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Can Winegrowing Cause Rural Development? Evidence from Baden-Württemberg

Thilo R. Huning[1], Fabian Wahl[2,*]
[1]*Department for Economics and Related Studies, University of York, Heslington, York YO10 5DD, UK*
[2]*Institute for Economic and Social History, Vienna University of Economics and Business, 1020 Vienna, Austria*

*Corresponding author: Institute for Economic and Social History, Vienna University of Economics and Business, 1020 Vienna, Austria. E-mail: fwahl@wu.ac.at

Historical winegrowing shaped modern rural development, even in areas in which its cultivation was given up after the early modern period. We provide evidence for this idea from municipality level data on Southwestern German viticulture over the last 1,300 years, and find a significant link between historical winegrowing and modern economic development. We rely on cross-sectional regressions and on an instrumental variable strategy using precipitation seasonality. Our findings highlight two mechanisms through which historical viticulture affected modern development: by leaving behind a more egalitarian inheritance norm, and a more collectivist society.

There is a long-standing debate among economic historians about the role of specific crops in economic development. The appearance of new crops, often of New World origin, has certainly shaped European development during the Industrial Revolution in many ways (Berger 2019; Dall Schmidt et al., 2018; Nunn & Qian 2011). The local geographic conditions that determine the choice of crops have been linked to the most fundamental differences between modern societies (Alesina et al. 2013; Mayshar et al. 2022). In this paper, we show that winegrowing has had a significant economic impact.

We provide the first evidence for the positive causal effect of winegrowing on local economic development. Our case study is Baden-Württemberg, the state in the southwest corner of Germany. With more than 10,000 vineyards, the state has a 30 percent share of all German vines. Wine has often been highlighted as essential to the understanding of Germany's southwest, which is populated by more than 11 million people and generates a gross regional product comparable to Sweden. This effect goes beyond the 28,000 hectares of viticulture and beyond the produce with a market value of around 350 million euros (amounting to 15 percent of all plant production in the state). The contribution of wine to the emergence of a common Baden-Württembergian identity after World War II cannot be overstated, given the severity and longevity of conflicts between the predecessors of this "hyphenated" state.[1]

[1] Significant historical territories in the area were Baden, Württemberg, different Hohenzollern territories, and several cities, which used to be independent for most of their history. Hyphenated states are those states that, after WWII, were formed from formerly independent states (unlike Bavaria, Hesse, Thuringia, or the city states).

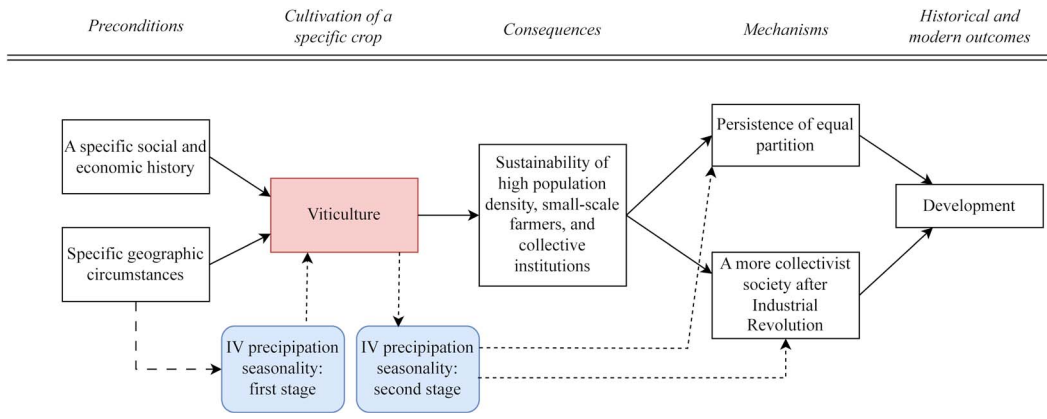

Figure 1. A directed acyclic graph (DAG) of the argument

Our argument is summarized in figure 1. The labor-intensive, complex, and risky nature of winegrowing, in combination with its tendency to encourage and sustain a structure of small-scale family-run farms, has altered local economies to the present day. The legacy of viticulture can also be found in areas that stopped growing wine hundreds of years ago. We provide an overview of the historical and theoretical literature on why viticulture has these properties, and then establish empirically the degree to which regions that have once grown wine are better developed in the past and today. We identify two mechanisms through which wine has affected local development: by affecting inheritance traditions and by forming a relatively collectivist society that persists to this day.

Regarding agricultural inheritance traditions, we argue that viticulture is a crop that allowed subsistence agriculture even on small plots due to its high yields per area. Huning & Wahl (2021a, 2021b) have argued that this impeded a global trend to transition from equal partition to primogeniture, because areas with a high yield per area were not as prone to overfragmentation (a downside of equal partition) as areas with a low yield per area. Baden-Württemberg provides small-scale variation in local agricultural inheritance traditions (not only basic forms, but also transitional and mixed traditions), and the state is the only German area with an identifiable historical border between the main inheritance traditions. Regarding the link between winegrowing and agricultural inheritance traditions, Baden-Württemberg is an interesting case study because other European winegrowing regions (for example, in France or Italy) do not have this variation in customs. Equal partition is positively linked to local economic development, particularly because during the industrialization of Germany, the rural equal partition area industrialized earlier. This was because the farms were small and the farmers were poor there. Hence, when the demand for non-agricultural jobs grew during industrialization, many farmers there became part-time farmers, splitting their time between farm work and work in the industrial sector, typically within the framework of the putting-out system (for a more comprehensive discussion of the link between equal partition and industrialization see Huning & Wahl 2021a).

Our second mechanism, collectivism, is inspired by recent economic literature that links the roots of our modern social norms and individual preferences to our agricultural past (e.g., Eder & Halla 2020; Galor & Özak 2014). In particular, this line of research has revealed a robust relationship between labor-intensive agricultural activities such as irrigation or rice

farming and collectivist attitudes. Due to its sensitivity to climate, the complexity of its production process, and the fact that it allowed denser populations winegrowing in Baden-Württemberg was linked to a high level of social cooperation, as evidenced by the longer survival of common lands, the existence of common production facilities such as wine presses, the emergence of agricultural cooperatives, and the early appearance of rural institutions of self-government (e.g., Hirbodian & Wegner 2017; Röhm 1957; Schröder 1953). Therefore, we expect to find a link between wine production, collectivism, and, as Fiszbein et al. (2022) revealed for the US, higher levels of cooperation and social capital—which are all conducive to long-run economic development.

We contribute to a long discussion on the origins and consequences of rural proto-industries in general (Hirzel 1788; Mendels 1972, 1980; Pfister 1992) and rural development in Baden-Württemberg specifically (Medick 1996; Ogilvie 1997) by showing that not only subsistence farming in fringe, mountainous areas with extensive agriculture and low productivity can be conducive to the emergence of proto-industry. In addition, intensive agriculture, such as wine production, in connection with local institutions (such as equal partition), has led to development in the countryside. It also shows that proto-industry originating from fragmented and small-scale winegrowing areas in Baden and Württemberg allowed for higher population densities and urbanization, unlike the rural proto-industry in other areas, such as the mountainous Black Forest.

This paper relies on data from 3,382 municipalities in Baden-Württemberg in 1953. First, we elaborate geographic information related to the spread of historical winegrowing from Nüske (1977). This provides us with details on which municipalities cultivated wine in which periods between the years 799 and 1624. We extend the data sets presented in Huning & Wahl (2021a, 2021b) by collecting additional variables on geography, historical developments, and indicators for municipal economic development in 1950.

We first study the determinants of winegrowing in different periods between the early Middle Ages and 1624. We find that, according to the oenological literature, geographic factors (such as elevation, terrain ruggedness, and soil suitability) are important for winegrowing in all periods. Proximity to Roman roads is significant for the locations of the earliest viticulture, in the 8th century and during the early Middle Ages (800–1000). The historical literature argues that monasteries pioneered viticulture, a fact we also find in our data. Our results confirm the conjectures of historians concerning the role of the Romans and the Church in the spread of early winegrowing in Germany. The geographic variables, precipitation seasonality and the share of Trias rock strata (which are relevant for viticulture on steep hills that provide a high exposure to solar radiation), predict wine growth statistically significantly during the Middle Ages, but not in other periods. This is also in line with the rapid spread of winegrowing into the most suitable areas in this period, following technological discoveries that first made viticulture on precipices possible.

We then explore the relationship between late medieval winegrowing and local economic development in Baden-Württemberg and a variety of outcome variables measured between 1950 and 2019. We rely on a large data set with rich geographic controls to provide OLS results first. To establish causality, we propose an instrumental variable based on a specific need of wine compared to other crops: precipitation seasonality. We provide ample tests to show that this instrument is valid. The IV results provide further evidence for the existence of a persistent legacy of historical viticulture in modern Baden-Württemberg. They, for example, imply that population density in late medieval winegrowing municipalities was around 60 percent higher. This result is robust to adding county fixed effects, accounting for spatial autocorrelation, measuring winegrowing in the 17th and 19th centuries, and to the

inclusion of different control variables like barley or wheat suitability. We also investigate the relationship between winegrowing and local economic development in the 17th century Duchy of Württemberg and between late medieval winegrowing and the location of late 18th century proto-industry in Baden-Württemberg. In both cases, we find a significantly positive relationship, implying that our main results are not due to studying a particular type of outcome or a time period.

We then investigate the two mechanisms through which viticulture explains modern development: equal partition and collectivism. Confirming our theoretical priors, we find a statistically significant and positive relationship between late medieval viticulture and the historical predominance of equal partition. To investigate the relationship between winegrowing and collectivism, we follow the literature and proxy collectivism with the share of rare given names (Fiszbein et al. 2022). We take these data from World War I casualty lists. In doing so, we find a positive association between winegrowing and collectivism. As suggested by the theory, wine regions today are more collectivist than other regions. In horse race regressions in which late medieval winegrowing, collectivism, and equal partition are included simultaneously, we can also show that the effect of viticulture in local economic development is exhaustively mediated by its effect on collectivist attitudes and rural inheritance traditions. Historical winegrowing set some municipalities on a different development path. These results reveal a novel effect of winegrowing on the state's local economy that goes far back into history, as early as medieval times.

1. Literature review

Our findings highlight the role of specific crops for economic development, in the tradition of Nunn & Qian (2011). There is also a lively debate on the role of alcohol in human society. An overview of this literature is provided in Slingerland (2021), who argues that the production of alcohol has coincided with collaborative societies and has shaped culture (even the human brain) for thousands of years. Wine is also a central topic for economic historians (see Simpson (2011), and more recently Federico & Martinelli (2018)).

Since wine is ubiquitous in Southwestern German geography, culture, and daily life, this article adds a new economic narrative to understanding this region and the cultural heterogeneity of Germany and Europe, not least because wine is also a part of the Roman inheritance of the southwest (see Wahl 2017). We contribute to the literature on the effect of specific crops, but also on specific types of agriculture, namely labor-intensive agriculture. To name an important contribution from this literature, Vollrath (2011) shows that population growth, output per capita, population density, and industrialization within a Malthusian world depend on the labor intensity of agricultural production. Fiszbein et al. (2022), using data from US counties, have shown empirically that labor-intensive agriculture is linked to lower levels of individualism and therefore higher social capital. They reason that higher returns to cooperation occur where geographic circumstances allow a low land-labor ratio, and that a higher division of labor translates into higher population densities and closer social ties. They also argue that non-marginal reductions in labor input result in considerable social losses, thereby supporting the emergence of a sense of equality and community among the inhabitants of winegrowing areas.[2] We contribute to this literature by postulating a long-run

[2] It is important to note that this literature is moving fast and has so far produced mixed results. Ang et al. (2021) for example focus on rice farming in Asia and find it associated with more conformity and less democratic attitudes. Buggle (2017) studies the historical prevalence of irrigation agriculture in a global cross section of

positive relationship between a particular type of intensive agriculture, winegrowing, on local economic development. We deepen the knowledge of transmission channels through which intensive agriculture is affecting economic development by shedding light on two not yet well-understood mechanisms: the emergence and persistence of inheritance traditions and collectivist attitudes.

Regarding agricultural inheritance traditions, we continue the debate on the role of agricultural inheritance traditions in regional development (Hager & Hilbig 2019; Huning & Wahl 2021a, 2021b), while shedding light on a specific channel: the role of crops with a high labor-to-land ratio. The identification strategy in this paper can also provide more causal evidence for the effect of agriculture on development. More generally, our study is motivated by the proposition of David (1985) that historical circumstances (in our case, the suitability to grow wine to a medieval standard) have a persistent effect on the modern economy, even though the circumstances have themselves faded. This adds to an influential literature on economic geography and path dependence in Germany (see Nitsch & Wolf 2013; Redding et al. 2011; Voigtländer & Voth 2012; Wahl 2017, for example).

By studying the link between viticulture, inheritance traditions, and collectivist attitudes, this paper extends the literature on the persistence of cultural traits (Bisin & Verdier 2001). Specifically on the subject of inheritance traditions, Hager & Hilbig (2019) find that equal partition areas are more egalitarian today. Huning & Wahl (2021b) trace these traditions through history and study their origins in Baden-Württemberg. Their results highlight the role of geography and settlement history. In areas with favorable agricultural traditions, equal partition is more likely to be prevalent. Areas that have been settled later are more likely to rely on primogeniture. They also find that the political economy of feudalism had a significant effect. Our findings indicate that feudal lords could impose primogeniture in areas that were deforested during the Middle Ages, and this tradition persists there to this day. Since primogeniture facilitated the collection of taxes, the nobility enforced this norm wherever it had the means to do so. In a second paper, Huning & Wahl (2021a) show that regions with equal partition are today more industrialized. The paper adopts a neoclassical model that features equal partition and primogeniture. This model explains how urban entrepreneurs searching for workers turn to equal partition regions. Since equal partition led to more fragmented and smaller plots than primogeniture, inhabitants of equal partition areas were more willing to work in proto-industry alongside the work on their own farm. As shown in the empirical section, our model explains the early industrialization of the countryside in Baden-Württemberg well.

More generally, this paper provides evidence for a link between small-scale farming and development, and focuses on the suitability for winegrowing, a specific mechanism. The historical literature has long noted the correlation between winegrowing, reliance on equal partition, and economic prosperity. It is particularly interesting to analyze the effect of historic winegrowing conditions on modern development, considering how the production and consumption of wine has changed over the centuries. Has Europe undergone a phase in which family-farming—as the rural counterpart of urban developments—was crucial for the rise and fall of regions? Has Europe experienced a similar "Triumph of Gardening" to

countries and finds a mixed and less positive picture of the effects of intensive agriculture. He finds no significant effect on income levels and democracy scores, but a negative effect on innovation, personal autonomy, and individual rights. We conclude from this that the effect of intensive agriculture could vary depending on the particular activity studied, the institutional environment, and the historical context of the studied sample of regions, countries, and individuals.

that which Studwell (2013) and others view as the cornerstone of the East Asian economic miracles?[3]

2. Historical background: the expansion and contraction of Southwestern German viticulture

There is no evidence for wine cultivation east of the Rhine in Roman times, but historians are certain that wine was consumed across a significant geographic spectrum west of the Rhine in antiquity (Kohl 2017; Schröder 1953). The first evidence of winegrowing in the region can be found in the ecclesiastical archives: a gift deed of a vineyard dated around 800. After the Romans, viticulture expanded into two distinct regions. First in the southwest of Baden between the Rhine and the Black Forest and in the region around Freiburg, and second in the northwest of the state in the Rhine–Neckar region around the cities of Heidelberg and Mannheim. From there, it spread eastward to colder areas of higher elevation, which were less favorable for viticulture. From the region around Mannheim and Heidelberg, it expanded in a southeastern direction, following the Rhine. It arrived in the region around Heilbronn before the end of the 10th century. It started in the region around Stuttgart during the high Middle Ages (1000–1250), and expanded from there until it hit the Swabian Jura first in a southern direction, and then also in a northern and a northeastern direction. Originally from the southwest of Baden, wine cultivation began to spread into the southeast of the state and around Lake Constance in the high Middle Ages. Viticulture in that area is made possible by an especially warm microclimate that protects the plants against the frosts of the adjacent Alps. There is no evidence to suggest the existence of winegrowing in the Black Forest at any time, and also the land to the north of Lake Constance has never had substantial wine cultivation. This can mostly be explained by its pre-Alpine climate and prohibitively high altitudes.

The rapid diffusion of winegrowing during this period in general can also be attributed to climate change (Hirbodian & Wegner 2017; Nüske 1977). Between approximately 1000 and 1300, wine only produced substantial grapes if the previous winter months provided the soil with enough hydration, given a warm period. During the late Middle Ages and early modern period, viticulture expanded well into areas with relatively unfavorable natural conditions (like parts of the Swabian Jura's high plain, and some Upper Swabian villages). Although it was predominantly an affair of monasteries and rural villages until around 1300, wine consumption and trade became increasingly urban after the Black Death, when many new vineyards were founded close to city walls (Hirbodian & Wegner 2017). The winegrowing area expanded until the 16th century. A main driver of this expansion was the improved ability to grow on ever-steeper slopes (Schröder 1953), as well as the increasing demand originating from an exploding urban population in the prospering Imperial cities in the area.

Historians have attributed the subsequent contraction of the wine cultivation area to climate change, wars, and finally a change in preferences. Quarthal (2017) argues that wine production in the Neckar region has plummeted since the 1560s due to less favorable climatic conditions. Jörg (2017) echoes this assessment for southwest Germany and surrounding regions, and explains how vines froze due to climatic changes from the 16th to the 18th centuries. The Thirty Years War (1618–48) reached what is today Baden-Württemberg in

[3] See also Huning & Wahl (2021a) for a discussion and a formal model.

1620, and was closely followed by the Palatinate Wars of Succession (1688–1697).[4] Both conflicts led to a decline in population and devastated whole villages. Quarthal (2017) argues that the lack of constant maintenance destroyed the vineyards and contributed to the shift of drinking preferences toward beer. The 18th century was then accompanied by a demand for higher quality. As explained by Fritz (2017), the Duke demanded the uprooting of lower-quality grapes (especially Tokajer), and the first experiments with sparkling wines were also recorded. The renaissance of widespread wine drinking since the 18th century, parallel to the Industrial Revolution that brought an increase in income (especially in cities), was already satisfied by a more quality-oriented (and also more global) supply (Krämer 2017; Schröder 1953). As such, many settlements that grew wine during the Middle Ages have given up viticulture.

3. Theoretical considerations

In this section, we explain why viticulture was economically particular, and then discuss ecological and botanical considerations that also inspire our empirical approach.

3.1 Viticulture is an extreme case of labor intensity

The Church was an important producer of wine in the region. Wine has always been central in Christian liturgy, and historical sources indicate that its consumption has also been an essential part of the everyday life of monks in southwestern German monasteries since the 8th century (Kohl 2017). Outside of ecclesiastical communities, wine was grown almost exclusively on small family-owned and operated farms.

Vineyards could thrive on otherwise relatively unsuitable land (e.g., Landsteiner 1999). As noted by Simpson (2011, p. xxxiv), "viticulture and wine production were generally family businesses. The vines were widely grown despite considerable volatility in production because the grapes could be successfully grown on land that was marginal to most other crops and therefore cheap". Second, the specific high labor intensity coupled with the low necessity to invest in physical capital made "small plots of wines [...] excellent vehicles for family producers with limited means to acquire a capital asset". Third, overcoming the limitations of family farming was especially difficult in the wine industry. Both rental agreements or wage labor were relatively scarce in the wine industry because "vines can be easily and permanently damaged if the pruning, plowing, and hoeing operations are badly carried out" (see Simpson 2011, p. 9). The link between wine cultivation and family farming draws our attention to family traditions, especially how the inter-generational transfer of the farm was organized.

The specific literature on Baden-Württemberg mirrors these ideas. The labor intensity of wine is estimated to be seven to eight times greater relative to grains (Mersiowsky 2017). Fritz (2017) argues that a vineyard of 3/4 to one hectare was sufficiently sized for the existence of a family, compared to an average of three to eight hectares necessary for other crops. He argues that this was also made possible because winemakers used the spaces between the grapes to grow their own staple foods. As a consequence, by the middle ages, winegrowing areas were usually characterized by high population densities and land fragmentation (Kohl 2017; Landsteiner 1999).

[4] It is interesting to note that recent historical research following Parker (2017) has linked the Thirty Years War itself to climatic changes.

Especially in areas with small plots (a process also fueled by equal partition), vineyard owners concentrated completely on grape production and sold these instead of barrel wine (Krämer 2017). Wine trade, however, which was usually conducted in cities in winegrowing regions, such as Reutlingen, Ulm, Rottenburg, and Stuttgart, was, at least during the late Middle Age (when the quality of the wine was high) a very profitable activity.[5] The wine trading cities in Württemberg were among the richest and most prosperous in the south of Germany (Mersiowsky 2017; Quarthal 2017). Consequently, since wine was a highly taxed commodity, it also contributed significantly to the revenue of territorial rulers during the late medieval period.[6]

3.2 Viticulture transforms the structure of the local society

The historical literature on viticulture in Baden-Württemberg has produced ample arguments to suggest that the social structure of the winegrowing regions was different and more collectivist. There are three main reasons for this in the literature: the specific risk associated with winegrowing, the need to cooperate due to the many tasks involved in the process, and the fact that its complexity required the emergence of advanced judicial and political institutions.

Winegrowing is a gamble, creating the need to share the risks. Kohl (2017) argues that the nature of wine as a perennial plant does not allow the flexibility to adjust the crop to the weather conditions of the year, but forced wine makers to commit. Its high risk of harvest failures may have contributed to an attitude of risk sharing among the community. As such, it does not seem to be a coincidence that one of the first agricultural cooperatives was founded by a winemaking collective in Asperg in 1854 (Fritz 2017). Kohl (2017) also explains that wine production was an important driver of social cohesion, not only because it allowed (and indeed forced) people to live more densely, but also because there is evidence for shared tools and buildings (such as wine presses). The fact that wine presses were often communal facilities also highlights a peculiarity of wine production. Although winegrowing does not require much capital, the processing of grapes to produce good quality wine is not only labor-intensive, but also capital-intensive (Landsteiner 1999). Mersiowsky (2017) makes the argument that due to the high degree of organization necessary to produce wine, winegrowing villages were early adopters of political institutions of self-government such as town halls, judicial institutions such as courts, and financial institutions such as money lending. Furthermore, winegrowing villages were often walled (which was commonly a singularity of cities) making them attractive and safe places to live (Nüske 1977).

Finally, the complexity of winegrowing also led to the rise of specialized craftsmen such as coopers, and therefore boosted the rural economy in areas beyond the agricultural sector (e.g., Nüske 1977; Quarthal 2017).

[5] This is also why one can argue for a pronounced effect of winegrowing on urbanization. In the historical literature, one often finds the statement "Weinland ist Städteland", ("wine land is town land") (e.g., Nüske 1977, p. 4). Note also that Ulm, Reutlingen, and Stuttgart are still among the largest cities in Baden-Württemberg today.

[6] Mersiowsky (2017), for example, notes that in 1438–1439 around 34 percent of the total income of the county of Hohenberg, located along the Neckar, between Stuttgart and the Swabian Jura, originated from wine.

3.3 Can winegrowing cause industrialization?

The question whether agriculture and proto-industry (a precondition for industrialization of the countryside) benefit each other goes back to the work of Arthur Young. Optimists, such as Gullickson (1986), argue that income from the latter could be invested in the former. Skeptics, such as Mendels (1980), argue that agriculture with a high marginal product absorbs all available labor, leaving no room for industry.[7] Mendels (1980), looking at the case of Flanders, introduced the idea that proto-industry might have been essential for some lower peasant classes, allowing them to subsist on small-scale farming while providing their excess labor to the market. Hirzel (1788) argued that the effect of proto-industry on agriculture depends on its interaction with specific local institutions in combination with the local social structure. In a detailed statistical analysis of German-speaking Switzerland, Pfister (1992) finds that an unconditioned negative relationship between viticulture and proto-industry, as postulated by Mendels (1980), does not exist. Instead, a careful consideration of the structure of local geography, farm sizes, as well as social and political institutions, also of historical nature, can reveal a positive link between viticulture and proto-industry in one region (predominantly north of Zurich) while a negative link exists in another (for example, around Lake Zurich). He also notes that there seems to be a positive relationship between proto-industry and viticulture in the area around Winterthur, characterized by small-scale farming.

This provokes a thorough look at Baden-Württemberg. As noted by Mersiowsky (2017), viticulture in Baden-Württemberg was always small scale; the average size of a vineyard in the early 20th century was only 0.36 hectares per winemaker (Fritz 2017)—too small to make a living from it. As with Pfister's case of Zurich's north, as a consequence, peasants have always relied on work opportunities outside agriculture, and the relatively proximate urban centers and towns (foremost the independent cities) supplied the winemakers with these opportunities, especially when proto-industry expanded in the late 18th century and urban areas began to industrialize during the 19th century (see Fritz 2017; Nüske 1977). As described by Fritz (2017), vineyard owners often had an income source outside of agriculture, when many wine farmers worked as craftsmen during the time outside of their busy months. This idea is consistent with the model and the findings in Huning & Wahl (2021a), who argue that the transition between agriculture and proto-industry has been a feature of the local economy for some time.

3.4 Wine is ecologically and botanically peculiar

Even more than today, historical winegrowing depended on a multitude of specific factors. The microclimatic conditions required are characterized by a complex interplay of terrain characteristics such as slope, elevation, and soil, but also climatic factors such as temperature, humidity, solar radiation, and precipitation levels (see Chen 2011; Fraga et al. 2016; Irimia et al. 2011; Sommers 2008). As temperature and rainfall are known to vary systematically with elevation, altitude is one of the most important determinants of winegrowing. Consequently, wine is usually cultivated at modest elevation levels (in Germany this is typically below 500 meters). It is also known that locations close to rivers are favorable for growing wine as they reflect and bundle solar radiation, and lead to warmer and wetter winters. Similarly, hills oriented to the south with a slope of around 45 degrees are most exposed to solar radiation

[7] See Pfister (1992, Ch. 5.4) for an overview of this debate.

and have a favorable micro-climate. Therefore, a south-oriented hill, with the correct slope, located next to a river and in an area with modest elevation levels (for example, in the valleys of the German rivers Mosel, Neckar, or Rhine) can be considered optimal for growing wine. These locations are often not favorable for general agriculture, as large slopes or hilly terrain make it difficult to grow most other crops.

The seasonality of the climate is more significant for the growth of grapes than for any other agricultural crops. Wine is sensitive to rain during the growing season but is highly adaptable to drought during the summer. Excess summer rain leads to overshooting growth and early ripeness and also makes grapes vulnerable to pests. As such, a highly seasonal precipitation pattern with a lot of rain during winter and spring, but modest levels of rain in summer, is optimal (Sommers 2008). This makes wine's botanical properties favorable from an empiricist's perspective. The reason for this peculiar dependence on precipitation seasonality is the root system of grapevines. Smart et al. (2006) provide a review of this literature and calculate the ratio between width and depth of the vine plant, concluding that "the depth distribution of grapevine roots in the vadose zone is among the deepest observed for plants worldwide" [p. 89].[8]

Figure 2 provides an illustration of a grapevine showing how the creeping roots allow the plant to access immediate rainfall before it evaporates. These roots are deep in comparison to cereals and other plants, which are re-seeded in any harvest season. However, more important for the grapevine are the deeper so-called plunging roots, which often reach ground water. These roots are not only well protected from frost in colder periods, but also allow the vine to reach the water stored underground in the seasons of lower precipitation. It is through this system that the grapevine has the ability to take advantage of large differences in rainfall between the growing seasons. In summer and autumn, grapes can mature in the sun, while plunging roots guarantee photosynthesis and hydration of the grape itself (grapes are 80 percent water). In winter and spring, the plant can efficiently manage its soil hydration by reducing evaporation through its creeping root network, allowing excess water to resupply the level of hydration of deeper layers. This botanical particularity of the grapevine inspires our precipitation instrument in the empirical section.

Finally, the geology of the location plays a significant role in its winegrowing potential, first because geology influences the soil type of an area, but also because Württemberg has been characterized by steep slope viticulture since the late Middle Ages. Its hills with slopes as steep as 45 degrees consist of rock strata from the Trias period (lacustrine limestone). Technical innovations during the High Middle Ages enabled the exploitation of these sunny spots, which were unsuitable for any other crop (Schröder 1953; Simpson 2011).

4 Data

Data on historical winegrowing. We digitized municipality level data on historical winegrowing in Baden-Württemberg from a map on the spread of winegrowing in Baden-Württemberg until 1624 by Nüske (1977). The data are part of the "Historischer Atlas von Baden-Württemberg" (Historical Atlas of Baden-Württemberg) and are based on the

[8] The vadose zone is the Earth's layer just above ground water.

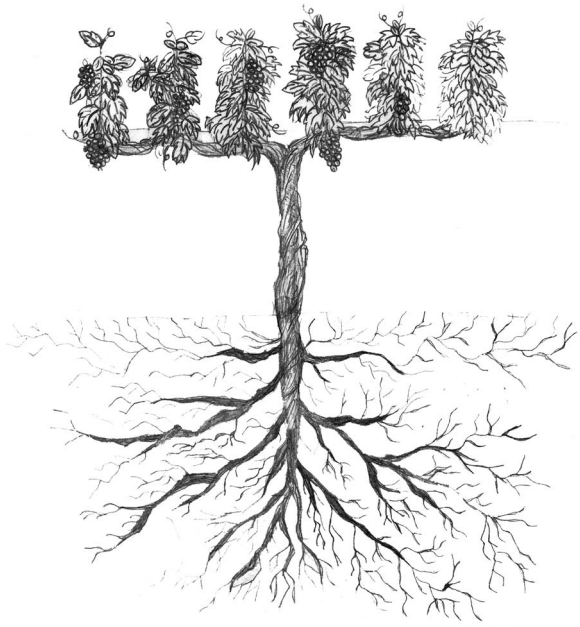

Figure 2. The grapevine features a large network of creeping (horizontal) and plunging (vertical) roots. The implication of this botanical particularity for hydration throughout the year inspires our instrumental variable strategy. *Note:* Illustration by Isabelle Huning.

municipalites of Baden-Württemberg in the year 1957.[9] These data are shown in figure 3. This map shows the spread of winegrowing in categories of five historical periods: before 700, between 800–900, 1000–1299, 1300–1624, and before 1624 (the last category captures the municipalities in which Nüske saw evidence for earlier wine cultivation, but lacked the data to provide a clear categorization into one of the four former categories). It also shows winegrowing municipalities in 1865, which we also take from this map.

Nüske's explanation for these categories is straightforward and oriented among historical breakpoints and developments closely connected to winegrowing, and consistent with our historical outline in Section 2. The period from 800 to 900, for example, marked the period of the first significant expansion of winegrowing during the reign of the Carolingians. 1000–1299 covers the high Middle Ages with its many city foundations and expansion of settlement spaces, and 1300–1624 marks the period up to the Thirty Year War in Southwestern Germany.

In addition, data on the size of vineyards in around 700 municipalities of the Duchy of Württemberg in 1634 and 1655 are obtained from the "Steuer- und Kriegsschaden-bericht 1629-1655" (Tax and War Damage Report 1629–1655), which are available from

[9] We match the municipalities in the map to the slightly different borders of municipalities in 1953 to be consistent with the rest of our data set containing information from the official statistics in 1950 and the survey of inheritance traditions by Röhm (1957) in 1953. The differences are, however, minor.

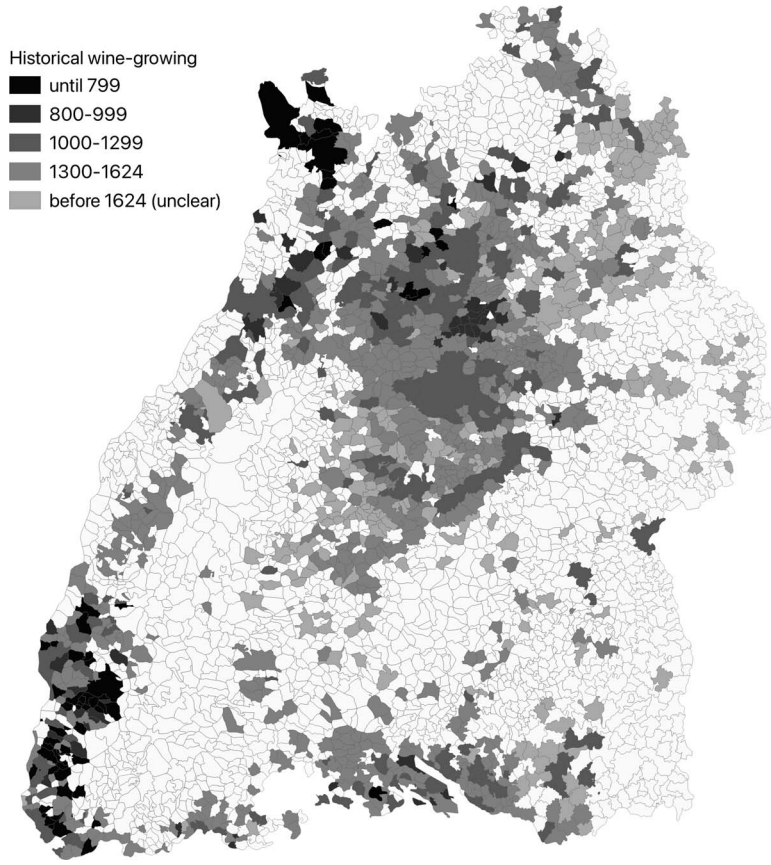

Figure 3. Historical winegrowing in Baden-Württemberg.

Von Hippel 2009.[10] This allows us to create dummy variables to indicate the presence of winegrowing in the 17th century, as well as to calculate a variable for the extent of wine production: the proportion of vineyards in the total area of a municipality. The winegrowing variables are our main variable of interest and many other variables derived from the "Historischer Atlas von Baden-Württemberg" or other sources (e.g., the inheritance data from Röhm (1957)) are available for municipalities in the 1950s. These municipalities preceded postwar reforms aimed at a more efficient local administration, which subsumed villages into a single administrative municipality, and to our understanding reflect historically grown villages better. We therefore decided to use these 1950s municipalities as our units of observation.

Data on local economic development in the 20th and 21th centuries. We measure local economic development and industrialization levels with two variables: population and firm density. We obtain these from the official municipal and county statistics of

[10] We match the 17th century municipalities to those in 1953 to be able to merge them with the rest of our data using various different sources like the official online encyclopedia of historical places in Baden-Württemberg (https://www.leo-bw.de/themen/ortslexikon)

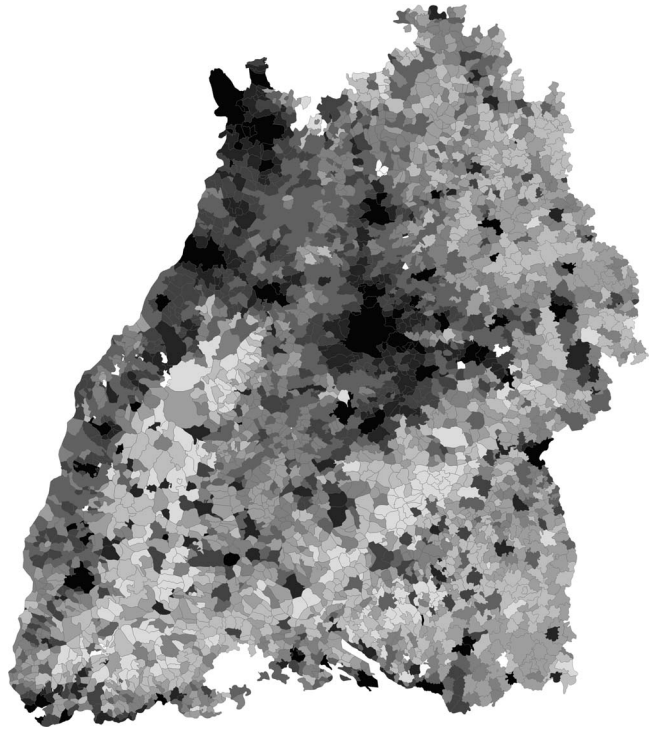

Figure 4. Population density in 1950. *Note:* This figure shows the population density of municipalities in Baden-Württemberg in 1950. The darker shaded municipalities have a higher population density.

Baden-Württemberg of 1950 and 1961 (Statistical Office of Baden-Württemberg 1952).[11] We measure contemporary local economic development with nighttime luminosity levels for the year 2019, the last year for which data unaffected by the COVID-19 pandemic are available. Luminosity data comes from the Earth Observation groups VIIRS Annual Nighttime Light v. 2.1 data set. Figure 4 shows the population density of the municipalities in Baden-Württemberg in 1950. Figure 5 visualizes the firm density. Figure 6 features the average nighttime luminosity in 2019. It shows that the economically most prosperous areas of Baden-Württemberg in the 20th and 21th century are the area around the capital Stuttgart in the center of the state and the area along the Rhine and Neckar in the West. A comparison of the economic core areas and the historical winegrowing areas depicted in figure 3 shows a significant overlap of both, suggesting a high correlation between winegrowing and local economic development.

Data on local economic development in the 17th and 18th centuries. We take municipal population data from Von Hippel (2009) to calculate population densities for the municipalities of the Duchy of Württemberg in 1634 and 1655. A map by Boelcke (1977) shows the location of proto-industrial factories in Baden-Württemberg between 1770 and

[11] "Gemeinde- und Kreisstatistik Baden-Württemberg".

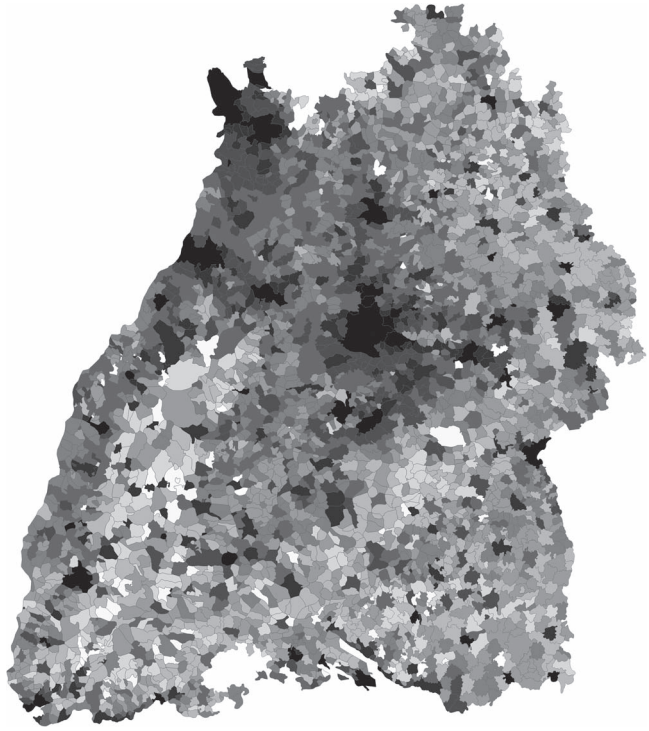

Figure 5. Firm density in 1950. *Note:* This figure shows the firm density of municipalities (firms per hectare) of municipalities in Baden-Württemberg in 1950. The darker shaded municipalities have a higher firm density.

1780. These data allow us to test the relationship between historical winegrowing and local economic development.

Data on inheritance traditions. Data on the historical prevalence of equal partition in the 3,382 municipalities of Baden-Württemberg for the year 1953 are available from Röhm (1957). Röhm collected these data by sending a one-page questionnaire to each municipality's mayor. Based on this survey, Röhm drew a map showing the predominant inheritance tradition in each municipality in 1953. He also drew a division line that separated the areas in which equal partition was prevalent from the areas where primogeniture was applied, representing the state in 1800. To measure the local prevalence of equal partition, we digitized the map and created a dummy variable equal to one if a municipality is located within the borders of the historical equal partition area. The main advantage of these data is their uniqueness in providing municipal level information on historical agricultural inheritance traditions.[12]

Data on collectivism. To proxy collectivism, we follow Fiszbein et al. (2022) in constructing an index measuring the frequency of rare given names among the population. To do so, we rely on casualty lists from the First World War. The casualty lists contain the

[12] A critical discussion of these data is provided in Huning & Wahl (2021a) and Huning & Wahl (2021b). The same data are used by Hager & Hilbig (2019) to study the long-term consequences of equal partition on economic and social inequality. The original map of Röhm (1957) is provided in figure A.1 of the Online Appendix.

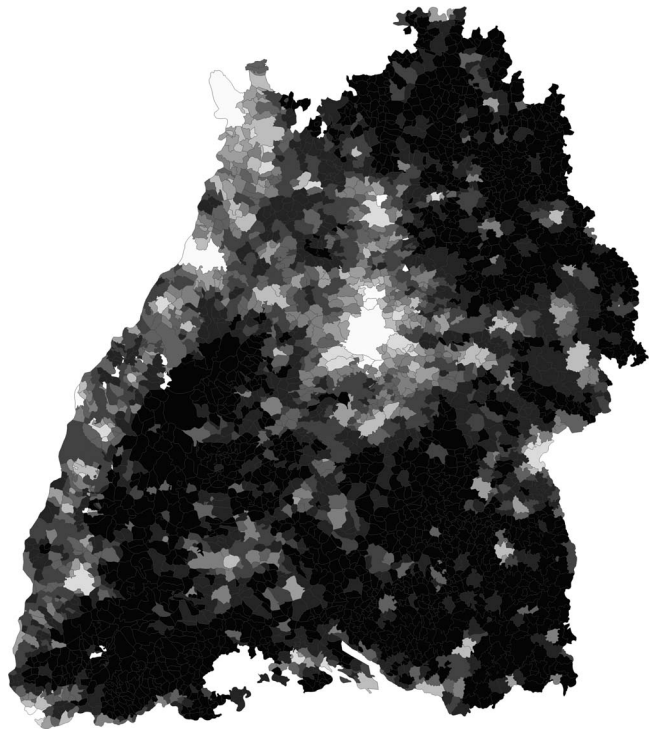

Figure 6. Nighttime luminosity in 2019. *Note:* This figure shows the average nighttime luminosity in each municipality in 2019. The lighter the shade, the higher the luminosity.

name and residence of 397,620 fallen and wounded soldiers in each year of the war, and the type of army unit in which the soldiers served. The lists provide information on casualties in 3,352 of the 3,382 municipalities in our data set. They are available from the private website wiki-de.genealogy.net, which is run by the "Verein für Computergenealogie" (Association of Computer Genealogy) and hosts several different genealogical data sets (also, for example, historical address books).[13] Assuming that soldiers were born in the last decades of the 19th century and conscripted in their hometown, we extract the given name of each soldier in the database alongside the place of residence. We identify the ten most frequent names in the sample.[14] We then calculate, per municipality, the share of individuals with all other (rare) names. Figure 7 shows the distribution of rare given names among municipalities in Baden-Württemberg (as of 1953). It is clearly visible that in the winegrowing areas the frequency of rare names is significantly less, while they are especially frequent in the area between Stuttgart and Lake Constance in the south, as well as in the east of the state—areas in which most of the time no significant amount of wine was grown.

Control variables and predictors. The control variables and predictors of historical winegrowing originate from various sources. The area of each municipality in km² stems

[13] The website of this sub-project is http://wiki-de.genealogy.net/Verlustlisten_Erster_Weltkrieg/Projekt.
[14] These are Karl, Wilhelm, Friedrich, Josef, Georg, Hermann, Johann, Otto, August, and Albert.

Figure 7. Distribution of rare given names in Baden-Württemberg. *Note:* The figure shows the share of rare given names in municipalities in Baden-Württemberg as of 1953 and according to WW I casualty lists. Darker colors indicate higher shares.

from the municipal statistics of 1950 (Statistical Office of Baden-Württemberg 1952). Our measure of soil quality is the agricultural suitability index devised by Zabel et al. 2014. Their closest measure is average agricultural suitability 1961–1990. They provide one data point for each geographic grid cell of 30 arc seconds × 30 arc seconds in size.[15] Their index considers climate (temperature, precipitation, solar radiation), soil (including pH value, texture, salinity, or organic carbon content), and topography (elevation and slope). The measure is calculated for 16 different crops and then averaged over all of them. We calculate the municipal averages of this measure by overlaying these raster data with the municipal borders. Crop specific suitabilities for barley, maize, potato, and summer and winter wheat are also taken from this source.

The Digital Elevation Model (DEM) of the US Geological Survey's Center for Earth Resources Observation and Science (EROS), the GTOPO30 data set, provides us with elevation data above sea level. From these data, we calculate terrain ruggedness as outlined in Riley et al. (1999). The distance to Rhine or Neckar is calculated using a shapefile with the location of rivers and lakes in Europe.[16] We consider these variables as proxies for the natural

[15] This is equivalent to 0.86 km² at the equator.

[16] These data can be downloaded from the European Environment Agency (EEA), the "WISE large rivers" shapefile.

conditions for agriculture, but they may potentially also have determined the timing of when a certain area was first settled. Proximity to rivers also proxies for second nature geography, via their effect on market access especially in premodern times. Data on average growing season solar radiation levels between 1970 and 2000 can be downloaded from the WorldClim database. The share of the municipalities' areas comprised of trias rock strata is provided by an official geological map of Baden-Württemberg.[17] Data on precipitation seasonality is contained in the WorldClim database.

Other historical variables stem from (and are discussed in) Huning & Wahl (2023). These are distance to the closest Imperial city, historical political fragmentation, and the share of each municipality located in church territories in 1556.

To proxy pre-industrial economic development and energy availability, both relevant for growing wine and economic development alike, we include a variable for the number of historical water mills in each municipality, derived from various different sources and data bases like the book on the history of paper mills by Bayerl (1987).

We include dummy variables for Alemmanic, Frankish, and Swabian dialect areas originating from the University of Tübingen's "Sprachatlas Baden-Württemberg" (Language Atlas of Baden-Württemberg). Dialect similarity is meant to be correlated with a lot of other cultural similarities, trade patterns, sense of identity, and, last but not least, early historical states (like the duchies of Swabia and Franconia). As such, dialect areas are potentially related significantly to local economic development, as well as inheritance practices, and collectivism.

To control for the possibly significant impact of Roman legacies on inheritance traditions and local economic development, we use the established Roman road network data from Talbert (2000). Here, we calculate the density of Roman roads for each municipality (kilometer of certain Roman roads per square kilometer).

We calculate market potential following the methodology of Crafts (2005) and the data by Bairoch et al. (1988). We consider the market size of a municipality's products by calculating the domestic market potential in 1500, which means that the set of possible trade partners is limited to other municipalities in Baden-Württemberg.

The Online Appendix provides a descriptive overview of all variables used in the empirical analysis (tables A.1 and A.3), and a more detailed description (section A.3).

5 Results

5.1 Determinants of historical winegrowing

We start our empirical analysis with the determinants of historical winegrowing. Following our discussion in Section 3, we run the following probit estimation to explain the determinants of viticulture in Baden-Württemberg:

$$\Pr(W_i|\mathbf{G}_i, ROMAN_i) = \Phi(\alpha + \beta'\mathbf{G}_i + \gamma ROMAN_i + \epsilon_i) \quad (1)$$

The dependent variable W_i is a dummy variable equal to one if wine is grown in a municipality i and in any of the historical periods considered. We discriminate between the seven different period categories in our data: before 799, 800–999, 1000–1299, before 1300,

[17] This is provided by the "Landesamt für Geologie, Rohstoff und Bergbau" (State Office of Geology, Raw Materials and Mining) of Baden-Württemberg.

1300–1624, and before 1624. The set of geographical and geological predictors of winegrowing, $\mathbf{G}_i$, includes precipitation seasonality, elevation, terrain ruggedness, distance to Rhine and Neckar (in kilometers), soil suitability, the natural logarithm of growing season radiation, the share of each municipality's area consisting of Trias rock strata, and the kilometer distance to the closest monastery in 800 AD. $ROMAN_i$ represents a variable that measures the average kilometer distance from the area of each municipality to the closest Roman road.

Table 1 shows the results. All geographic and geological variables are significant. Their coefficients have the expected signs: wine is more likely to be grown at low elevations, in rugged terrain, close to rivers, in areas with good soil quality, high levels of radiation in the growing season, where precipitation seasonality is high, and in municipalities with a large share of Trias rock strata.

In line with our discussion in Section 3, the share of Trias rock strata begins to be statistically significant for the regressions on the periods after the year 1000. This provides evidence for the historical narrative that the technology to exploit the sunny but steep hills created in the geological period developed only during the Middle Ages. The distances to Roman roads mattered most in the early Middle Ages (before 799).

This is in line with the hypothesis that wine was introduced to the area by the Romans and then expanded from these early germ cells to other areas. Similarly, the results confirm the proposition that wine was first grown in monasteries. As shown by the negative and significant distance variable, viticulture was significantly more prevalent in areas close to 8th century monasteries, at least before 1300. Precipitation seasonality also became more significant during the high Middle Ages, as suggested by the climatic changes throughout this era, especially the 950–1250 warm period.

5.2 Winegrowing and local economic development

We continue our study by investigating the explanatory power of late medieval and early modern winegrowing for local economic development and industrialization levels in the 20th century. We estimate the following equation using OLS:

$$Y_i = \alpha + \beta W_i + \gamma' \mathbf{X}_i + \epsilon_i. \tag{2}$$

Y_i is an indicator of regional economic development in municipality i in 1950, 1961, or 2019. We measure economic development in 1950 and 1961 with the natural logarithm of population (inhabitants per hectare) and firm density (firms per hectare). Local economic development in 2019 is measured by the natural logarithm of nighttime luminosity. W_i is (again) a dummy variable equal to one if wine was grown in a municipality in the period before 1300. We decided to measure winegrowing before 1300 as this seems to reflect the extent of viticulture during its heyday in the late Middle Ages, where it had the largest impact on economic development. A set of variables that feature geographical and historical covariates $\boldsymbol{X_i}$ includes the municipality's mean elevation, terrain ruggedness, and soil quality, the kilometer distances to Rhine, Neckar, to the state capital Stuttgart and the closest historical Imperial city, the historical average share of the municipality's area that belonged to an ecclesiastical territory, its average historical political fragmentation, domestic market potential in 1500, number of historical watermills, Roman road density (measured in kilometers of road per square kilometer), and dummy variables indicating whether a municipality belongs to the Frankish and Swabian dialect area. ϵ_i is the error term. Standard errors are clustered on the (1950) county level. Tables 2 and 3 show the results of estimating variants of equation 2. Panel A of table 2 shows the results for 1950, and panel B shows the

Table 1. *Determinants of historical winegrowing in Baden-Württemberg.*

Dep. var.	Winegrowing before 799	Winegrowing 800–999	Winegrowing before 999	Winegrowing 1000–1299	Winegrowing before 1300	Winegrowing 1300–1624	Winegrowing before 1624
	(1)	(2)	(3)	(4)	(6)	(5)	(7)
Precipitation seasonality	-0.0004	0.0004	0.0001	0.0218***	0.0130***	0.0093***	0.0252***
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
Elevation	-0.0001***	-0.0001***	-0.0001***	-0.0008***	-0.0005***	-0.0006***	-0.0009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Terrain ruggedness	0.0001***	0.0001***	0.0002***	0.0014***	0.0008***	0.0008***	0.0015***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distance to Rhine and Neckar	-0.0008**	-0.0007***	-0.0012***	-0.0040***	-0.0032***	-0.0015***	-0.0052***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distance to Roman road	-0.0036***	0.0005	-0.0009	0.0003	-0.0004	0.0008	0.0042***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Soil suitability	0.0005**	0.0009***	0.0015***	0.0065***	0.0042***	0.0037***	0.0115***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
ln(Growing season radiation)	0.7322***	0.1057	0.9074***	1.6678***	0.8765*	2.4663***	2.2059***
	(0.187)	(0.123)	(0.217)	(0.566)	(0.517)	(0.413)	(0.626)
Share Trias rock strata	-0.0100	-0.0009	-0.0080	0.2647***	0.1897***	0.0787***	0.3274***
	(0.008)	(0.006)	(0.010)	(0.024)	(0.023)	(0.019)	(0.026)
Distance to closest monastery	-0.0004**	-0.0003**	-0.0008***	-0.0011*	-0.0016***	-0.0001	-0.0010
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
	(0.009)	(0.006)	(0.010)	(0.024)	(0.019)	(0.022)	(0.025)
Pseudo-R^2	0.303	0.166	0.244	0.213	0.132	0.203	0.226
Observations	3,378	3,378	3,378	3,378	3,378	3,378	3,378

Notes. Heteroskedasticity robust standard errors are in parentheses. The coefficient is statistically different from zero at the ***1 %, **5 %, and *10 % level. The table shows Probit estimates and the coefficients report average marginal effects. The unit of observation is a municipality in 1953. All regressions include a constant not reported.

Table 2. *Historical winegrowing and local economic development in the 20th century.*

	(1)	(2)	(3)	(4)
Panel A: Economic development in 1950				
Dep. var.	ln(Population density 1950)		ln(Firms per hectare 1950)	
Winegrowing before 1300	0.628***	0.267***	0.590***	0.286***
	(0.0731)	(0.0462)	(0.0730)	(0.0423)
Control variables	–	✓	–	✓
Observations	3,378	3,371	3,365	3,365
R^2	0.112	0.383	0.084	0.267
Panel B: Economic development in 1961				
Dep. var.	ln(Population density 1961)		ln(Firms per hectare 1961)	
Winegrowing before 1300	0.743***	0.336***	0.550***	0.290***
	(0.0857)	(0.0558)	(0.0710)	(0.0454)
Control variables	–	✓	–	✓
Observations	3,377	3,370	3,377	3,370
R^2	0.038	0.249	0.054	0.246

Notes: Standard errors clustered on county level are in parentheses. The coefficients are statistically different from zero at the ***1%, **5%, and *10% level. The unit of observation is a municipality in 1953. All regressions include a constant not reported. Control variables include a municipality's mean elevation, terrain ruggedness and soil quality, its distance to Rhine or Neckar, to the state capital Stuttgart, and to the next historical Imperial city (in km), the historical average share of a municipality's area that belonged to an ecclesiastical territory, its average historical political fragmentation, domestic market potential in 1500, number of historical watermills, Roman road density (km of road per km^2 of area), and dummy variables indicating whether a municipality belongs to the Frankish and Swabian dialect area (the base group is the Alemannic dialect).

Table 3. *Historical winegrowing and local economic development in the 21st century*

	(1)	(2)
Dep. var.	ln(Luminosity 2019)	
Winegrowing before 1300	0.637***	0.278***
	(0.0801)	(0.0484)
Control variables	–	✓
Observations	3,382	3,374
R^2	0.142	0.505

Notes. Standard errors clustered on county level are in parentheses. The coefficients are statistically different from zero at the ***1%, **5%, and *10% level. The unit of observation is a municipality in 1953. All regressions include a constant not reported. Control variables include a municipality's mean elevation, terrain ruggedness and soil quality, its distance to Rhine or Neckar, to the state capital Stuttgart, and to the next historical Imperial city (in km), the historical average share of a municipality's area that belonged to an ecclesiastical territory, its average historical political fragmentation, domestic market potential in 1500, number of historical watermills, Roman road density (km of road per km^2 of area), and dummy variables indicating whether a municipality belongs to the Frankish and Swabian dialect area (the base group is the Alemannic dialect).

results for 1961. Columns (1) and (3) include the results of the bivariate estimations. Columns (2) and (4) report the results including the full set of control variables.

The results reveal a statistically significant and robust positive effect of historical winegrowing on the level of local economic development. The coefficients are similar for 1950 and 1961. For 1950, the estimated semi-elasticity from the model with all control variables implies that in historical wine municipalities, on average, the population density is around 30 percent

higher ($[(e^{0.267}) - 1] \cdot 100$) and firm density is around 33 percent higher ($[(e^{0.286}) - 1] \cdot 100$). With respect to contemporary local economic development, the results with luminosity as a dependent variable suggest a similar effect. They are shown in table 3. For example, according to the coefficient in column (2), nighttime luminosity in historical winegrowing municipalities is on average 32 percent higher ($[(e^{0.278}) - 1] \cdot 100$).

In table A.4 of the Online Appendix, we show that these results are virtually identical when we include county fixed effects in the regression specification and only exploit within-county variation. The inclusion of a county fixed effect ensures that, according to Moran's I-test, no spatial autocorrelation exists in the residual of these regressions, and our results are not subject to the "Kelly critique" (Kelly 2020).[18]

In table A.5, of the Online Appendix, we also test whether the results are robust to the use of winegrowing before 1624 and in 1865 as the main explanatory variable. The resulting coefficients are again significantly positive and suggest a similar effect size.

In table A.6, we also test the robustness of our results by including the foreign market potential, instead of only the domestic market potential, in the regression equation. The domestic and foreign market potential in 1500 are highly correlated with each other (the correlation coefficient is 0.72), indicating why foreign market potential is always insignificant in these regressions. As a consequence, our results remain virtually identical when including foreign market potential.

In table A.7, we also include suitability measures for barely, maize, potatoes, summer wheat, and winter wheat, as well as a dummy for municipalities that have intensive agricultural activities other than winegrowing in 1961 (intensive agricultural activities are mainly the growth of tobacco, hops, and fruits). This is to make sure that winegrowing is not coincidentally correlated with a high suitability for other eligible crops (e.g., potatoes), and therefore, we might pick up their effect when measuring winegrowing or other intensive agricultural activities. The results are virtually identical to those without these additional variables. The takeaway from this is that our results are not driven by a correlation between the adoption of relevant crops, other intensive agricultural activities, and winegrowing.

In table A.8, we control for additional proxies of pre-wine economic development. These are the share of a municipality located in the Neolithic settlement area and a dummy equal to one if a municipality was settled in the early medieval period by a Germanic tribe. This is to ensure that the results do not reflect the fact that before the expansion of winegrowing during the Middle Ages the population density in the later winegrowing areas could already have been larger. Although we already account for this in the main specification with Roman road density, it is insightful to include proxies for the settlement history of the region before the Roman era and immediately after it. The results turn out to be virtually unchanged by the inclusion of these variables.

5.3 Understanding local economic development by instrumenting winegrowing with precipitation seasonality

In this section, we study whether historical winegrowing had a causal effect on local economic development in the 20th and 21st centuries. We infer causality by making use of the relationship between winegrowing and climate. We run 2SLS instrumental variables

[18] To further ensure that the results in table 2 are not due to spurious autocorrelation patterns, we re-estimated the regressions in this table using Conley standard errors (Conley 1999) assuming a Bartlett kernel (linear decay of the spatial autocorrelation with distance) and 100km as cutoff point. The results remain highly statistically significant.

regressions using a peculiar and important determinant of winegrowing as an instrument for the historical prevalence of viticulture: *precipitation seasonality*.

We test the validity of our instrumental variable first with a placebo check. To understand the idea behind this check, recall our regressions in table 1 that have shown that winegrowing from the high Middle Ages onward is significantly predicted by precipitation seasonality. Based on this observation, if our instrument is valid, there should be no effect of precipitation seasonality on the suitability to grow other important medieval crops, namely winter and summer wheat and barley, which have relatively short roots. This means that during their summer growing period, grains cannot reach the water reservoirs built up in the winter months, while grapes can. As such, precipitation seasonality is a plausible exogenous predictor of whether rational farmers prefer to grow wine over grains.

Consequently, in table 4, columns (1) to (3), we test whether the suitability of a municipality to grow important medieval crops is significantly predicted by our instrument precipitation seasonality and the set of covariates from our baseline OLS regressions. [19] As we do not have information on where these crops were actually grown during the Middle Ages, we choose the general suitability to grow them today, as our dependent variables.

As predicted by our ecological background and validating our exclusion restriction, precipitation seasonality is not a relevant determinant of growing winter wheat, summer wheat, or barley. In column (4) of table 4, we additionally show that, as in table 1, precipitation seasonality is also correlated with wine production in 1300 when using baseline controls as predictors. In conclusion, precipitation seasonality is not yet another proxy of general natural conditions.

In another test for the validity of the instrument, we compare the relationship between precipitation seasonality and local economic development for municipalities in west German federal states in which wine is grown (Baden-Württemberg, Bavaria, Hesse, Rhineland-Palatinate) versus municipalities in states in which it is not (Bremen, Hamburg, Lower Saxony, North Rhine-Westfalia, and Schleswig-Holstein). This placebo test is passed if we find a significant effect on precipitation seasonality in winegrowing states, but not in those without wine (the placebo group).

To estimate these regressions, we use the data set by Hager & Hilbig (2019), who provide municipality level information on local economic development for western Germany in 2014. We merge our data on precipitation seasonality into their data set and, based on these data, run reduced-form regressions with precipitation seasonality as the left-hand side variable and (the natural logarithm of) the average wage income of a municipality in 2014 as the dependent variable. We include a set of geographic and historical control variables from their data set (distance to the closest coal field, latitude and longitude, mean elevation, a Roman dummy, a dummy for participation in the Peasant War, distance to Wittenberg, and a variable indicating the prevailing legal code in 1894) along with county fixed effects.[20] We run the regression separately for municipalities in winegrowing states and the other states. Table 5

[19] There is no reason to believe that today's precipitation seasonality should have decisively changed compared to that in the medieval or early modern period. This is why we believe that it can act as a valid proxy. Predicting contemporary winegrowing also does not seem to be a preferable option, as today through selective breeding and genetic manipulation, most widely grown grapes are less sensitive to natural conditions than historical grapes. Today, wine is no longer produced in all areas that would be suitable; the quality bar has been raised since the early modern period. Winegrowing today is likely to be more endogenous to economic development than it was historically.

[20] Table A.2 in the Online Appendix provides a descriptive overview of this data set.

Table 4. *Precipitation seasonality, crop suitability, and historical winegrowing.*

Dep. var.	(1) Winter wheat suitability	(2) Summer wheat suitability	(3) Barley suitability	(4) Winegrowing before 1300
Precipitation seasonality	-0.137	0.00374	0.155	0.0208***
	(0.161)	(0.156)	(0.167)	(0.00461)
Elevation	-0.0167***	-0.00802	-0.0300***	-0.000978***
	(0.00584)	(0.00585)	(0.00582)	(0.000127)
Distance to Stuttgart	-0.0349	-0.00419	-0.00569	-0.000926
	(0.0375)	(0.0341)	(0.0380)	(0.00103)
Terrain ruggedness	-0.0626***	-0.0610***	-0.0333***	0.00126***
	(0.0106)	(0.0105)	(0.0121)	(0.000263)
Distance to Rhine or Neckar	-0.0412	-0.0772*	-0.0606	-0.00549***
	(0.0434)	(0.0412)	(0.0513)	(0.00107)
Share ecclesiastical territory	-4.288***	-4.431***	-3.611***	-0.0644*
	(1.173)	(1.119)	(1.304)	(0.0329)
Distance to Imperial City	-0.300***	-0.271***	-0.286***	0.000280
	(0.0865)	(0.0865)	(0.0834)	(0.00233)
Roman Road density	2.917	4.112	3.186	-0.0379
	(2.871)	(2.663)	(3.035)	(0.0922)
Historical political fragmentation	5.48e-06	-2.48e-06	2.30e-06	1.96e-07
	(2.38e-05)	(2.51e-05)	(2.33e-05)	(7.10e-07)
Domestic market potential	-5.120***	-4.782***	-7.572***	-0.127*
	(1.378)	(1.269)	(1.783)	(0.0657)
Watermills	-0.918**	-0.804**	-0.910*	0.0121
	(0.399)	(0.397)	(0.459)	(0.0114)
Soil suitability	1.507***	1.372***	1.838***	0.00769***
	(0.118)	(0.116)	(0.116)	(0.00155)
Frankish dialect	-0.602	-2.342	1.377	-0.0905
	(2.866)	(2.651)	(3.429)	(0.100)
Swabian dialect	9.744***	10.93***	8.483***	-0.177**
	(2.712)	(2.656)	(3.119)	(0.0777)
Observations	3,374	3,374	3,374	3,374
R^2	0.648	0.631	0.639	0.265

Notes: Standard errors clustered on county (Landkreis) level are in parentheses. The coefficient is statistically different from zero at the ***1%, **5% and *10% level. The unit of observation is a municipality in 1953. All regressions include a constant not reported. All reported coefficients are the result of an OLS model (in column (4), this means a linear probability model is estimated).

shows the results. We find that seasonality of precipitation is not a significant predictor of local economic development in states without viticulture, while it is in winegrowing states.

These tests suggest that precipitation seasonality is significantly and specifically related to winegrowing, and therefore can act as a valid instrument.

Consequently, we proceed by estimating 2SLS regressions of the following form:

$$W_i = \alpha_1 + \beta_1 PS_i + \gamma_1' \mathbf{X}_i + \epsilon_i \tag{3a}$$

$$Y_i = \alpha_2 + \beta_2 \widehat{W}_i + \gamma_2' \mathbf{X}_i + \eta_i, \tag{3b}$$

Table 5. *Precipitation seasonality and economic development—placebo check.*

	(1)	(2)
Dep. var.	ln(Average wage income 2014)	
Sample	Winegrowing states	Other states
Precipitation seasonality	0.00373**	-0.00779
	(0.0017)	(0.0085)
Control variables	✓	✓
County fixed effects	✓	✓
Observations	5,878	1,990
R^2	0.463	0.233

Notes. Standard errors in parentheses are clustered on county level (Landkreisebene). The coefficient is statistically different from zero at the ***1%, **5%, and *10% level. The unit of observation is a municipality in 2014. All regressions include a constant not reported. Control variables include distance to the closest coal field, latitude and longitude, mean elevation, a Roman dummy, a dummy for participation in the Peasant War, distance to Wittenberg, and a variable indicating the prevailing legal code in 1894.

PS_i is the precipitation seasonality in the municipality i and Y_i are the same measures of local economic development as before. $\boldsymbol{X_i}$ is also the same vector of control variables as in equation 2. Geographic variables account for the effect of geography on economic development.

Table 6 reports the results of 2SLS together with the estimates of the coefficients of the reduced form estimated with OLS. Panel A shows the second stage, Panel B the first stage, and Panel C the reduced form results.

For each of the outcome variables, we estimate regressions with the full set of control variables. Panel B suggests that precipitation seasonality is a significant predictor of medieval winegrowing in all regressions. The F value of the excluded instrument is around 20 and therefore well above common thresholds. In conclusion, the instrument is relevant and sufficiently strong.

The second stage shows a significant relationship of the instrumented medieval winegrowing with the outcome variables. The coefficients have the expected sign but are notably larger than the OLS estimates, suggesting a downward bias of the OLS results. The effect size of both models is reasonable. The IV results imply that the population density is on average 60 percent higher (column (1)) in a medieval winegrowing municipality. Given the large variation in population density in our sample (which varies between 0.48 and 5473.9), and the fact that most of the major agglomerations and large cities in Baden-Württemberg are located in winegrowing areas, these effect sizes are plausible.

To put this in perspective, the coefficient implies that a municipality without wine and with median population density (around 93 inhabitants per hectare) would see an increase of its population density to the average (around 147) if it were to grow wine. Panel C shows a significant positive influence of the precipitation seasonality on the outcome variables, which is economically sizable. The reduced form is estimated with OLS and, provided that the validity of our instrument is unbiased regardless of whether the 2SLS estimations suffer from a weak instrument, we find the significant reduced-form results reassuring.

In conclusion, these 2SLS estimations confirm that our empirical results are robust to alternative identification strategies.

Table 6. *Historical winegrowing and local economic development—IV estimations.*

	(1)	(2)	(3)	(4)	(5)
Panel A: Second stage					
Dep. var.	ln(Population density 1950)	ln(Firms per hectare 1950)	ln(Population density 1961)	ln(Firms per hectare 1961)	ln(Luminosity 2019)
Winegrowing before 1300	0.472**	0.496*	0.651**	0.569**	0.554**
	(0.240)	(0.267)	(0.282)	(0.239)	(0.257)
Panel B: First stage (Dependent variable: Winegrowing before 1300)					
Precipitation seasonality	0.0207***	0.0207***	0.0208***	0.0208***	0.0208***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
F Value of excluded IV	20.28	20.16	20.34	20.12	20.34
Panel C: Reduced form					
Dep. var.	ln(Population density 1950)	ln(Firms per hectare 1950)	ln(Population density 1961)	ln(Firms per hectare 1961)	ln(Luminosity 2019)
Precipitation seasonality	0.0098*	0.0103*	0.0135**	0.0118**	0.0115**
	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)
Control variables	✓	✓	✓	✓	✓
Observations	3,371	3,365	3,374	3,373	3,374

Notes: Standard errors in parentheses are clustered on county level (Landkreisebene). The coefficient is statistically different from zero at the ***1%, **5%, and *10% level. The unit of observation is a municipality in 1953. All regressions include a constant not reported. Control variables include a municipality's mean elevation, terrain ruggedness and soil quality, its distance to Rhine or Neckar, to the state capital Stuttgart, and to the next historical Imperial city (in km), the historical average share of a municipality's area that belonged to an ecclesiastical territory, its average historical political fragmentation, domestic market potential in 1500, number of historical watermills, Roman road density (km of road per km^2 of area), and dummy variables indicating whether a municipality belongs to the Frankish and Swabian dialect area (the base group is the Alemannic dialect).

5.4 Mechanisms: equal partition and collectivism

In this section, we inspect the two main mechanisms through which winegrowing has influenced local economic development over time: Equal Partition and collectivism. We test both of these possible mechanisms by explaining the historical prevalence of equal partition and rare names with medieval winegrowing. We estimate the following equation using Probit:

$$\Pr(EP_i|W_i, \mathbf{X}_i) = \Phi(\alpha + \beta W_i + \gamma' \mathbf{X}_i + \epsilon_i) \tag{4}$$

EP_i is a dummy variable equal to one for municipalities in the historical equal partition area, W_i is either a dummy for winegrowing before 1300 or before 1624, and $\mathbf{X}_i$ is the same set of control variables as in table 2.

In the case of the collectivism–winegrowing relationship, we estimate the following equation again using Probit:

$$\Pr(N_i|W_i, \mathbf{X}_i) = \Phi(\alpha + \beta W_i + \gamma' \mathbf{X}_i + \epsilon_i) \tag{5}$$

N_i is a dummy variable for municipalities with a high or very high share of rare names (municipalities that are in the 75$^{\text{th}}$ or 90$^{\text{th}}$ percentile of the rare names frequency distribution).

Table 7. *Historical winegrowing and local economic development—potential mechanisms.*

Dep. var.	(1) Equal partition	(2) Equal partition	(3) Rare given names (75th percentile)	(4) Rare given names (90th percentile)
Winegrowing before 1300	0.1110***		-0.0787***	-0.0366**
	(0.026)		(0.025)	(0.018)
Winegrowing before 1624		0.0948***		
		(0.027)		
Control variables	✓	✓	✓	✓
Observations	3,374	3,374	3,374	3,374
Pseudo R^2	0.477	0.475	0.112	0.092

Notes: Standard errors clustered on county level are in parentheses. The coefficients are statistically different from zero at the ***1%, **5%, and *10% level. The unit of observation is a municipality in 1953. All regressions include a constant not reported. All columns are estimated using Probit and report average marginal effects. Control variables include a municipality's mean elevation, terrain ruggedness and soil quality, its distance to Rhine or Neckar, to the state capital Stuttgart, and to the next historical Imperial city (in km), the historical average share of a municipality's area that belonged to an ecclesiastical territory, its average historical political fragmentation, domestic market potential in 1500, number of historical watermills, Roman road density (km of road per km^2 of area), and dummy variables indicating whether a municipality belongs to the Frankish and Swabian dialect area (the base group is the Alemannic dialect).

W_i is a dummy for winegrowing before 1300. All other variables are identical to equation 2. Table 7 shows the results. Consistent with the significant effect of winegrowing before 1624 on the prevalence of equal partition in 1950 found in Huning & Wahl (2021b), the effect of medieval winegrowing on the historical prevalence of equal partition is positive and significant (see columns (1) and (2)).

Regarding the effect of historical winegrowing on collectivism, our results suggest a significantly negative effect of medieval winegrowing on the prevalence of rare given names (see columns (3) and (4)). This confirms previous results on the effect of intensive agriculture on collectivism and suggests that historical winegrowing made people more collectivist, contributing to a higher level of in-group cooperation and social capital, which then positively influences local economic development. Testing this more thoroughly is up to future research, because a good proxy for both social capital as well as an individual-level measure of collectivism is needed—neither of which is readily available on a municipality level for the 1950s or today.

We quantify the extent to which equal partition and collectivism explain away the effect of winegrowing on local economic development by running horse race IV regressions that include our dependent variables from table 7 as explanatory variables and winegrowing before 1300 dummy. Everything else is identical to the regressions in table 6. Table 8 reports the second stage IV results. They show that the coefficient of medieval winegrowing is significantly reduced and becomes insignificant all the time, while equal partition and a high frequency of rare given names are significant in all regressions. The results imply that, depending on the outcome considered, between around 20 to 40 percent of the total effect of winegrowing on local development is mediated by our two channel variables. Together with the fact that the coefficient of winegrowing—although statistically insignificant—is

Table 8. *Historical winegrowing, equal partition, collectivism, and local economic development—horse race.*

	(1)	(2)	(3)	(4)	(5)
Dep. var.	ln(Population density 1950)	ln(Firms per hectare 1950)	ln(Population density 1961)	ln(Firms per hectare 1961)	ln(Luminosity 2019)
Winegrowing before 1300	0.3121	0.3011	0.3793	0.4636	0.4167
	(0.287)	(0.254)	(0.273)	(0.299)	(0.259)
Equal partition	0.2419***	0.2223***	0.2269***	0.2437***	0.1977***
	(0.070)	(0.062)	(0.071)	(0.077)	(0.066)
Rare given names	-0.1172***	-0.0634**	-0.0785***	-0.0739**	-0.0990***
(75^{th} percentile)	(0.038)	(0.030)	(0.028)	(0.036)	(0.036)
F-value of excluded IV	15.39	15.44	15.46	15.46	15.27
Control variables	Yes	Yes	Yes	Yes	Yes
Percent mediated	33.88	39.29	41.74	18.52	24.78
Observations	3,365	3,371	3,374	3,374	3,373
R^2	0.306	0.428	0.514	0.429	0.314

Notes: Standard errors in parentheses are clustered on county level (Landkreisebene). The coefficient is statistically different from zero at the ***1%, **5%, and *10% level. The unit of observation is a municipality in 1953. The table shows results from the second stage. All regressions include a constant not reported. Control variables include a municipality's mean elevation, terrain ruggedness and soil quality, its distance to Rhine or Neckar, to the state capital Stuttgart, and to the next historical Imperial city (in km), the historical average share of a municipality's area that belonged to an ecclesiastical territory, its average historical political fragmentation, domestic market potential in 1500, number of historical watermills, Roman road density (km of road per km^2 of area), and dummy variables indicating whether a municipality belongs to the Frankish and Swabian dialect area (the base group is the Alemannic dialect). The row "Percent mediated" shows how much of the total effect of late medieval wine-growing is mediated by collectivist attitudes and equal partition. To do so, following formula is applied: $(1-(\frac{ADTE}{LATE}))*100$, where ADTE (average direct treatment effect) is the remaining direct effect of winegrowing as depicted by the coefficients in this table, and LATE is local average treatment effect, i.e., the coefficient from the 2SLS estimations reported in table 6.

still relatively large, this suggests that our mechanisms are important, but other important channels seem to exist.[21]

A final robustness check is concerned with the problem resulting from the possibility that the OLS estimates of both the relationship between the treatment and the mediator and the treatment and the outcome can be biased due to endogeneity. The methods we have used until now only account for a possible endogeneity bias in the relationship between treatment and outcome, but not between treatment and the mediators. To do so, we use the method

[21] Such horse race regressions are informative, but they are subject to shortcomings and have recently been criticized (e.g., by Acharya et al. 2016). The mechanism variables are by construction endogenous to the treatment and hence their inclusion together with winegrowing can cause a so-called post-treatment bias (or intermediate variables bias). To account for this and arrive at an unbiased estimate of the direct effect of winegrowing on local economic development, the ACDE (average causal direct effect), we therefore apply the sequential g-estimation method proposed by Acharya et al. (2016), which is able to avoid such a bias. We modify their original procedure (which estimates everything using OLS) to estimate the ACDE based on a 2SLS estimation. The results of estimating the horse race regressions in table 8 with sequential g-estimation are shown in table A.9 in the Online Appendix. Overall, the method results in larger OLS estimates and, consequently, also larger, significant ACDEs. The percentage of the total effect that is mediated, however, remains between around 15 to 30 percent. Therefore, our overall conclusion, that our mechanisms are explaining a significant portion of the overall wine effect, remains intact.

developed by Dippel et al. (2020). Their approach addresses the fact that both the treatment and mediator may be endogenous and provides a solution where a single instrument is enough to identify both the causal treatment and the mediation effects. Although this method has the benefit of requiring only one instrument, its drawback is that it restricts us to including only one mediator in the regression at a time, rather than two, as we would have preferred. In the Appendix, table A.10, we present the total, direct, and indirect effects of mediation analysis using Dippel et al. (2020)'s Stata command `ivmediate` for either equal partition or rare given names as mediator, and the same set of outcomes and control variables as used in table 8. The results suggest that between 35 and 40 percent of the effect of winegrowing on local economic development is mediated by collectivism (the frequency of rare given names) and between 50 and 60 percent is mediated by equal partition. Therefore, both variables appear to explain a substantial part of the overall effect of winegrowing even when one takes into account that both treatment and mediators could be endogenous.

5.5 Further results—winegrowing and economic development in the 17th and 18th centuries

To ensure that our results on the impact of historical winegrowing on local economic development are robust to the use of a different data source, estimation sample, and time period, we resort to data on the size of vineyards and population in the municipalities of the Duchy of Württemberg in 1634 and 1655 from the "Steuer- und Kriegsschadenbericht 1629-1655" (Von Hippel 2009). We also use data on the location of proto-industrial ("late mercantilist") factories in 1780 from Boelcke (1977) to construct measures for the local presence of proto-industry in 1780 for all the municipalities of Baden-Württemberg in the 1950s. The results are shown in the Online Appendix, section A.5. They show that winegrowing was also significantly positively related to local economic development in these pre-industrial periods.

6. Conclusion

This paper provides evidence that historical viticulture can account for comparative development. Our argument hinges on the fact that winegrowing is a highly labor-intensive agricultural activity, which facilitates farming on marginal and relatively small plots. This led to the emergence and persistence of equal partition and, as we demonstrate, is also related to the development of collectivist attitudes among the population in winegrowing regions.

Our causal identification strategy draws inspiration from a unique botanical characteristic of the grapevine, specifically its deep-reaching roots, which allow it to flourish when winters are rainy and summers are hot and dry. Therefore, we use precipitation seasonality as an instrumental variable for historical wine cultivation and find our baseline OLS results corroborated: there is a causal positive impact of wine cultivation on both historical and contemporary local economic development. This study underscores the role of wine in the shaping of modern Southwest Germany.

We want to end by noting that, while we have found suggestive evidence for a causal link between winegrowing and rural social norms and customs, the latter are still poorly understood and difficult to measure, particularly in historical contexts. Thus, a promising direction for future research would be to conduct a more detailed examination of how attitudes and norms of rural populations are formed, and their relationship to economic development.

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Data availability

The data and methods underlying this article are available in its online supplementary material.

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