for each additional hectare of wine per capita. This is a somewhat smaller number than what we found in the department-level specification, but the two numbers are not statistically different, and are of the same order of magnitude. The fact that this specification, which uses a much finer level of variation, provides results that are consistent with the department-level results is reassuring.

Table 5 investigates the effects of the phylloxera on various regions and cohorts. Columns 1 to 4 estimate the effect of the phylloxera on various cohorts. Column 1 is a specification check: We define a “born after phylloxera” dummy, and confirm that those born immediately after the phylloxera epidemics are no shorter than those who were born before. This is another element suggesting that the effect is probably not due to an omitted changing trend. Column 2 examines the effect on those who were young children (1 to 2 years old), or toddlers (2 to 5 years old) at the time of the epidemic. Interestingly, we find no long-run effects on them. Finally, column 3 looks at the effect on those who were teenagers during the crisis, and finds again no effect on them. It seems that the shock had no long-lasting effects if it was experienced later in childhood.

Column 4 presents another specification check: We run a specification similar to equation (2) (with the dummy set to 1 for regions where wine represents at least 15 percent of agricultural production), but we also include a phylloxera dummy for regions where wine production is less than 15 percent of agricultural production. Vineyards in those regions were also affected by the phylloxera (so that the “phylloxera” variable can be defined as for all regions), but we do not expect this to really affect average height, since wine did not affect most of the people in this region. Indeed, the coefficient of the phylloxera dummy in regions producing little wine is insignificant (and slightly positive).

Column 5 separates the regions that were affected early and those that were affected late (we code as “early” regions where the phylloxera was first spotted before 1876, the median year at which it reached the regions). Since the disease was progressing slowly from one region to the next, the regions affected later might have been able to anticipate the crisis, and thus avoid a part of the negative impact. This is not what we find: The effect seems to be just as large in regions affected later on. This is surprising, as one could imagine that these families would have undertaken measures to smooth the shock (savings, in particular).

## 4.2 Other Health Indicators

While height is an important indicator of long-run health, it is also important to estimate whether the phylloxera affected more acute indicators of health, both in the short run (infant mortality) and in the longer run (morbidity, life expectancy).

### 4.2.1 Mortality and Life Expectancy

We start by looking at various measures of mortality. A first measure is given by our data: Since after 1872, everyone age 20 was called for the military service and since, as we will show below, it does not appear that there was selective migration out of the phylloxera departments, a proxy of survival by age 20 for males is given by the size of the military cohort (*classe*), divided by the number of births in that cohort (column 3). This measure also shows no effect of phylloxera. We also construct the ratio of the size of the *classe* and the number of children who have survived to age 1 (column 4), and again see no effect. Finally, column 6 presents the results on infant mortality (mortality before 1). There again, we find no impact.

Our next measure of health is the life expectancy of those born during the phylloxera periods. To study this question, we take advantage of data constructed by Bonneuil (1997) from censuses and corrected vital statistics. Bonneuil constructed life expectancy at birth for women born every five years from 1801 to 1901.[19] In column 1 of table 6, we use this variable as the dependent variable, still using the specification from equation (2). We find no impact on life expectancy. This is not surprising since we find no impact on child mortality, and life expectancy is in a large part driven by child mortality.

#### 4.2.2 Military Health Data

To investigate the size of the impact of the phylloxera infestation on health, we then exploit the data collected by the military on those exempted for health reasons, and the reasons for which they were exempted. We use the same specification as before, with the total number of people exempted, and then the number of people exempted for various conditions, as dependent variables. We use the specification in equation (2) (with department-specific trends).

Column 1 of table 7 displays a surprising result: The number of young men exempted for health reasons is actually *smaller* for years and departments affected by the phylloxera outbreak. However, the following columns shed light on this surprising result: The incidences of all the precisely defined illnesses (such as, myopia, goiter, epilepsie, etc.) are in fact unaffected. The only categories of health condition that are affected are that of “faiblesse de constitution” (or weakness) and hernia. Weakness was explicitly a residual category at the time; in her story of military conscription, Roynette (2000) quotes an 1886 treaty of military hygiene, which describes this category as one that could cover “any other ailment which could not be more precisely identified due to lack of time or information” (Morache, 1886). A first reason why the number of rejections for weakness is lower is that there is a mechanical link between rejection for height and rejection for

[19] Focusing on women avoids biasing the results due to the massive mortality of men during the first World War. The data is constructed with care, but embodies assumption and corrections that are sometimes considered inadequate.

weakness: the height criteria was evaluated first so a “weak” person was necessarily not short. A second possibility is that, faced with the necessity of drafting a fixed number of people for the contingent, the military authorities were stricter with the application of the “weak” category at times where they were rejecting more people for reasons of height. The negative effect on hernia is more puzzling, but could be due to the fact that these cohorts performed less hard physical labor at young ages.

Overall there seems to be no clear evidence of a negative long-run impact of phylloxera on any health condition: While it affects long-run height, it seemed not to cause any other physical problems. The conclusion is similar when using “canton” level data (table 4), in the three wine-producing regions. In this data, we have the number of people exempted from military service because of weakness. If we consider the years until the year of birth 1881 (class of 1901), there is no impact of the phylloxera on exemption for weakness. After 1901, however, the military adopted a policy of not rejecting anyone because of height and when we include the post-1901 period, we do see an increase in the number of those exempted for weakness during the phylloxera period. This suggests that after 1901 some of those who would have been exempted based on their height were now exempted based on being labeled as weak, another indication of the permeability of those two categories.

### 4.3. Robustness to Sample Selection

Table 5 presented a number of specification checks confirming the fact that those conscripted 20 years after the department where they reported was affected by phylloxera, are shorter than others born in other years.  However, as we have pointed out above, while a strength of the military data is that it covers a large sample of the male population, there are some reasons to worry about selection biases. The main source of potential selection bias comes from the composition of the military class (the cohort who was drafted in each department in each year), and whether it is representative of all the children born in the department, or of all the children that would have been born in the department in the absence of the phylloxera.

Selection could arise at several levels. First, there could be fewer births during the phylloxera period, either due to fewer conceptions or to more stillbirths. The “marginal” (unborn) children could be different than the others; in particular, they could have been weaker, had they lived. We regress the number of live births in a year, as well as the ratio of stillbirths to total births in the phylloxera years in table 6 (columns 2 and 5). There does not appear to be a significant effect on the number of births.

Second, there could be more infant mortality in the phylloxera years, thus selecting the “strongest” children. However, we have seen in table 6 that life expectancy and the ratio of the size of the class over the number of births, or the number of survivors by age 1, were not significantly affected.

While none of the estimates in table 6 are significant, it is useful to see whether they could induce a selection bias that may produce spurious results. We see an insignificant *reduction* in infant mortality which could potentially bias our results upwards. Suppose, for example, that there is no effect of phylloxera on height, but that it helps weak children to survive (perhaps because women drank less wine during pregnancy). Suppose all these marginal children are below 1.56 meters. This would generate a coefficient equal to what we estimate in table 3. However, all the other coefficients go in the other direction: the number of births is slightly lower in the phylloxera area, which would introduce positive selection (if unborn children would have been weaker), and may be the reason for the negative effect on infant mortality. The class size is also slightly lower, again suggesting a positive selection. Thus, on balance, we do not think that the results can reasonably be caused by selective birth or survival.

Third, children born in phylloxera years may have been less likely to report for service where they were born. Since they have to report in the place their parents live, this would be due either to avoidance by the child or to migration of the child’s parents: Some people may have left the affected regions during these years. Table 8 shows some evidence that neither avoidance nor migration are likely to be biasing our results. To measure avoidance, we construct the ratio of the size of five subsequent military cohorts on the size of the census cohorts for people aged 15 to 19 (as discussed above, the mean of this ratio is 99 percent). As shown in column 3 of table 9, this is no different for children who were affected by the phylloxera, suggesting they were no more likely to avoid military service. Finally, columns 1 and 2 use data constructed by Bonneuil on the migration of women. We use the fraction of women aged 20 to 29 and aged 20 to 60 who migrated as dependent variables. There appears to be no effect of the phylloxera on migration out of the affected departments. This does not mean that people did not migrate at all In the three departments for which we have canton-level data, we find that the classes born in phylloxera years are smaller in the *cantons* that relied more intensively on wine production (column 4, table 4). This, combined with the fact that we see no migration out of the departments, suggests that some of the families may have migrated out of the wine-producing cantons but remained in the department.[20]

## 5. Conclusion

The large income shock of the phylloxera had a long-run impact on adult height, most likely due to nutritional deficits during childhood. We estimate that children born in affected regions during the years of the crisis were 0.5 to 0.9 centimeters shorter than their unaffected peers. This is a large effect, considering that height increased only by 2 centimeters over the period. Similar results are obtained when comparing departments with each other or when using data at a lower level of aggregation, the canton, which reinforces our confidence in their robustness. The effects are concentrated on those born during the crisis, and imply that they suffered substantial nutritional deprivation in-utero and shortly after birth, and that had a long-term impact on the stature they could achieve.

However, this crisis did not seem to result in a corresponding decline in other dimensions of health, including mortality, even infant mortality. This suggests, as suggested by

[20] A regression of the urbanization rate on the phylloxera dummy (controlling as usual for department dummies, year dummies, and specific department trends) suggests indeed that urbanization progressed significantly faster in phylloxera years in the affected departments.

Deaton, Cutler and Lleras-Muney (2006), that despite the shock to income and corresponding decline in nutrition, health status may have been protected by other factors, such as public health infrastructure (see Goubert (1989) on the importance of clean water in the period).

Appendix: Data sources and construction[21]

This article relies on a number of data sources, often assembled in electronic form for the first time. We are pleased to make all the data available for distribution. This appendix details the sources and the procedures followed to construct the data.

1. Wine and wheat production

    a. Aggregated data on wine production

The aggregate data on wine and production comes from Statistique Générale de la France, Annuaire Statistique, 1932, Paris, Imprimerie Nationale, 1933, p, 55*-56*.

    b. Department level wine production and phylloxera crisis

The source is Pierre Galet's *Cépages et Vignobles de France* (Galet, 1957), which gives yearly the area planted in vines and the volume of wine produced in almost every wine-growing department from 1860 to 1905. We used the yearly series on wine production as is. We computed a measure of pre-phylloxera area planted in wine by computing the average surface planted in vine during the years 1850 to 1869. We also obtain from Galet the year of the first time the phylloxera was spotted in every important wine-growing department.

    c. Department level yearly series on wheat production

From 1852 to 1876, the data comes from Ministère de l'Agriculture et du commerce *Récoltes des céréales et des pommes de terre de 1815 à 1876*, Paris, Imprimerie Nationale, 1878. From 1877 onwards, it comes from Statistique Générale de la France, *Annuaire Statistique*, 1932, Paris, Imprimerie Nationale, 1878--.

    d. Canton level data on wine production pre-phylloxera

We use the data on wine surface from the Agricultural Inquiry of 1866 (Ministère de l'Agriculture, du Commerce et des Travaux Publics, Enquête agricole, 2° série, enquêtes départementales, 22° et 23° circonscription, Paris, 1867), which are available at the level of the canton.

2. Population data

    a. Department level population

[21] (Note to referees: The data appendix could remain online if is not necessary in the print version.)

The population (and the agricultural population ) of each department was obtained from the 1876 census. Statistique de la France: Résultats généraux du dénombrement de 1876. Paris, Imprimerie nationale, 1878.

b. Canton level population

The data on the population of cantons was taken from the military data (see below). The wine superficie in 1866 was normalized by the canton population in 1872.

c. Births and deaths

Total number of births, stillbirths, and total number of deaths before age 1 are obtained from the vital statistics, reported annually in "Statistique Générale de la France: Annuaire statistique de la France, Paris, Imprimerie nationale" (various years). We computed infant mortality as the number of deaths before the age of 1 divided by the number of births during that year (this makes the assumption that most infant death occur in the first few months of life). Using instead an average of the birth this year and last as the denominator makes no difference to the result. As Bonneuil (1992) describes in detail, both the data on births and deaths are noisy, and the data has very large outliers. We exclude from the raw series the observations where the infant mortality is in the bottom percentile or the top percentile. This does not remove any department but removes a few very low or very high observations in some departments.

3. Military height and health data

a. Sources: Department level data

The department level data is reported yearly (beginning in 1836) in the yearly publications "Compte rendu sur le recrutement de l'armée". Young men born in a given year, for example 1852, formed the "classe of 1872." They were normally examined early the following year, at the age of between 20 years plus 8 months on average (plus or minus 6 months depending on the date of birth). They were measured and received a medical exam.

Before 1871, not everyone was called for the military service: Each young man received a random number, and people were examined in random order until the size of the "contingent" (active army) needed for the year was filled. It was also possible to exchange with someone else. The size of those exempted for health reasons was not reported.

The data becomes clearer after an 1872 law (following the defeat of Germany) that changed the nature of the military service: Everyone was now called, and replacements were not allowed. The statistics also reported the height of a much larger fraction of the class. There are two periods in the data:

1) From 1886 to 1912: Things are very simple. Every young man was examined, and a summary table reported the distribution of height for the *entire cohort* (as the

number of people falling into various bins—the number of bins varied from 10 to 26). The heights were not separately reported for different categories of people.

2) From 1872 to 1885:
    - Every young man was called to be examined. From 1872 to 1885, a “classe” was about 300,000 young men. Only about 10,000 per year did not present themselves (3 percent), and were therefore not measured.
    - Among those who were measured
        i. A fraction (about 50 percent of the cohort) was put in the “contingent,” or active service. Their height is recorded in bins in the table “contingent.”
        ii. A fraction (10 percent) was put in a category “auxiliaire” (they were asked to do an easier military service). Their height is recorded in bins in the table “auxiliaries,” with the same category as the table for the contingent.
        iii. A fraction (7 percent) was put in a category “ajournés” (they were asked to sit out and to go be examined again the following year. Fortunately, their data was not aggregated with that of the rest of the contingent the following year). A number of them were “ajournés pour défaut de taille” (too short), and we therefore know that they are smaller than the height threshold in those years (1.54m). A number were “ajournés pour faiblesse de constitution” (weakness), and following Weir (1997) we assume that they are taller than the minimum threshold (otherwise, they would have been “ajournés pour défaut de taille,” and that they are otherwise distributed like the rest of the population above this threshold. They represent only a fairly small fraction of the population (about 5 percent).
        iv. A fraction (another 10 percent of the population) was put in a category “exemptés” (exempted) for health reasons. Still following Weir (1997) we assume that their height has the same distribution as the rest of the population.
        v. A fraction (about 25 percent of the population) was “dispenses,” and did not need to do the military service, for reasons other than health (priests, sons of widows, etc., were put in this category). Their height was not reported in the summary descriptive either, and we assume that their height as the same distribution as the rest of the population.

Fortunately, since everyone was measured, it is possible to check some of these assumptions (which this paper is the first to do). Farcy and Faure (2003) collected individual level military data on about 50,000 young men born in 1860 (classe of 1880) in Paris and a few other departments. Figure A1 compares the distribution of height of those who serve in the active service to that of the “dispensés” (25 percent of people exempted from the military service for reasons other than health).[22] The distributions are

[22] For both figures we estimate the distribution with a kernel density estimator, using an Epanechnikov Kernel and a bandwidth of one centimeter.

right on top of each other. Figure A2 compares those exempted for health reasons to the entire observed population (dispensés+auxiliaires+ajournés). While the correspondence is less perfect (the distribution of height of the exempted has less mass at the mode), the median of the two distributions are the same (165 centimeters) and the means are also extremely close (165.09 centimeters for those exempted, and 165.26 centimeters for the rest of the population). This suggests that the approximations that are done in this paper are acceptable.

- There was a last complication: From 1872 to 1885, the aggregate data was not reported at the level of the department, but at a smaller level (military district). We entered the data at that level and re-aggregated at the department level.

b. Sources: Cantons level data

The height data were published after aggregation at the level of the department, but some data was also tabulated at the level of the "cantons." The yearly reports ("Comptes statistiques et sommaires") are kept in the departmental archives, where we collected them for three departments: Gard, Vaucluse, and Bouche du Rhône. The height distribution was not tabulated at that level, but the population of the canton, the number of youths placed in auxiliary service, the number of youths asked to sit out because they were too short, and the number of youths placed in the active service was recorded. Note that we lose this information after the class of 1881 since height stopped being a reason for exemption at this time.

c. Computations methods

The records on height provide data in a summary form, giving the number of conscripts in height bins of various widths. For example, the number of those between 1.54 and 1.63 meters or those between 1.67 and 1.7 meters. Men shorter than the minimum height requirement were exempt from service, and listed as "*défaut de taille*" (lack of height) in the exemption statistics, resulting in left-censored data.[23] The data are in fact double-censored, since the final category includes conscripts above a certain height, 1.73 meters for example. Between 1850 and 1912 the number of categories changes several times, reaching a maximum of 28 from 1903 to 1912 and a minimum of 9 from 1872 to 1900.

We estimate the departmental distributions of height two ways. First, we assume that the distribution is normal and estimate the parameters of the distribution by maximum likelihood estimation. The log likelihood function is maximized using a simplex search algorithm using starting guesses of 1.66 meters for the mean height and 0.04 meters for standard deviation.[24] Provided the assumption of normality holds, this technique yields

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[23] The minimum height is 1.56m from 1832 to 1871 and 1.54m from 1872 to 1900. From 1901 on there is no minimum height requirement.

[24] The general form of the log likelihood function for this data is

$$L = c_1 * \ln\left(\Phi\left(\frac{x_1-\mu}{\sigma}\right)\right) + \sum_{i=2}^{n-1}\left(c_i * \ln\left(\Phi\left(\frac{x_i-\mu}{\sigma}\right) - \Phi\left(\frac{x_{i-1}-\mu}{\sigma}\right)\right)\right) + c_n * \ln\left(1-\Phi\left(\frac{x_{n-1}-\mu}{\sigma}\right)\right)$$

efficient estimates of the means and variances of the distributions. We use the mean of the distribution estimated following this procedure.

While height typically follows a normal distribution among adult populations (and the graphs we just discussed indeed appear to be normal), the distribution of height among French conscripts may differ from a normal distribution. In particular, if the phylloxera crisis did affect long-term health, it could result in a distorted distribution. In a population with varying levels of initial health, an income shock might therefore not simply shift the distribution; it could have bigger effects at the tails. Imposing a normal distribution on affected regions may obscure these effects.

We therefore also estimate the height distributions non-parametrically. For each department-year cell, the number of observations equals the number of height categories. Each category is assigned the value of the mean of its limits and weighted by its count of conscripts. The extreme lower and upper categories are assigned values 1 centimeter below and above the censoring points. Using a kernel density estimator, we estimate the PDF evaluated at 50 evenly spaced heights.[25] Riemann summation transforms the points of the PDF into a CDF, and we interpolate to find the deciles of the distribution. We use this estimated data to compute a uniform series for the percentage of individuals measured who are shorter than 1.56 meters (very short), which we use as an alternative dependent variable.

4. Life Expectancy and Migration

The life expectancy and migration data were constructed by Bonneuil (1997) from vital statistics and census data that he very carefully corrected to provide consistent data.

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where n is the number of height categories, c is the number of observations in each category, and x is a boundary between categories and phi is the standard normal cdf.

[25] We use a Gaussian kernel with optimal bandwidth approximated by $h = \frac{0.9m}{n^{1/5}}$, where m is the sample variance of the midpoints of the height categories and *n* is the number of categories.

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Table 1: Summary Statistics

| | Mean | Std. deviation | Observations |
|---|---|---|---|
| | (7) | (8) | (9) |
| Superficie grown in wine (hectare) | 28205 | 33549 | 2165 |
| Log wine yield (value per hectare) | 2.55 | 0.83 | 2153 |
| Log(wine production) (value) | 12.03 | 1.87 | 3088 |
| Log(wheat production) (value) | 13.66 | 0.89 | 3209 |
| Share of wine in agricultural production (1863) | 0.15 | 0.14 | 3649 |
| Share of population working in agriculture | 0.58 | 0.15 | 3526 |
| Superficie grown in wine per habitant | 0.07 | 0.09 | 3769 |
| Share of population in agriculture multiplied by share of wine in agricultural Production | 0.09 | 0.08 | 3526 |
| Number of live births | 10751 | 8593 | 2795 |
| Share of males surviving until age 20 | 0.69 | 0.23 | 2683 |
| Share of males surviving until age 20 (conditional on surviving till 1) | 0.85 | 0.29 | 2599 |
| Share of stillbirths | 0.04 | 0.01 | 2795 |
| Infant mortality (death before age 1/live birth) | 0.17 | 0.04 | 2486 |
| Life expectancy (women) | 44.34 | 4.55 | 630 |
| Net outmigration of youth age 20-29 | -0.02 | 0.05 | 690 |
| Net outmigration (all) | -0.02 | 0.02 | 690 |
| Military class size | 3567 | 2708 | 3526 |
| Military class/census cohort aged 15-19 | 0.99 | 0.27 | 504 |
| Proportion exempted for health reasons | 0.24 | 0.07 | 3354 |
| Mean height of military class at 20 | 1.66 | 0.01 | 3526 |
| Fraction of military class shorter than 1.56 meters | 0.05 | 0.02 | 3526 |
| Height of percentile 10 | 1.57 | 0.01 | 3526 |
| Height of percentile 20 | 1.59 | 0.01 | 3526 |
| Height of percentile 25 | 1.60 | 0.02 | 3526 |
| Height of percentile 50 | 1.65 | 0.01 | 3526 |
| Height of percentile 75 | 1.69 | 0.01 | 3526 |
| Height of percentile 80 | 1.70 | 0.01 | 3526 |
| Height of percentile 90 | 1.72 | 0.01 | 3526 |

Notes:

1-Except when otherwise indicated, this table presents average by department of the variables used in this paper over the years 1852-1892 (corresponding to the military classes 1872-1912, and years of birth 1852-1892

2- Data sources are described in detail in the data appendix

Table 2: Impact of phylloxera on wine area and wine production

| | wine | | | wheat | | |
|---|---|---|---|---|---|---|
| | log(area) | log(yield) | log(production) | log(area) | log(yield) | log(production) |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **A. Controls: Year Dummies, Department dummies** | | | | | | |
| Phylloxera | -0.069 | -0.287 | -0.264 | 0.005 | -0.013 | -0.020 |
| | (.061) | (.06) | (.101) | (.024) | (.025) | (.037) |
| Observations | 2165 | 2153 | 3088 | 1020 | 1020 | 3172 |
| **B. Controls: Year dummies, department dummies, departement specific trend** | | | | | | |
| Phylloxera | -0.046 | -0.427 | -0.449 | 0.005 | -0.027 | 0.025 |
| | (.051) | (.077) | (.1) | (.017) | (.024) | (.03) |
| Observations | 2165 | 2153 | 3088 | 1020 | 1020 | 3172 |
| **C. Sample restricted to wine producing regions (with department specific trend)** | | | | | | |
| Phylloxera | -0.016 | -0.480 | -0.448 | -0.008 | -0.008 | 0.026 |
| | (.049) | (.092) | (.119) | (.016) | (.031) | (.036) |
| | 1058 | 1051 | 1519 | 456 | 456 | 1433 |

Notes:
1-Each column and each panel present a separate regression
2-All regressions include department dummies and year dummies
3-Standard errors corrected for clustering and auto-correlation by clustering at the department level (in parentheses below the coefficient)
4- The Phylloxera dummy is 1 every year production is lower than pre-phylloxera after the first year the aphid was seen in the region and before 1890.
5-There are fewer data points in this regressions than in the next tables, because the data on wine and wheat production is not available for every department in every year.

Table 3: Impact of phylloxera on height at 20

| | Dependent Variables | |
|---|---|---|
| | Mean height | Fraction shorted than 1.56 meter |
| | (1) | (2) |
| **A. Ratio of lost production during phylloxera period** | | |
| **A.1 Year Dummies, Department dummies** | | |
| % production loss during | 0.00216 | -0.00538 |
| Phylloxera period | (.0019) | (.00415) |
| Observations | 3403 | 3403 |
| Department trend | No | No |
| | | |
| **A.2 Year Dummies, Department Dummies, Department trend** | | |
| % production loss during | 0.00323 | -0.00734 |
| Phylloxera period | (.0019) | (.00329) |
| Department Trend | Yes | yes |
| | 3403 | 3403 |
| **B.Binary indicator for Phylloxera Year** | | |
| Born in phylloxera year | -0.00188 | 0.00381 |
| | (.00095) | (.00173) |
| Observations | 3485 | 3485 |
| Department trend | Yes | Yes |
| | | |
| **C. Hectare of vine per habitant** | | |
| born in phylloxa year *hectare | -0.00753 | 0.01928 |
| vine per habitant | (.00389) | (.01142) |
| Observations | 3485 | 3485 |
| Department trend | Yes | Yes |
| | | |
| **D. Hectare of vines per habitant (wine producing region only)** | | |
| born in phylloxera year*hectare | -0.01101 | 0.03074 |
| vine per habitant | (.00422) | (.01352) |
| Observations | 1558 | 1558 |
| Department trend | Yes | Yes |
| | | |
| **E. Share of population in wine growing families** | | |
| born in ohylloxera* | -0.00551 | 0.01198 |
| Importance of wine | (.00392) | (.00985) |
| Observations | 3485 | 3485 |
| Department trend | Yes | Yes |
| | | |
| **F. Share of population in wine growing families (wine producing regions)** | | |
| Phylloxera* | -0.00901 | 0.02257 |
| Importance of wine | (.00459) | (.01228) |
| Observations | 1558 | 1558 |
| Department trend | Yes | Yes |

Note:
1-Each column and each panel present a separate regression
2- The dependent variables are mean height (or proportion shorter than 1.56 meters among a military class in a department and year)
2-"Born in Phylloxera year" is a dummy equal to 1 if the department was affected by phylloxera in the year of birth of a military cohort (see text for the construction of this variable)
3-All regressions include department dummies and year dummies
4-Standard errors corrected for clustering and auto-correlation by clustering at the department level (in parentheses below the coefficient)
5- The share or population in wine growing families is estimated, as described in the text

**Table 4: Effect of phylloxera on height, weakness, and exclusion for other reasons**
**Canton-level regression for three Departments**

| | Dependent variable: Canton-level means | | | |
|---|---|---|---|---|
| | Fraction rejected for size | Fraction rejected for weakness | | Class size |
| | (1) | (2) | (3) | (4) |
| Hectare of vine per habitant in canton | 0.01498 | 0.00033 | 0.01664 | -64.38 |
| *phylloxera was present in department in year of birth | (.0074) | (.0186) | (.0081) | (37.52) |
| Observations | 2040 | 2040 | 2590 | 2610 |
| Department*year fixed effect | Yes | Yes | Yes | Yes |
| Canton fixed effects | Yes | Yes | Yes | Yes |
| Sample | 1852-1881 | 1852-1881 | 1852-1891 | 1852-1892 |
| | | | | |
| Mean of dependent variable | 0.019 | 0.090 | 0.10 | 147 |
| Standard deviation of dependent variable | 0.019 | 0.056 | 0.06 | 291 |

Notes:

1-Data source: archival canton-level data collected by the authors for three departments affected by the phylloxera: Vaucluse, Gard, and Bouches du Rhone

2-The data set contains canton-level data for these three department for the years 1852-1891

3-All the regressions include separate fixed effects for each year in each department and canton fixed effects

4- All standard errors (in parentheses below the coefficient) are clustered at canton-level

**Table 5: Who is affected?**

| | Dependent variables | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Height at 20 | | | | | Fraction shorter than 1.56 meters at 20 | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Born in phylloxera year | -0.00220 | -0.00177 | -0.00170 | -0.00301 | -0.00186 | 0.00550 | 0.00305 | 0.00349 | 0.00302 | 0.00221 |
| | (.00119) | (.00093) | (.00091) | (.00121) | (.00084) | (.00239) | (.00181) | (.00173) | (.00229) | (.0017) |
| Born 1 to 5 years after phylloxera | -0.00108 | | | | | 0.00563 | | | | |
| | (.00171) | | | | | (.00626) | | | | |
| Born 1 to 2 years before phylloxera | | 0.00000 | | | | | -0.00183 | | | |
| | | (.00091) | | | | | (.00127) | | | |
| Born 2 to 5 years before phylloxera | | 0.00079 | | | | | -0.00384 | | | |
| | | (.00119) | | | | | (.0011) | | | |
| Born in phylloxera year, region affected early | | | | | -0.00009 | | | | | 0.00705 |
| | | | | | (.00107) | | | | | (.00218) |
| Born in phylloxera year, region producing little wine | | | | 0.00127 | | | | | 0.00088 | |
| | | | | (.00081) | | | | | (.00176) | |
| Teenager during phylloxera | | | 0.00127 | | | | | -0.00222 | | |
| | | | (.00083) | | | | | (.00104) | | |
| Number of observations | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 |

Notes:

1-All regressions include year of birth dummies, department dummies, and department specific trends

2-All standard errors (in parentheses below the coefficient) are accounting for clustering and autocorrelation by clustering at the department level

**Table 6: Impact on fertility, mortality, and life expectancy**

| | Life expectancy (women) | Live births | Class size /live births in birth year | Class size /survivors at age 1 | Stillbirths/all births | Infant mortality (before age 1) |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Born in phylloxera year | 0.5087 | -39 | -0.0025 | -0.0082 | -0.0004 | -0.0033 |
| | (.3604) | (76) | (.0062) | (.0087) | (.0005) | (.0024) |
| | 622 | 2763 | 2651 | 2568 | 2763 | 2461 |

Notes:

1-All regressions include year of birth dummies, department dummies, and department specific trends

2-All standard errors (in parentheses below the coefficient) are accounting for clustering and autocorrelation by clustering at the department level

3- Data on life expectancy for women used in Column 1 is from Bonneuil (1997).

4-Data on live births, infant mortality, and stillbirths obtained from vital statistics

5-Data on class size obtained from mility record. A class observed in year t was born in year t-20

**Table 7: Effect on health outcomes, military data**

| | Exempt due to health | Myopia | Goiter | Hernia | Spinal problem | Epilepsy | Low IQ | Feeble | Blind | Deaf |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Born in | -0.0081 | -0.00012 | -0.00010 | -0.00092 | -0.00025 | 0.00001 | 0.00020 | -0.00218 | 0.00008 | 0.00020 |
| Phylloxera year | (.0044) | (.00014) | (.00014) | (.00032) | (.00028) | (.00011) | (.00023) | (.00077) | (.00012) | (.0001) |
| Number of observat | 3315 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 | 3485 |

Notes:

1-All regressions include year of birth dummies, department dummies, and department specific trends

2-All standard errors (in parentheses below the coefficient) are accounting for clustering and autocorrelation by clustering at the department level

Figure 1A: Phylloxera in 1870

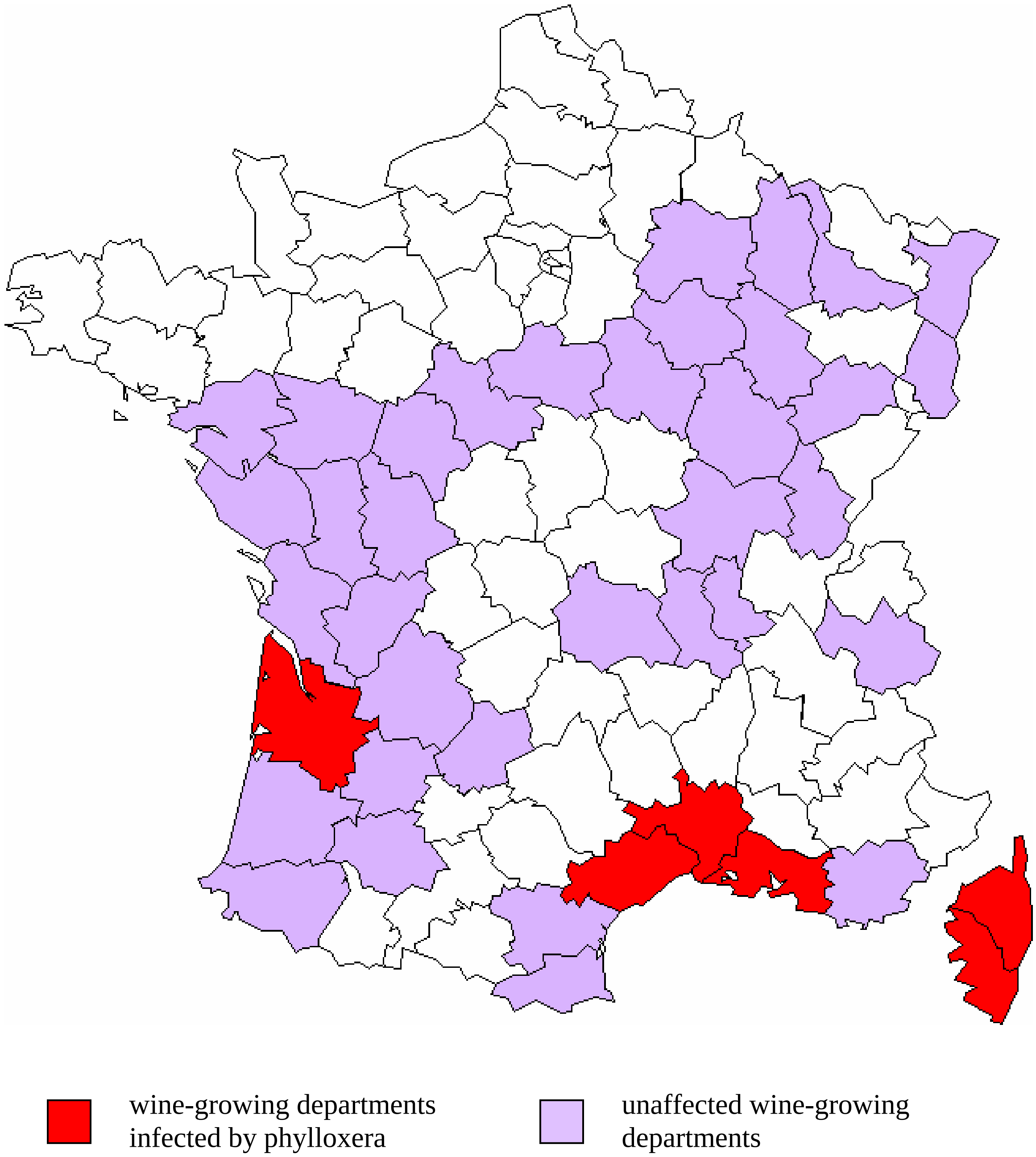
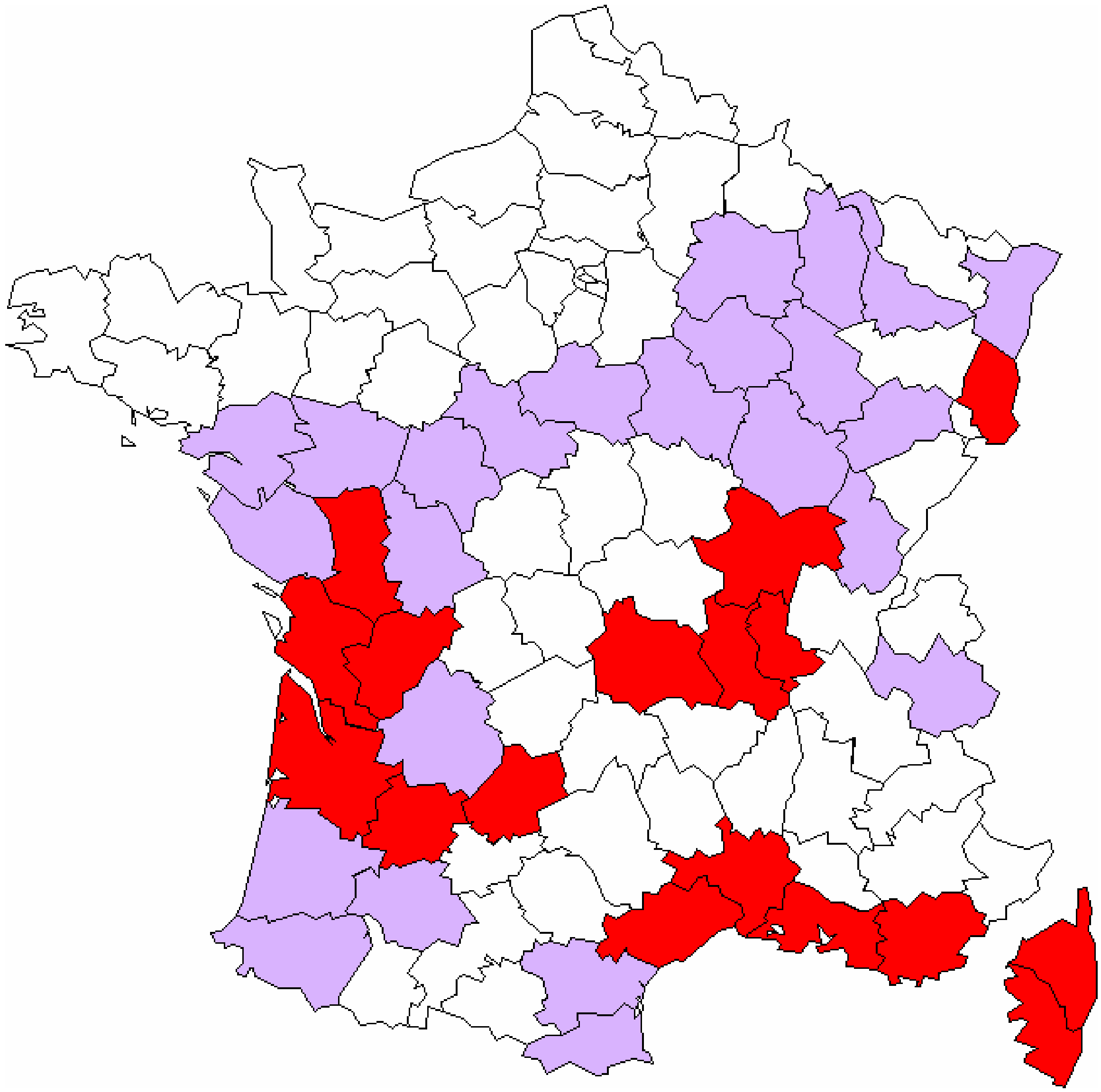


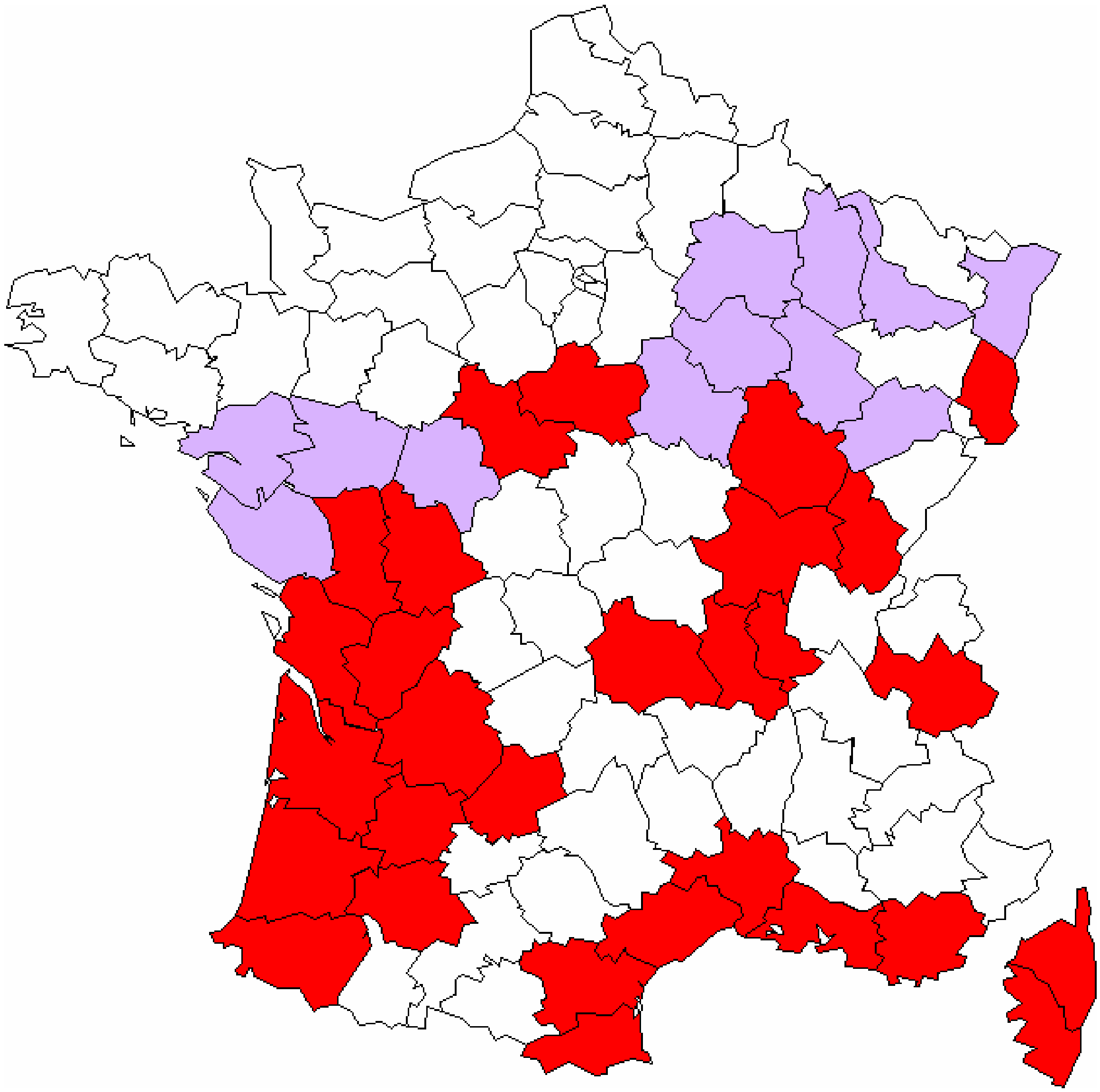
Figure 1B: Phylloxera in 1875



wine-growing departments infected by phylloxera

unaffected wine-growing departments

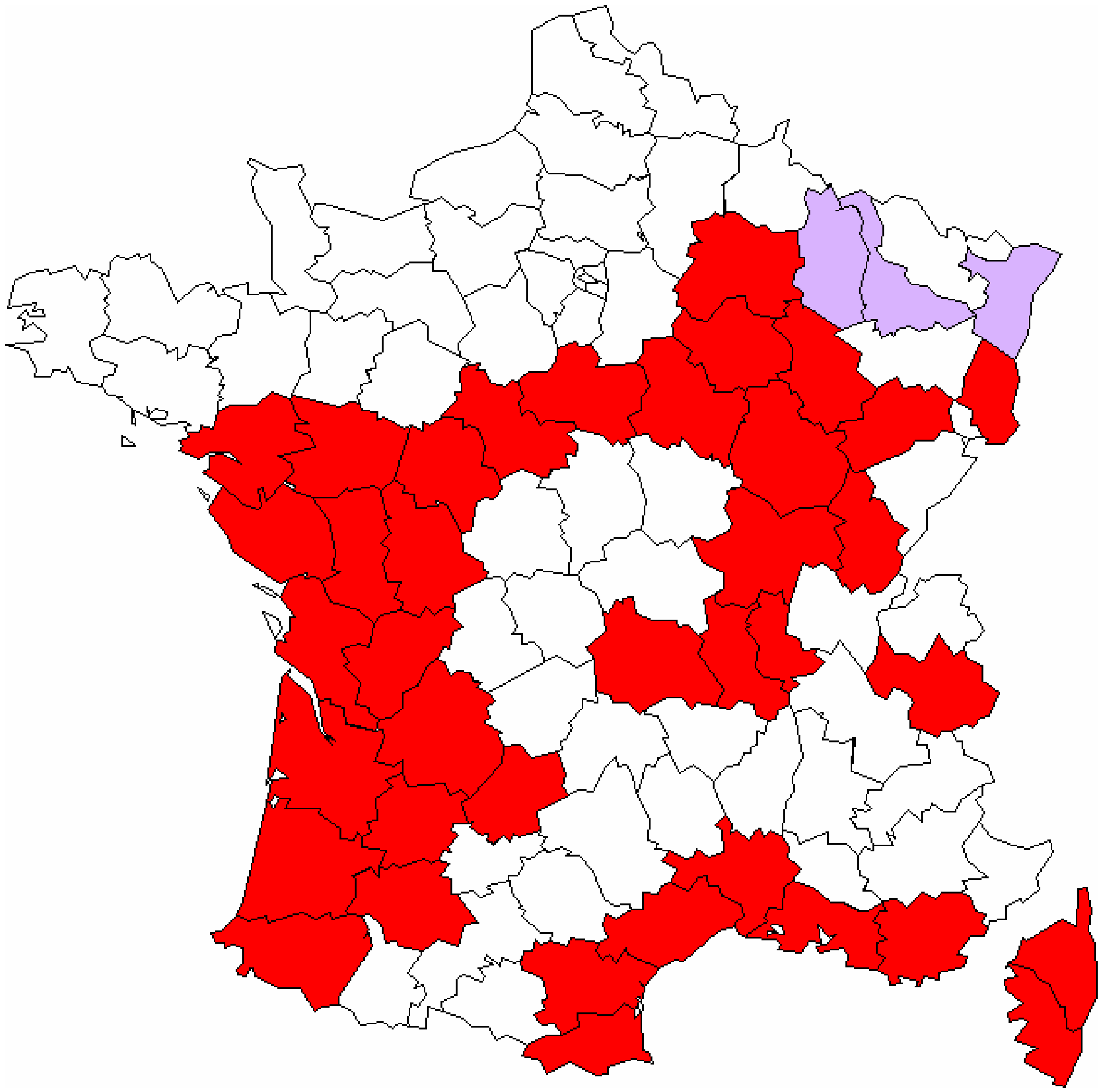
Figure 1C: Phylloxera in 1880



wine-growing departments infected by phylloxera

unaffected wine-growing departments

Figure 1D: Phylloxera in 1890



wine-growing departments infected by phylloxera

unaffected wine-growing departments

**Figure 2: Wine Production and Wine price**

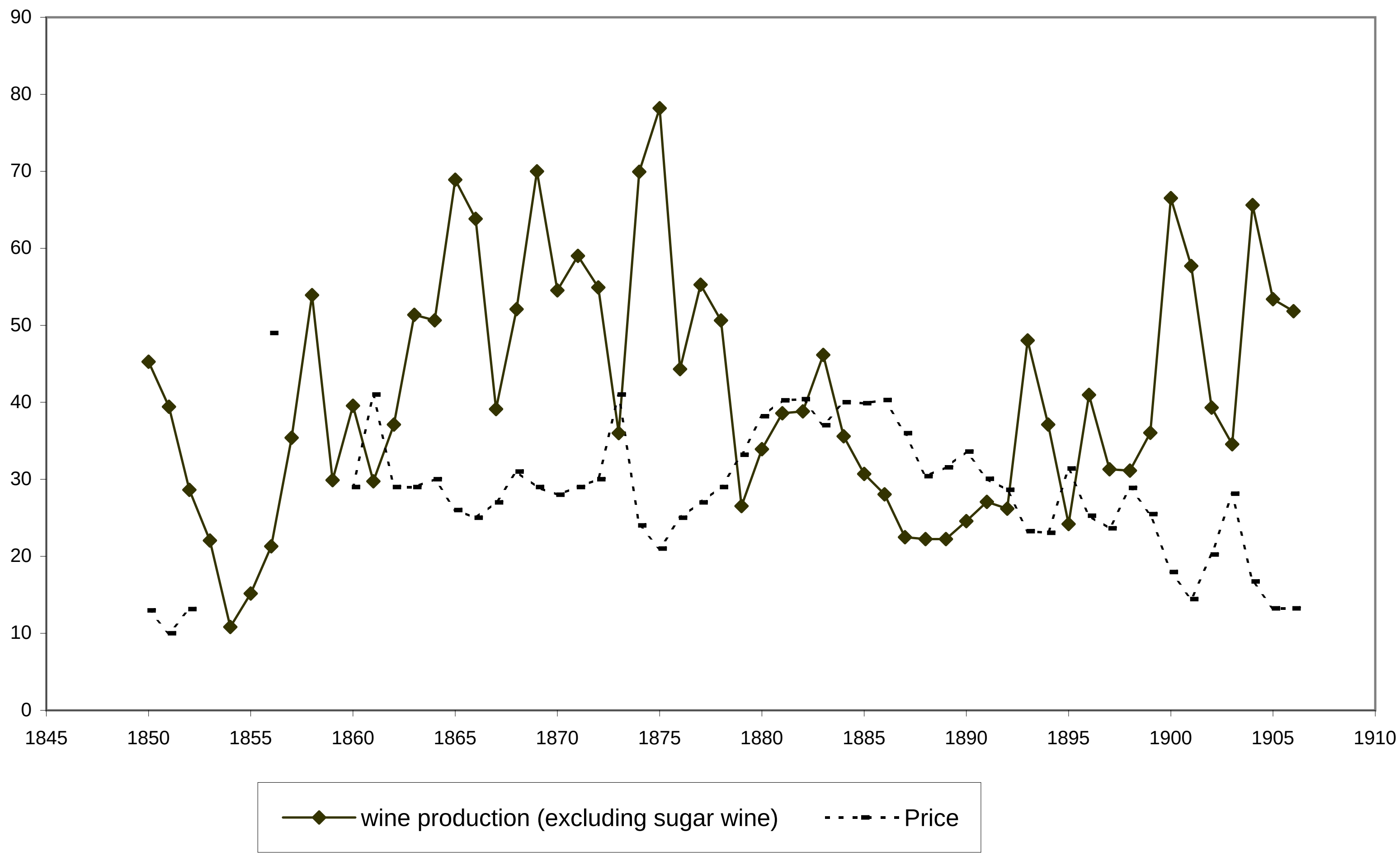


**Figure 3: Mean height over time: Wine producing regions and others**

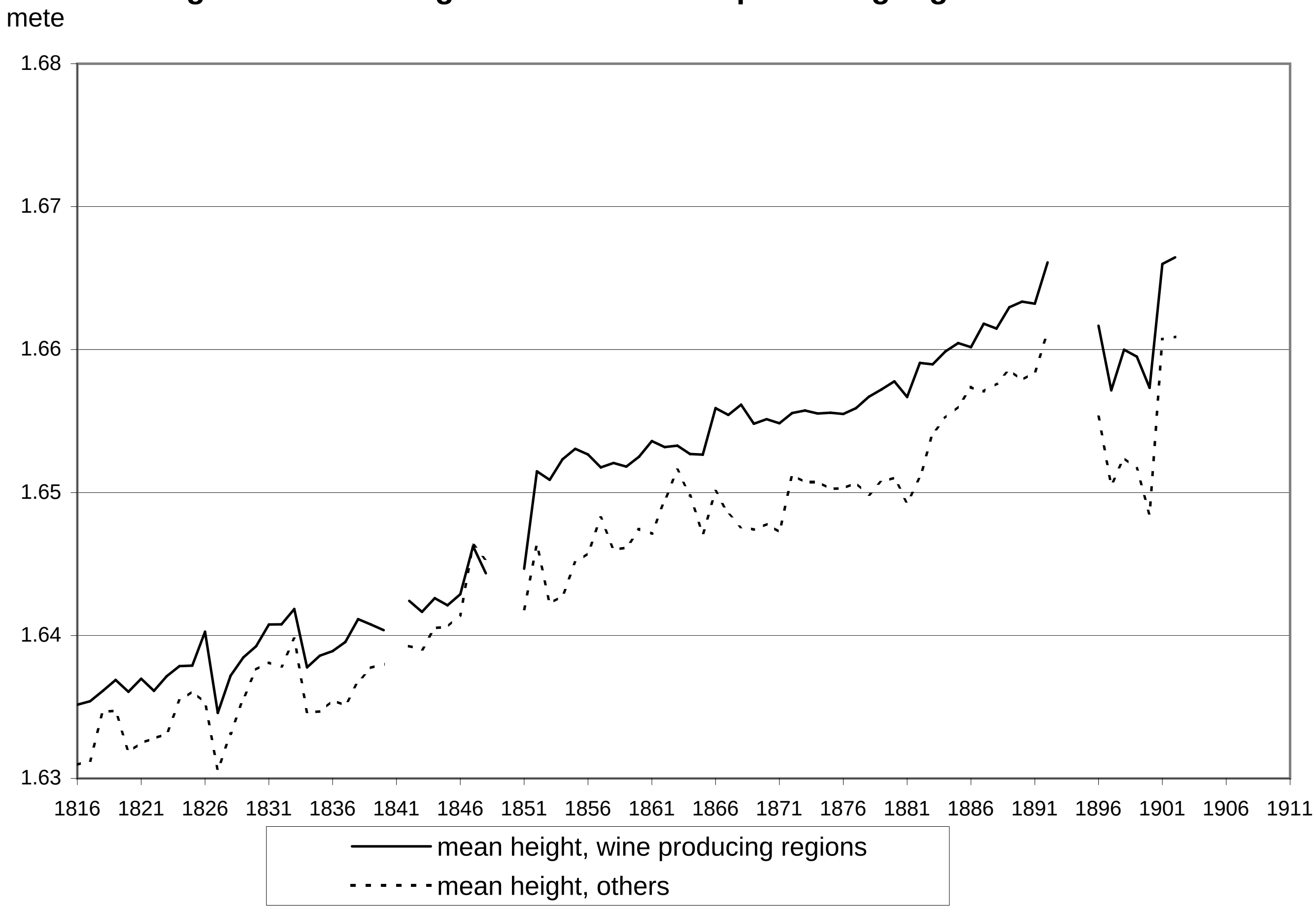


**Figure 4: Wine production and height differentials**

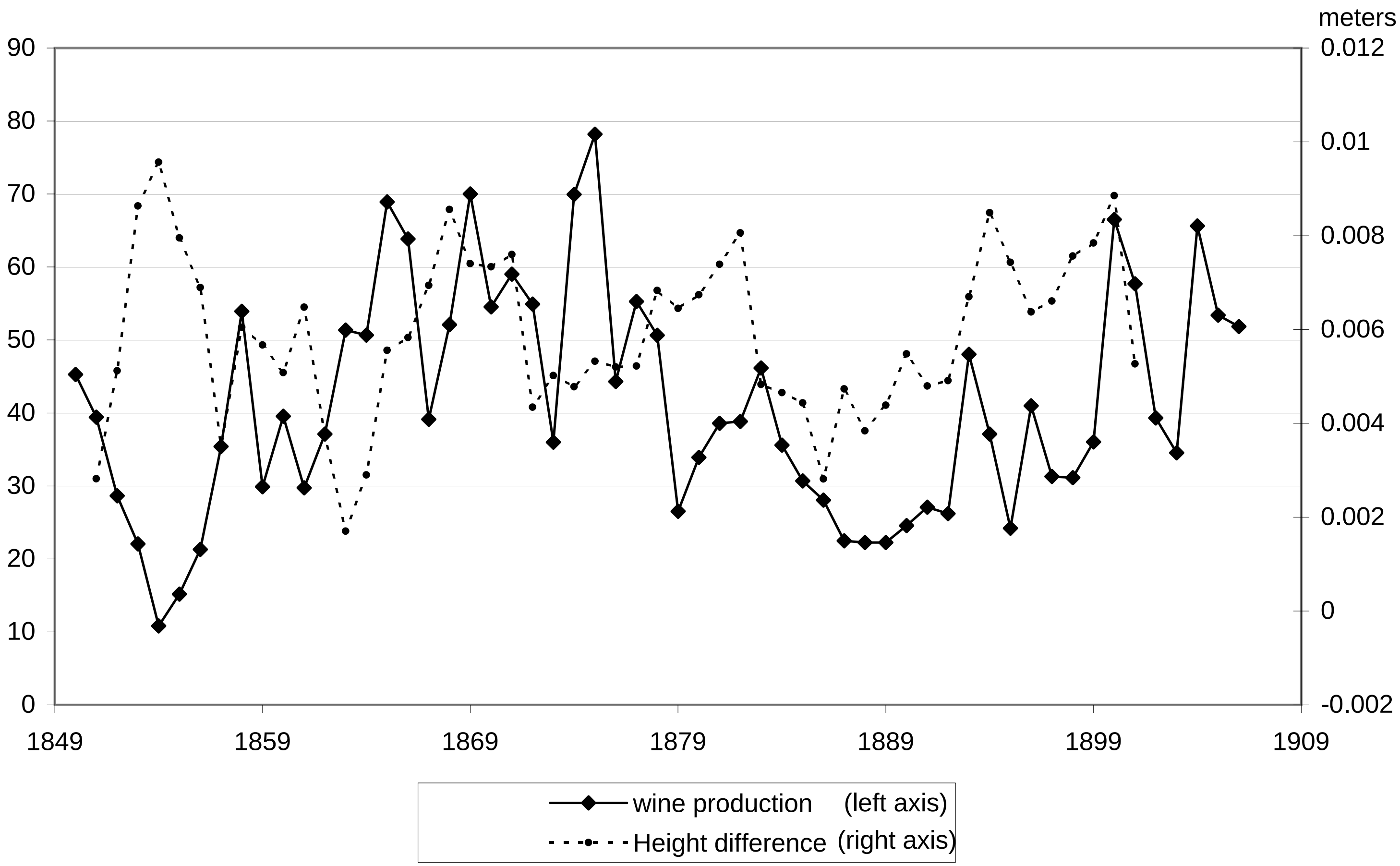


Figure A1: Height Distribution in Individual Data

Active service vs exempted (other than health)

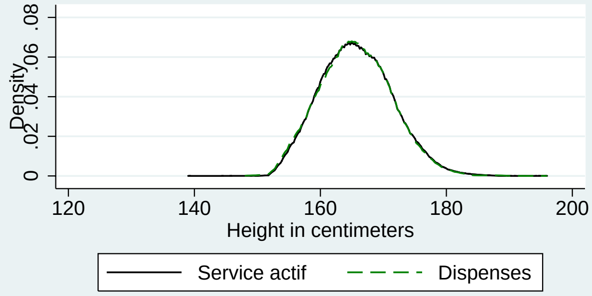
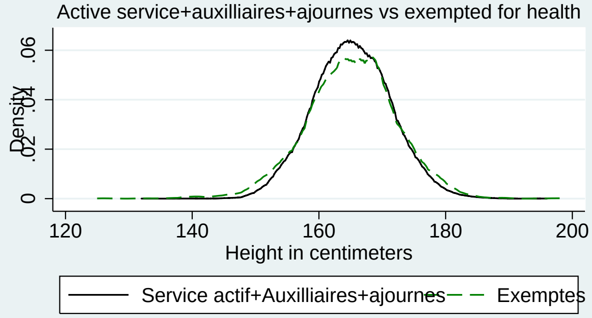



Figure A2: Height Distribution in Individual Data

Active service+auxilliaires+ajournes vs exempted for health




Source: Authors’ calculation from data reported in Farcy and Faure (2003)