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How Big is the "Lemons" Problem? Historical Evidence from French Wines

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How Big is the "Lemons" Problem?
Historical Evidence from French Wines

Abstract

This paper provides empirical evidence of large welfare losses associated with asymmetric information about product quality in a competitive market. When consumers cannot observe product characteristics at the time of purchase, atomistic producers have no incentive to supply costly quality. We compare wine prices across administrative districts around the enactment of historic regulations aimed at certifying the quality of more than 250 French appellation wines to identify welfare losses from asymmetric information. We estimate that these losses represent up to 13% of total market value, suggesting an important role for credible certification schemes.

Keywords: asymmetric information, adverse selection, quality uncertainty, welfare, wine appellation

JEL Classification: D82, N54, Q18

Quelle est l'ampleur du problème des "lemons" ?
Une analyse historiques des vins français

Résumé

Cet article donne des preuves empiriques de pertes importantes de bien-être causées par l'asymétrie d'information sur la qualité des produits dans un marché concurrentiel. Lorsque les consommateurs ne peuvent pas observer les caractéristiques du produit au moment de l'achat, les producteurs atomistiques n'ont aucune incitation à fournir de biens de meilleure qualité s'ils sont plus coûteux à produire. Nous comparons les prix du vin dans les différentes circonscriptions administratives autour de la mise en place d'une réglementation historique visant à certifier la qualité de plus de 250 vins français d'appellation d'origine, de manière à identifier les pertes de bien-être dues à l'asymétrie d'information avant la réforme. Nous estimons que ces pertes représentent jusqu'à 13% de la valeur totale du marché, ce qui suggère un rôle important pour des systèmes de certification crédibles.

Mots-clés : information asymétrique, sélection adverse, qualité incertaine, bien-être, appellation des vin

Classification JEL : D82, N54, Q18

How Big is the "Lemons" Problem? Historical Evidence from French Wines

1. Introduction

In his foundational paper, Akerlof (1970) formalized the notion that a consumer's inability to ascertain quality differences in products may "drive the good product out of the market," resulting in a socially undesirable outcome. If buyers cannot distinguish good products from bad, they will value a product's quality as average. This may keep sellers of the good product from trading, even if consumers' willingness to pay for the good product exceeds their reservation value. In equilibrium, a "lemons" market emerges whereby products of low quality are sold but good products remain in the hands of sellers, despite having higher social value in those of buyers.

A growing body of empirical work has sought evidence of the existence of the lemons effect in a variety of contexts, sometimes successfully. Yet, empirical evidence of its welfare significance remains elusive. One notable exception is insurance markets, which have been the object of much recent scrutiny. Even there, evidence is limited (Bundorf *et al.*, 2012), and existing estimates often point to small social welfare effects (Handel, 2013; Finkelstein *et al.*, 2019).

The present paper estimates welfare impacts of the lemons effect on the French wine market in the first three quarters of the 20th century. In this market, products are highly differentiated and supplied atomistically by more than one million producers. Using price data and a historic policy change intended to mitigate informational asymmetry between wine buyers and sellers, we provide evidence of a large welfare effect channeled through adverse selection in quality provision. We exploit spatial and temporal variation in the implementation of the policy to flexibly control for potentially confounding factors. Our estimates indicate that the lemons mechanism was responsible for losses up to 13% of total market value prior to the reform.

Our study differs from previous empirical work on the effects of asymmetric information in two critical ways. First, we leverage actual changes in the informational setting regarding product quality at the level of an entire market as the source of identifying variation. We therefore observe equilibrium outcomes, notably prices, under varying degrees of asymmetric information. Second, we document an original type of adverse selection. Not only can asymmetric information cause market unraveling by inducing owners of high-quality goods to hold on to them (Hendren, 2013, 2017), it also can deter sellers from undertaking socially valuable quality investments (Kim, 1985).[1] Thus, although the market equilibrium may involve a large volume of goods traded, there may be welfare gains forgone from not producing – and trading – higher-quality goods instead.

[1] For instance, owners having decided to sell a used vehicle may profitably forgo maintenance prior to sale.

We argue that such a lack of incentives to supply quality was at play in the French wine market during the decades preceding the adoption of a 1935 law that codified production rules and implemented official controls for fine wines claiming a reputable geographical appellation – like *bordeaux* or *champagne*. We show that this pioneering law, the first of its kind to be adopted in the world and the enduring template for regulations pertaining to geographical indications, profoundly and durably changed the quality of French wines.

The wine market is an ideal setting to study the effects of quality-related market inefficiencies. Wine is a highly differentiated product, partly due to the complexity of its production process. Beyond careful attention to the delicate chemical reactions that transform crushed grapes into wine, the quality of the final product crucially depends on the suitability of the grape varietal to the climate and soil of the vineyard. The area of origin may thus play a salient role in signalling quality. Yet, it may be difficult for the average consumer to know quality at the time of purchase, even with a geographical indication.[2]

As wine trade expands from geographically contained locales where local customs are easily preserved[3] to national and global markets, atomistic producers may be increasingly tempted to plant high-yielding but unsuitable grape varietals, expand production into inappropriate terrains, or cut costs by lowering quality while continuing to claim a theretofore reputable origin. And indeed, the history of wine production is riddled with anecdotes of such deceptive but profitable behavior. Whether these anecdotes add up to economically meaningful effects, and if so, whether some form of government intervention may be effective at restoring quality, is a more debatable proposition, which the present paper seeks to address.

To this end, we assemble a panel of yearly average wine prices received by producers in each department – a French administrative unit roughly the size of a US county – for the period 1907–1969. We pair it with detailed cartographic data reflecting the share of a department's vineyard acreage eligible for designation under *appellation d'origine contrôlée* (hereafter AOC), the official designation for appellation wines created by the 1935 law.[4] Because it took time for the French administration to define the 274 AOCs present during our sample period, our departmental measure of AOC eligibility grows as more AOCs are recognized over time.

To evaluate the effect of the reform, we regress the departmental average price of wine on the time- and space-varying share of eligible vineyard acreage, controlling for time-invariant unob-

[2]For instance, in 1935 there were more than 65,000 winegrowers in Gironde, where *bordeaux* is produced.

[3]These customs are referred to as "local, loyal, and constant uses" in the French legislation on appellations.

[4]There were several legislative attempts to define appellation wines prior to 1935. None of them included official controls or a systematic definition of production requirements. In many cases, definitions merely included broad geographical delimitations, which encouraged free-riding on other important aspects of quality provision within the delimitated zones, and most likely led to a worsening, not an improvement, of the asymmetric information problem (Capus, 1947; Simpson, 2004). This may partly explain why Haeck *et al.* (2018), who study the impact of these pre-1935 reforms, obtain mixed results.

servable factors through department fixed effects. We control for time-varying factors through year fixed effects differentiated by broad wine region. We also control for wine production to capture natural swings in wine prices arising from weather shocks and to ensure that our estimated effect reflects shifts in demand rather than movements along a demand curve.[5] Causal interpretation of our estimate requires AOC eligibility to be orthogonal to unobserved drivers of price across departments in the same wine region and year, after controlling for department fixed effects and production shocks. We feel comfortable making this assumption given the granularity of our time fixed effects and the length of our panel, and provide supporting evidence. Using 30 years of pre-reform data, we show that price trends before the reform were uncorrelated with eventual AOC recognition. We also show that excluding departments with low eventual AOC share, that is, focussing on the intensive margin of treatment, does not affect our result.

Our analysis yields an estimate of the marginal effect of AOC eligibility on the departmental wine price equal to 42%. That is, a department in which 100% of vineyards became eligible for AOC designation experienced, on average, a 42% increase in price. This estimate represents an intention-to-treat effect as not all eligible vineyards claimed an AOC; our estimate implies that AOC status led to an increase in price roughly equal to the size of the average wine price. This dramatic appreciation suggests that appellation wines had been produced at an inefficiently low quality prior to regulation, consistent with historical accounts of widespread abuse in the decades leading to the reform.

Of course, the fact that the average price of wine moved in direct relationship to the share of vineyard acreage that became eligible for AOC does not, by itself, imply that the reform had an impact on quality. Our analysis therefore considers alternative explanations. First, we do not find any evidence that the reform decreased wine production, which implies that the price increase in eligible departments cannot be attributed to a reduction in quantity. Second, the fact that we use *average* prices calculated across all wine segments within a department – as opposed to prices of individual appellation wines[6] – makes it very unlikely that the observed effect of AOC recognition on price could have been caused by the mere sorting of wines, that is, the shift from a pooling equilibrium to a separating equilibrium without any change in quality. Using information on the departmental share of wines sold under appellation before and after the reform, we formally reject this hypothesis. We also reject a related hypothesis according to which the increase in average price was caused by the *déclassement* (demotion) of wines within a department, that is, the denial of the use of an appellation for wines sold under appellation prior to the reform.[7]

[5] Our findings are robust to the removal of the production control.

[6] To be sure, historical prices are not available at the level of the individual vineyard.

[7] In a vertically differentiated market where consumers have heterogenous tastes for quality, prices in each market segment are determined by the willingness to pay of marginal consumers. As a result, the mere reallocation of quantities from one segment to another through relabeling can affect the price average calculated across all

Since the observed increase in average price in AOC departments cannot be attributed to changes in quantity or to the reshuffling of wines across market segments, we conclude that it was caused by shifts in demand arising from improvements in the quality for AOC wines – as the reform intended.[8] Consequently, the observed price increase provides a direct measure of the increase in buyers' marginal willingness to pay for wine that can be used for welfare analysis.

Our preferred estimate suggests that the lemons effect had substantial welfare impacts on the French wine market. At the end of our study period, the share of French vineyards eligible for AOC recognition reached 32%. Together with our estimated effect on the average wine price, this share implies a welfare loss of about 13% in the French wine market – inclusive of all wines – due to asymmetric information prior to the reform. This value represents a *gross* welfare loss in the sense that it does not account for the added cost of quality-enhancing practices required for wines sold under AOC designation. While these cost increases could be substantial, the fact that a large share of eligible producers decided to claim an AOC suggests that the policy was beneficial to wine producers, and welfare-enhancing. Irrespective of the actual costs of supplying quality, our gross welfare measure reveals the considerable size of the latent unsatisfied demand for higher-quality wine under asymmetric information, suggesting that the lemons problem may severely affect market performance in vertically differentiated markets with atomistic supply, even when the volume of trade is large.

Our paper directly relates to a rich literature seeking empirical evidence of adverse selection in real-world markets. Some studies have focussed on the trade of used vehicles (Bond, 1982; Genesove, 1993; Lewis, 2011), in line with Akerlof's original setting. These papers do not find strong evidence of adverse selection, suggesting a limited role of asymmetric information. A richer strand of literature has investigated insurance markets (Puelz and Snow, 1994; Cutler and Reber, 1998; Cawley and Philipson, 1999; Chiappori and Salanié, 2000; Cardon and Hendel, 2001; Finkelstein and Poterba, 2004; Einav *et al.*, 2010; Einav and Finkelstein, 2011; Handel, 2013; Hackmann *et al.*, 2015; Panhans, 2019; Finkelstein *et al.*, 2019). In these markets, sellers (insurance firms) have less information than buyers because they cannot fully observe buyers' riskiness. The quantitative evidence on adverse selection is mixed (Einav and Finkelstein, 2011), but welfare effects of adverse selection, when present, typically fall within a few percent of market value (Handel, 2013; Hackmann *et al.*, 2015). Closer to our setting, Jin and Leslie (2003) examine the effects of quality information provision on firms' choices of quality in the context of restaurant hygiene. Like us, they exploit a policy change that mitigated information asymmetry and find evidence of quality improvements, although they are unable to make welfare claims.[9]

segments, even if quality does not change. In that case, welfare gains are not precluded, but are limited to those associated with reallocation of products across consumers, reflecting improved matching. See Appendix A.2.

[8] Our main estimated effect is robust to the exclusion of years around World War II (WWII), when the French wine market is believed to have been disrupted, notably due to forced government procurement.

[9] More recently, Bai (2018) conducts an experiment in the retail market for watermelons in a Chinese city. Her

Our paper also relates to an empirical literature exploiting wine quality signals to analyze markets for quality-differentiated products (Ashenfelter, 2008; Ali *et al.*, 2008; Cross *et al.*, 2011; Crozet *et al.*, 2012). In related work, Gergaud and Ginsburgh (2008) study the effect of *terroir*, that is, natural endowments such as soils and climate, on the quality of wines produced in Haut-Médoc, and find virtually no effect. Their result does not contradict ours, as they compare wines *within* a given AOC, whereas our paper speaks to quality differences between AOC and non-AOC wines.[10]

Finally, we contribute to a broader literature on the impact of information disclosure on economic outcomes. A series of experimental studies have shown how improved access to and control of information can increase market efficiency by lowering search costs and limiting corruption (Jensen, 2007; Jensen and Miller, 2018; Andrabi *et al.*, 2017; Duflo *et al.*, 2013), or instead generate perverse selection effects (Dranove *et al.*, 2003). In their extensive literature review, Dranove and Jin (2010) note that although *there are many examples in which quality disclosure has allowed consumers to find sellers who best meet their needs [...] there is less evidence that sellers respond by boosting quality*. Our study contributes to filling this gap.

The rest of the paper is organized as follows. Section 2 provides some historical and institutional background. In Section 3, we develop a simple model of endogenous quality provision in a vertically differentiated market with asymmetric information. We use our conceptual framework to guide the interpretation of our empirical estimates. Section 4 describes how we collect and construct our data. In Section 5, we present our identification strategy, our empirical results, and a series of robustness checks. Section 6 concludes.

2. Historical and institutional background

Long before any regulation on wine appellations was adopted, the names of France's most renown vineyards (*vignobles*, meant here as potentially large sets of parcels) were commonly used as appellations to identify the wines produced therein. Free-riding and malpractice became widespread during the acute production shortage of the late 19th century.[11] This crisis generated strong incentives to increase production while lowering quality. Producers were often aided in this enterprise by the rapid progress of chemistry.[12] Malpractice was so prevalent that in 1889,

study focusses on product grading, so welfare gains arise from allocative improvements and incentives to screen product at wholesale, rather than from upstream quality changes like the ones documented here.

[10] In addition, *terroir* merely reflects exogenous determinants of quality, whereas AOC recognition depends on both natural factors and producers' behavior.

[11] In the 1860s, a pest imported from America called phylloxera started to ravage French vineyards, eventually causing production to be cut by half between 1875 and 1890.

[12] A common way to increase volume while maintaining the alcohol content of wine was to add sugar to the must and dilute wine with water. Another way was to fabricate wine from raisins. Various chemicals were used to speed up fermentation, add color, or control spoilage (Stanziani, 2003). In 1884, chemist Emile Viard published an award-winning "General Treaty on Wines and their Falsifications," whose objective was to "describe procedures for the certain identification of wine adulterations."

French authorities decided to pass a law defining wine as the exclusive produce of grape juice fermentation. During this episode, quality vineyards were especially harmed since the general trend was to produce lower quality wines at higher yields, and at the time there existed no legal definition of wine appellations (Stanziani, 2003). Unsurprisingly, counterfeiting was common, as famous names were often usurped by producers located in other wine regions or used without consideration for the production techniques and attendant wine characteristics that had brought reputation to the place (Jacquet, 2005).

In 1905, France adopted its first general law on the prevention of fraud and falsification. Although its scope was much broader than the protection of wine appellations, the law provided a mechanism by which the French administration would take on the task of delineating the geographical limits of each wine appellation.[13] Those boundaries were to be defined by administrative decrees. A few appellations were thus delimited, starting with the *champagne* appellation in 1908, followed by *banyuls*, *cognac*, and *armagnac*. The administration then delimited *clairette de Die* in 1910 and *bordeaux* in 1911 (Humbert, 2011). This top-down definition of appellation regions proved problematic to many stakeholders. It is often cited as a leading cause of the Champagne Riots of 1911, as producers in excluded regions felt they had been wrongly denied the appellation. Administrative delineations were also contested in the Bordeaux region.

In addition to generating political unrest, administrative delineations had a fundamental weakness: they established a legal right to utilize a place name based solely on broad delimitations at the level of the municipality, irrespective of the type of terrain, grape varietal, or production practices. Not surprisingly, unscrupulous producers located in eligible regions started to market mediocre wines under famous appellations. This situation raised concerns among higher-quality producers who were often supportive of precise eligibility criteria for appellation wines (Capus, 1947).

In an attempt to correct the failures of previous legislation, a 1919 law removed the authority to define appellation wines from the executive branch and gave it to the courts. Any stakeholder who thought they were being hurt by the abusive use of a place name could file a lawsuit. Courts were given the right to not only define geographical boundaries but also to take account of "local, loyal, and constant uses." However, most judges refrained from defining production practices, and in effect, for most appellations the court only specified geographical boundaries, just as the former administrative decrees.[14] As a result, in the early 1930s most appellations only had requirements pertaining to the eligible area. This period also saw a rise in the number of new appellations claimed by producers as a way to escape the stringent production controls applicable to ordinary wines starting in 1931 with the *Statut Viticole*. This situation led to what

[13] This task was defined in a 1908 amendment to the 1905 law.

[14] Another law passed in 1927 explicitly allowed courts to include a list of specific grape varieties as well as soil restrictions in the definition of an appellation, but these precisions were left optional, and very few judgements included restrictions on terrain or varietal (Ministère de l'agriculture, 1937; Capus, 1947).

is known as the "appellation scandal," that is, the proliferation of unwarranted appellations, which further eroded the reputation of historical appellations (Capus, 1947).

Our study investigates the economic consequences of a new law adopted in 1935, whose stated goal was to guarantee the quality of appellation wines by codifying eligible practices and implementing official quality control. The law introduces a new category of so-called "controlled origin appellations" (*appellations d'origine contrôlée*, or AOC), without – at first – eliminating existing appellations. These new appellations are to be defined by administrative decrees. But unlike the early administrative delimitations, the provisions of the AOC decree are not dictated by the administration. Instead, the decree sanctions a set of production requirements that emanate from a committee composed, by order of importance, of representatives of local wine associations and wholesalers, members of Parliament, and representatives of the administration – the CNAO, *Comité national des appellations d'origine*. As such, the definition of the requirements applicable to each AOC is left to a technical body of experts that includes representatives of each wine region.[15]

In contrast to pre-existing appellations, subsequently referred to as "plain appellations" (*appellations simples*), AOCs are subject to official control. Wines can claim an AOC if they are grown on an eligible parcel, according to the specified practices, and meet a set of criteria pertaining to, *e.g.*, alcohol content. The AOC is not compulsory in the sense that producers may elect to sell their wines as ordinary wines, or under a plain appellation if they can claim one based on location. Typical requirements for an AOC, beyond parcel and terrain eligibility, are the grape varietal, the specification of a maximum yield per hectare, and minimum levels for alcohol and sugar contents.[16] Importantly, a parcel may be eligible for several AOC designations. For instance, a parcel located on appropriate terrain in the municipality Pauillac would be eligible for the following appellations, ranked from the most common to the most exclusive: *bordeaux*, *bordeaux supérieur*, *médoc*, *haut-médoc*, and *pauillac*.

Soon after the 1935 law, many appellations were officially recognized by an AOC decree: 78 AOCs were created in 1936 and 69 others in 1937.[17] These new AOCs did not exactly replace the former appellations of the same names: both an AOC and a plain appellation could coexist under the same name in the same region. For instance, after the creation of the *bordeaux* AOC in 1936, Bordeaux wines that did not meet the strict requirements of the AOC could still be sold

[15]The CNAO was initially financed by a tax on the sales of AOC wines of 2 francs per hectoliter. Its agents were sent to delimit each AOC at the parcel level and to control production conditions.

[16]In the late 1920s, some appellation wines were produced at very high yields, between 120 and 200 hectoliters per hectare but with only 7% of alcohol content in volume (Capus, 1947). The minimum alcohol content for AOC wines was typically set to between 10% and 15%, and the maximum yield between 20 and 50 hectoliters per hectare. These figures are still current standards for AOC wines.

[17]We consider different denominations within the same AOC as different AOCs. For instance, the original denomination *pommard* created in 1936 and the more prestigious denomination *pommard premier cru* created in 1943 belong, strictly speaking, to the same appellation *pommard*. But since they have different production requirements, we count them as two distinct AOCs.

under the plain appellation. This coexistence of both plain and controlled appellations, known as the "double appellation regime," although arguably confusing, was necessary to garner political support for the new system as it allowed producers willing to claim an AOC to transition to the new requirements. However, this regime was soon to be abolished.

A first law passed in 1938 allowed the CNAO to forbid the use of a plain appellation at the request of the most representative local producer organization. This option was immediately adopted in many small, upper-quality regions, and by the end of 1939, wine producers in half of the AOCs had successfully obtained the elimination of plain appellations. However, large regional appellations like *bordeaux* and *bourgogne* survived the creation of their AOC counterpart as no consensus was found in their respective local unions in favor of abolition. This situation was put an end in 1942 when a new law granted the CNAO the right to unilaterally suppress a plain appellation wherever an AOC also existed under the same name. All remaining duplicate appellations were eliminated the following year. Thus, the only surviving plain appellations were those for which no AOC had been created.

The AOC label quickly became the standard for premium quality wines. By 1940, 177 different AOCs had been created and the production of AOC wines exceeded that of plain appellation wines (Humbert, 2011).[18] Nonetheless, the CNAO did reject several AOC requests, as some less-known vineyards were found too heterogeneous and therefore unfit to bear the AOC designation.[19] From the years following the 1935 law to the year 1969 that marks the end of our observation period, AOC wines represented on average between 10% and 15% of total French wine production.

3. A model of the wine market with endogenous quality

3.1. Market equilibrium

We model wine production at the level of a French department. We assume vineyard acreage is inelastic and that yields can vary over space but remain unaffected by the regulation. We later show that these assumptions are reasonable when evaluated against the data. Since there are no quantity effects, we can focus on the impact of regulation on wine quality.

For simplicity, we assume that there are two categories of wines, (i) ordinary wines grown in places where climate and soils can only allow the production of low-quality wine, and (ii) appellation wines grown in places endowed with beneficial natural factors, the effects of which may be further enhanced by appropriate production practices, such as varietal choice, winemaking

[18] As of today, more than 300 wine AOCs have been recognized in France. The concept of AOC has been extended in 1990 to all agricultural products such as cheese, fruits, or olive oil, and is now in use throughout the European Union.

[19] The examination of an application included a tasting session and an assessment of the reputation of the wines produced in the candidate region (Humbert, 2011).

techniques, *etc.* The second category of wine is distinguished from the first at wholesale and retail by the prominent use of the name of the place from which the wine originates – the appellation. In a department, there may be more than one appellation, but we assume that before the reform consumers' valuation of appellation wine is uniform across appellations. In contrast to appellation wines, ordinary wines are assumed to have a fixed quality that cannot be enhanced through costly practices.[20]

We further assume that there are many identical consumers, each with unit demand for wine, and that there are more consumers than units of wine produced.[21] Therefore, wines are sold at a price equal to their consumer valuation, and some consumers are not served. The consumer valuation of ordinary wines is denoted p_0, and that of appellation wines, when no costly production practices are used, is denoted p_1.

Note that before any regulation on production practices is enacted, a market equilibrium does not involve any costly production practices for appellation wines. The reason is that a single producer engaging in such practices would have an incentive to shirk since consumers cannot tell quality differences among appellation wines at the time of purchase, and there are many wines claiming the same appellation.[22] We assume that $p_1 \geq p_0$, that is, appellation wines cannot be of lower quality than ordinary wines.

We denote by s_1 the share of appellation wine produced and by $s_0 = 1 - s_1$ the share of ordinary wine produced in a department. Appellation and ordinary wines are sold at different prices, but in the data we only observe the average price of wine, $p_m \equiv p_0 s_0 + p_1 s_1 = p_0 + s_1(p_1 - p_0)$.

After the reform, the use of a place name is restricted, for wines bearing the AOC label, to wines produced according to certain quality-enhancing practices. For plain appellation wines no specific production techniques are mandated. The reform therefore generates a difference between two types of appellations, plain appellations and AOCs, that may sell at different prices.

The reform leaves consumers' valuations of ordinary wines and plain appellations unaffected. In contrast, wines sold under the AOC designation, which were previously sold as plain appellations, have a (weakly) higher valuation after the reform, say $p_2 \geq p_1$. Denote by s_2 the share of wine eligible for AOC after regulation. We assume $s_2 \leq s_1$, with the strict inequality corresponding to the case where not all wine previously sold under appellation can claim an

[20] Technically, we could allow for the possibility of quality enhancement, but the free-rider problem would prevent any producer from profitably pursuing it.

[21] This assumption may seem at odds with the observation that in some years, there may exist production surpluses, leading to very low wine prices. Our model is to be understood as a static representation of a multi-year market equilibrium where production is inelastic and weather shocks average out.

[22] One implicit assumption is that individual producers of appellation wines cannot reliably signal quality to consumers, perhaps because of the very large number of producers in a given appellation region, which makes it very difficult for a single producer to create a reputation beyond the collective reputation of the appellation.

AOC.[23]

After regulation, we can thus write the average price of wine in a department as:

$$\begin{aligned} p_m &= (1-s_1)p_0 + (s_1-s_2)p_1 + s_2 p_2 \\ &= \underbrace{p_0 + s_1(p_1-p_0)}_{(A)} + \underbrace{s_2(p_2-p_1)}_{(B)}. \end{aligned} \tag{1}$$

The terms (A) in Equation (1) depend only on a department's appellation share and exogenous characteristics, but not on regulation, while term (B) depends on the extent of regulation. The effect of the reform on the department's wine price is $\Delta p_m \equiv s_2(p_2 - p_1)$.

Fundamentally, we are interested in an empirical measure of the value $p_2 - p_1$, which captures consumers' valuation of the quality of an appellation wine that fails to be supplied under asymmetric information. If there is no lemons effect, *i.e.* quality does not improve after the reform, then $p_2 = p_1$. In addition, the product of the price increase $p_2 - p_1$ by the quantity of AOC wine directly translates into a partial (or gross) welfare increase:

$$\Delta \text{GW} = Q s_2 (p_2 - p_1) \tag{2}$$

where Q denotes total wine output. Note that in our model with perfectly elastic demand for wines of a given quality and perfectly inelastic supply, all welfare accrues to producers. However, our measure of welfare improvement is partial because it does not account for the cost of quality-enhancing practices adopted on the share s_2 of production.

Figure 1 depicts the gross and net welfare losses from asymmetric information, in the case where $s_2 = \frac{s_1}{2}$, that is, only half of appellation wine production is deemed worthy of an AOC. Total wine output is normalized to one. Since the price of ordinary wines does not change with regulation, only the market for appellation wine is depicted. The average cost of supplying appellation wine is assumed to be constant and equal to r_1 while that of supplying AOC wine is assumed to be constant and equal to $r_2 > r_1$. The net welfare loss from asymmetric information, which is resolved by regulation, is the difference between the area shaded in medium gray (which represents the gains from trading regulated wine under full information) and the area shaded in dark gray (the gains from trading this wine under asymmetric information). The gross welfare loss only relates to differences in consumer valuations (or market prices) and is given by the sum of the areas shaded in medium and light gray.

[23] We could further differentiate the valuations of plain appellations and AOC wines before the reform, based on the idea that wines declared eligible for an AOC likely benefit from different natural factors than those only worthy of a plain appellation. This refinement would complicate the model without adding anything to our argument or the interpretation of our regression coefficients.

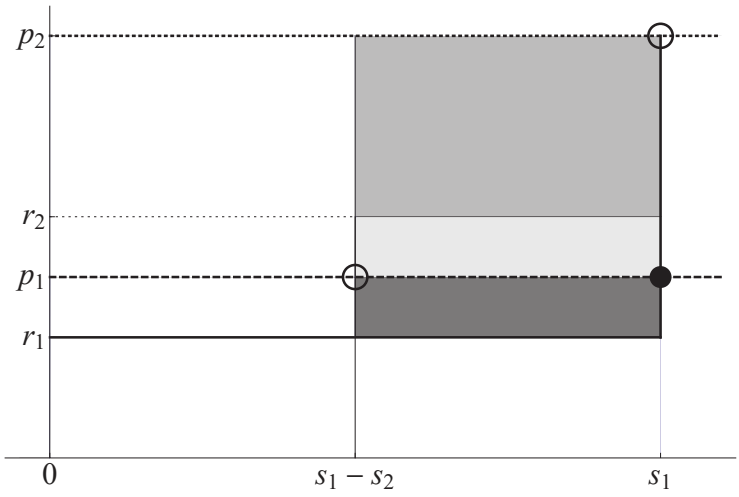


Figure 1: Welfare effects of asymmetric information in the appellation wine market

Notes: Only the appellation wine market is represented. Before the reform, the lemons effect leads to the equilibrium represented by the black disk. After the reform, half of the appellation market is eligible for AOC. The cost structure (r_1, r_2) and the valuation structure (p_1, p_2) imply a market equilibrium (hollow disks) whereby AOC wines sell at price p_2 and non-AOC appellation wines sell at price p_1.

Importantly, Equation (2) can also be used to derive the relative change in gross welfare

$$\frac{\Delta \text{GW}}{\text{GW}} = \frac{Q s_2 (p_2 - p_1)}{Q\left[(1 - s_1)p_0 + s_1 p_1\right]} = \frac{\Delta p_m}{p_m} \approx \Delta \log p_m \tag{3}$$

where $\Delta \log p_m$ represents the change in the department's log average price attributable to regulation.

3.2. Implications for the empirical analysis

Regressing $\log p_m$ on the share s_2 of a department's wine production eligible for a controlled appellation (with appropriate covariates to control for confounding factors) yields the partial derivative $\frac{\partial \log p_m}{\partial s_2}$, which multiplied by the ultimate share of production eligible after the reform becomes a predictor of $\Delta \log p_m$ and thus of $\frac{\Delta \text{GW}}{\text{GW}}$. We can further interpret the coefficient on s_2, say β, as the price premium relative to the average price of wine. This is because $\log p_m = \log\left(p_0 + s_1(p_1 - p_0) + s_2(p_2 - p_1)\right)$, and thus $\beta \equiv \frac{\partial \log p_m}{\partial s_2} = \frac{p_2 - p_1}{p_m}$. Given Equation (3), the coefficient β itself has a clear welfare interpretation: it is the relative rate of increase in gross welfare with respect to the share of wine production eligible for quality certification. Section 5 presents our strategy to obtain an unbiased estimate of β.

Before moving on to estimation, we wish to make three remarks. First, not all wines eligible for AOC recognition are marketed as AOC wines. In particular, some producers eligible based on vineyard location may supply baseline quality valued at price p_1 because the associated costs make AOC production unprofitable for them. The coefficient β should then be interpreted as the average valuation difference for eligible wines (accounting for the fact that some of them

remain plain appellations), *i.e.* an intention-to-treat effect. Formally, denote by $0 \leq \kappa \leq 1$ the share of eligible wine actually sold under AOC. Then, $p_m = (1-s_1)p_0+(s_1-s_2\kappa)p_1+s_2\kappa p_2 = p_0 + s_1(p_1-p_0)+s_2\kappa(p_2-p_1)$, $\Delta p_m = s_2\kappa(p_2-p_1)$, and $\Delta\text{GW} = Qs_2\kappa(p_2-p_1)$. Therefore, the coefficient on the eligible share, β, can still be used for welfare inference.[24]

Second, the derivation of ΔGW in Equation (2) assumed that all consumers have identical tastes. In the Appendix, we formally derive the expected welfare effects from wine regulation in a model where consumers have different tastes for quality. Importantly, we show that the gross welfare measure ΔGW derived above constitutes a lower bound to the gross welfare change when consumers are heterogenous in their valuation of quality. The intuition is that the valuation of the marginal consumer of AOC wine is lower than that of inframarginal consumers, and prices reflect marginal valuations.

Third, although the model in Equation (1) uses the share of wine *production* eligible for AOC (s_2) as a determinant of the average price of wine p_m, in our empirical implementation we use the share of *acreage* in vineyards eligible for AOC rather than a volume share. To the extent that yields are not affected by the reform,[25] using the acreage share in place of s_2 affects the structural interpretation of our regression coefficient if yields differ for ordinary and appellation wines. Let σ_1 denote the share of vineyard acreage initially under appellation, σ_2 the share of vineyard acreage eligible for AOC, y_0 the yield of ordinary wine, and y_1 the yield of appellation wines (assumed to be unaffected by the reform). Then, the change in the average wine price can be written as $\Delta p_m = s_2(p_2-p_1) = \sigma_2\frac{(p_2-p_1)y_1}{(1-\sigma_1)y_0+\sigma_1 y_1}$. To the extent that $y_1 \leq y_0$, the multiplier on the acreage share is therefore interpretable as the valuation increase modulated by the ratio of the appellation yield to the average yield. In the context of a regression of $\log p_m$ on σ_2, the coefficient of interest is interpretable as the relative rate of increase in gross welfare with respect to the share of vineyard acreage eligible for AOC.

4. Data

Our dataset combines several sources. We obtain departmental average wine prices, areas in vineyards, and wine production from France's *Statistique agricole annuelle*, a yearly publication of the Ministry of Agriculture only available in print for the historical period. We focus on the period 1907-1969. This window excludes the period, starting in the 1860s, when France's vineyards were destroyed by phylloxera, a pest that affects native European vines. It further excludes an ensuing period of generalized fraud through wine adulteration, which ended with

[24] If, in addition, a share $1-\kappa$ of wines eligible for AOC recognition end up being sold as ordinary wines rather than plain appellations (perhaps because there is no plain appellation after the reform), the average valuation for ordinary wine will increase to $\bar{p}_0 = \frac{(1-s_1)p_0+s_2(1-\kappa)p_1}{1-s_1+s_2(1-\kappa)}$, so that the average wine price will still be $p_m = (1-s_1)p_0 + s_2(1-\kappa)p_1 + (s_1-s_2)p_1 + s_2\kappa p_2 = p_0 + s_1(p_1-p_0) + s_2\kappa(p_2-p_1)$. This case is functionally similar to the previous one.

[25] We provide empirical evidence in support of this fact in section 5.3.3.

the adoption of the 1905 Law against fraud and falsification and the creation of the fraud repression service in 1907. We end our analysis in 1969, one year before the adoption of the first European regulation pertaining to the common organisation of the market in wine (Council of the European Communities, 1970).

We construct the time-varying share of vineyards eligible for AOC status in a department from several sources. The first one is the set of governmental decrees defining each AOC pursuant to the 1935 law that were in force during the sample period. These decrees provide information on the administrative area eligible for an appellation, typically by stating which municipalities (*communes*) are eligible for a given appellation (this area may cross departmental boundaries).

Historical records of which parcels within an eligible *commune* are eligible for an AOC are kept in the cadastral archives of each of France's 35,000 municipalities. Reconstructing the precise historical record of eligible parcels would require visiting each municipality, which is prohibitive. Instead, we make use of a recent effort by France's *Institut national de l'origine et de la qualité* (INAO) to map out eligible parcels. In April 2019, INAO released a series of shape files indicating the current geographical delimitations of most of France's current AOCs. Notable exceptions include *champagne* and *vins doux naturels*. For certain AOCs, only a share of the set of eligible municipalities is covered by the file.[26] Here, we only consider AOCs that existed during our sample period, that is, we exclude the AOCs defined after 1970. For AOCs that existed during our sample period but are not part of the INAO file, we select the entire surface of the municipalities listed in the historical decrees of AOC recognition as the eligible area.

Several AOC delimitations have changed since their first definition, with modifying decrees either excluding or adding municipalities. We account for such changes by only considering areas located in municipalities eligible for AOC wine production at any given point in time.[27] If a municipality eligible for an AOC in a given year does not have any eligible area in the 2019 INAO file, either because it is not eligible as of 2019 or because the INAO file is incomplete, we consider the entire area covered by the municipality.[28]

Finally, because eligible areas often include land not actually in vineyards (for instance, they may include hedgerows or access roads, or, in the cases specified above, the entire municipality), we intersect these delimitations with a land use raster file that shows pixels planted in vineyards in the years 1990, 2000, 2006, 2012, or 2018. The land use information comes from satellite imagery and these are the only years for which it is available. We intersect the two files by first

[26] Direct discussions with INAO representatives did not reveal the date when the complete set of AOCs will be made available by INAO.

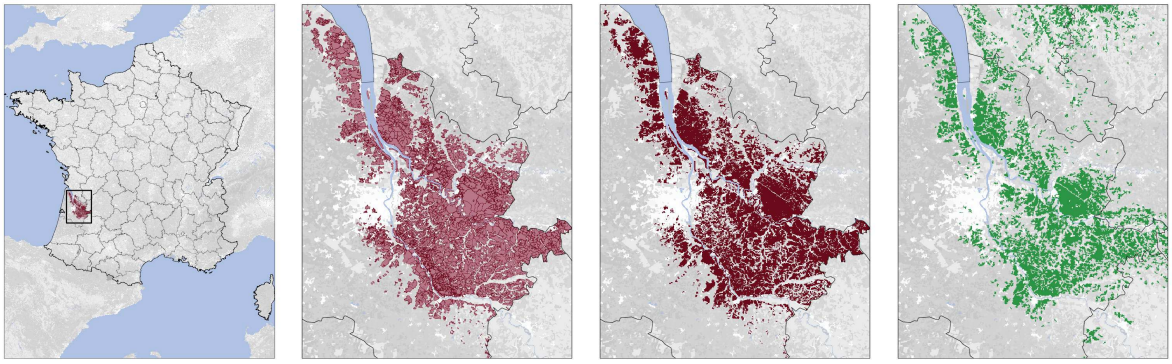
[27] We thank Florian Humbert (University of Burgundy) for sharing data on changes in eligible municipalities.

[28] We do not proceed with this adjustment for the regional appellations *bourgogne*, *bourgogne-aligoté*, *bourgogne-passe-tout-grains*, and *alsace* as their AOC decrees do not provide a precise list of eligible municipalities. Instead, we rely entirely on the INAO map of eligible areas.

rasterizing the INAO shape file and then overlaying it with the land use file. Each pixel covers 1 ha of land.

Figure 2 depicts the selection of the eligible area for the AOC *bordeaux*, entirely located within the Gironde department. Panel (b) depicts the polygon file from INAO, showing the contours of the eligible area. Panel (c) shows the pixelation of the eligible area, and panel (c) shows the pixels planted in vineyards from the land use dataset. The intersection of the areas selected in panels (c) and (d) represents our measure of the eligible vineyard area.

To construct the share of vineyards eligible for AOC recognition at the level of a department, our unit of analysis, we divide the area eligible for at least one AOC (while being grown in vineyards) in the department by the maximum of the area planted in vineyards during the period 1907–1969, which comes directly from the historical record in the *Statistique agricole annuelle*. This calculated share represents our best estimate of the historical share of eligible vineyards. For each AOC, we use the year following the year of enactment of the decree as the starting date for counting AOC eligibility.



(a) Location in France (b) Eligibility: polygons (c) Eligibility: pixels (d) Vineyards: pixels

Figure 2: The area eligible for the *bordeaux* AOC

Note: Department boundaries are shown as they were during the period of investigation.

Formally, denote by i a department, by m a municipality, by t a year, by l an AOC, and by p a one-hectare pixel. Let us further denote:

$$\mathbb{1}^l_{mt} = \begin{cases} 1 & \text{if municipality } m \text{ is eligible for AOC } l \text{ per regulation in force} \\ & \quad \text{in year } t \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{1}^l_{p} = \begin{cases} 1 & \text{if AOC } l \text{ is not covered by the 2019 INAO map} \\ & \text{or if pixel } p \text{ belongs to AOC } l \text{ per the 2019 INAO map} \\ & \text{or if pixel } p \text{ belongs to a municipality } m \text{ not eligible for AOC } l \\ & \quad \text{per the 2019 INAO map} \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{1}_{p} = \begin{cases} 1 & \text{if pixel } p \text{ was grown in vineyards in 1990, 2000, 2006, 2012, or 2018} \\ 0 & \text{otherwise} \end{cases}$$

Given that we start counting recognition in the year following an AOC decree, the indicator $\mathbb{1}^l_{mt}$ equals zero from 1907 until the year in which a decree for AOC l is enacted that includes municipality m as eligible, and one thereafter. If m is excluded from that AOC by a modifying decree enacted during the sample period, the change is assumed to take place the year following the publication of the modifying decree.

Denoting by $m(p)$ the municipality to which belongs pixel p, we also define $N_{pt} = \sum_l \mathbb{1}^l_{m(p)t}\mathbb{1}^l_p\mathbb{1}_p$ as the number of distinct AOCs for which pixel p was eligible in year t.[29] Denoting by Σ_{is} the area in vineyards (under production or not) in department i in year s and by $P(i)$ the set of pixels in department i, we construct our main regressor as

$$s^k_{it} \equiv \frac{\sum_{p \in P(i)} \mathbb{1}_{N_{pt} \geq k}}{\max_s \Sigma_{is}}$$

which indicates the share of department i's vineyards eligible for k or more AOCs as of year t. Our main set of regressions only use s^1_{it}, the share of vineyards eligible for at least one AOC, but in Appendix C we also consider s^3_{it} and s^5_{it} in order to investigate whether prices are influenced by the number of AOCs that an area can claim. For five departments largely covered by broad regional AOCs, our proxy of the acreage eligible for at least one AOC eventually becomes greater than the maximum area in vineyards over the sample period.[30] In these cases, we set the share of eligible acreage equal to one.

[29] In doing so, we do not double-count AOCs recognizing different colors of wine. For instance, if a parcel is eligible for producing both red and white AOC wine, we only count one AOC, the idea being that a given wine can only be sold under one color. As a result, the multiplicity of AOCs for a given parcel arises solely from the hierarchical structure of the AOC system.

[30] These departments are Aisne, Aube, Charente, Gironde, and Marne.

Table 1: Summary statistics

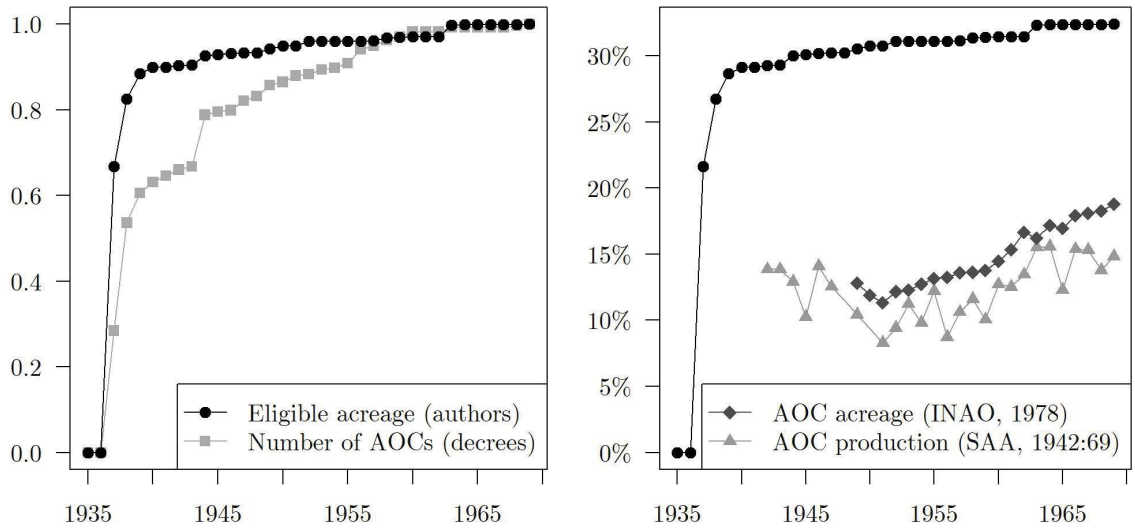
Variable (unit)	Mean	Median	Std. dev.	Min.	Max
Price (1969 Franc per hectoliter)	108.9	92.5	87.1	8.4	1,784.8
Production (million liters)	70.6	20.4	156.7	0.0	1,538.3
Acreage (thousands hectares)	18.4	7.6	30.3	0.0	199.0
Yield (hectoliters per hectare)	29.2	27.0	14.8	0.5	258.0
Share of acreage eligible for at least one AOC	0.067	0.000	0.202	0.000	1.000

Lastly, we verify that our proxy is consistent with the AOC production data reported in the *Statistique agricole annuelle* from 1942 onwards. For three departments, we find the share of eligible acreage to be unreasonably small relative to the share of AOC production. We correct these shares using ancillary data on current AOC acreage reported in the 2010 edition of the French wine guide *Guide Hachette*.[31] Conversely, four departments with a nonzero eligible acreage yet report zero AOC wine production. We can rationalize these discrepancies, however. Three of them are only eligible for the brandy AOCs *cognac* and *armagnac*, for which the corresponding wine production is not reported as AOC (perhaps because the AOC is granted to the final liqueur but not to the wine itself). The fourth one is Haute-Marne, where only two municipalities are eligible for the AOC *champagne*. The AOC production in this department was thus either very small and neglected in the reports or reported in an adjacent department.

Table 1 shows summary statistics for a set of variables relevant to our analysis, including the eligible vineyard shares s^1_{it}, s^3_{it}, and s^5_{it}. Figure 3 depicts the temporal rollout of AOC recognitions and, whenever available, the national vineyard area under AOC and the national AOC wine production.[32]

[31] Our algorithm yields an eligible acreage share equal to zero in Ain and Haute-Savoie, although both departments report a small AOC production. This is because the AOC *seyssel*, which has eligible parcels in these departments, has no pixel planted in vineyards in the land use data. For Pyrénées-Atlantiques, our algorithm attributes a share of eligible acreage more than three times smaller than the share of AOC production. One possibility is that AOC yields are three times larger than non-AOC yields in that department (and even more if not all eligible producers comply), which is doubtful. A more likely explanation is that the AOC *jurançon* has too few planted pixels in the land cover data (only 1% of the eligible pixels are reported as planted in vines). Since *seyssel* and *jurançon* are still produced in non-negligible volumes today, the satellite imagery clearly fails to identify all pixels in vines in the regions covered by these appellations, perhaps due to their relatively high altitude and the declivity of the terrain. Hence, we use the average cultivated acreage reported in the wine guide, which leads to shares of eligible acreage (respectively 0.3, 1.1 and 9.3% for Ain, Haute-Savoie, and Pyrénées-Atlantiques) that are in line with the average shares of AOC production (respectively 0.3%, 3.8%, and 6.0%) over the available years. An alternative correction strategy is to consider all eligible pixels in the INAO maps as being planted, which leads to qualitatively identical regression estimates. Our results also hold when using the data without any correction and when excluding these three departments. Finally, Isère, a department located in the Alps, reports an infinitesimal AOC wine production, however we failed to find any official AOC in use in this department. Our results are robust to the exclusion of that department.

[32] The vineyard area under AOC was obtained from estimates reported in INAO (1978) and corresponds to vineyards producing AOC wine.



(a) Cumulative distribution (b) Share in France total

Figure 3: Temporal rollout of AOC recognitions and AOC production

Notes: The count of decrees represented in this figure includes the 34 Burgundy *premiers crus* created in 1943 but excludes the 577 *climats* relative to these *premiers crus*. Similarly, it excludes the 64 municipality names which can be attached to the AOCs *beaujolais* and *mâcon*. All these appellations are duly accounted for in the econometric analysis as additional layers.

5. Analysis

We begin with a discussion of our strategy to identify the effect of the reform on wine prices and assess its statistical significance. We then present our empirical results, including the effect on the average wine price, its interpretability in terms of quality improvements, and an estimate of the AOC price premium.

5.1. Identification strategy

We exploit two sources of variation to identify the effects of the reform on the average wine price: variation in the exposure of a department to the reform (through its eligible share of vineyards) and variation in the timing of the decrees taken in application of the 1935 law. Most decrees were enacted during the years 1936 and 1937, although several were adopted later, notably those pertaining to the Alsace region in 1962. Importantly, the reform affected wine-producing departments unevenly: many had no AOC area, some had complete AOC eligibility, and many had only a share of their vineyards recognized as eligible. This cross-sectional variation provides both an extensive and an intensive margin of treatment that allows us to control for common shocks to departmental wine prices through year fixed effects.

One concern when assessing the effect of a program or rule on outcomes is that implementation is not exogenous, *i.e.* rules happen to be implemented concurrently with other factors affecting the outcome. For instance, if appellation decrees happen to be in force at the same time

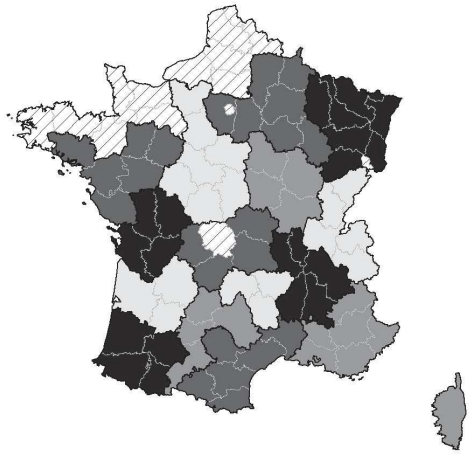


Figure 4: Definition of *vignobles*

Notes: Delineations in light gray represent departments. Delineations in black represent *vignobles*. Hatched departments are excluded from the analysis because they produced little to no wine during the period.

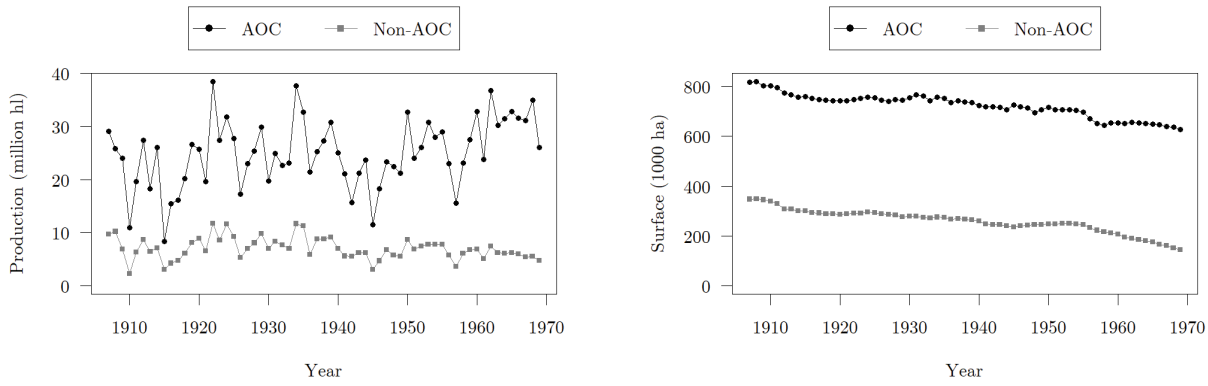
that demand factors, say expanding export markets, are affecting wine prices, then the effect of foreign demand might be mistakenly attributed to regulation if it happens to affect treated and untreated departments differently. Our strategy to control for such potentially confounding factors is to further differentiate the year fixed effects by *vignoble*, that is, the broad geographical area that defines wines, such as "Loire" or "Midi." To define these *vignobles*, we largely follow the classification adopted by INAO, making sure that each *vignoble* is large enough to include at least a couple of departments, our cross-sectional units of analysis. Our dataset includes 16 *vignobles* and 76 departments, depicted in Figure 4.

Formally, our preferred specification can be spelled out as follows:

$$\log p_{it} = \alpha_i + \gamma_{vt} + \boldsymbol{\beta}' \mathbf{s}_{it} + \boldsymbol{\delta}' \mathbf{x}_{it} + \epsilon_{it} \tag{4}$$

where i denotes a department, t denotes a year, v denotes the unique *vignoble* to which department i belongs, p_{it} is the average price of wine in department i in year t, α_i is a department fixed effect, γ_{vt} is a *vignoble*-by-year fixed effect, $\mathbf{x}_{it}$ is a vector of quantity controls, and $\mathbf{s}_{it}$ is a vector of treatment variables capturing the extent of AOC recognition in department i in year t. For instance, the vector $\mathbf{s}_{it}$ may include the share of a department's vineyard acreage eligible in year t for one or more and three or more AOCs. The vector $\boldsymbol{\beta}$ captures the effects of interest.

We include controls for quantity produced, either in year t or in year $t-1$, because wine production is highly dependent on weather. Indeed, departmental output displays wide fluctuations from year to year (see Figure 5). These fluctuations are not due to planting decisions, as vineyard acreage has moved smoothly over time, but rather to yield effects channeled through weather shocks. Conditional on *vignoble*-by-year fixed effects, output variations can therefore be considered exogenous to price, and we thus interpret Equation (4) as an (inverse) demand



(a) Wine output

(b) Productive acreage

Figure 5: Wine output and productive acreage in AOC and non-AOC departments

Notes: Areas exclude departments with missing data. AOC departments (23) have a 1969 share of vineyards eligible for AOC larger than 20%. Non-AOC departments (32) have a 1969 share of vineyards eligible for AOC smaller than 2.5%. Departments with an intermediate share (11) not represented.

equation.[33] The coefficient δ represents the (derived) demand flexibility for wine at the departmental level. The coefficient β represents the shift in marginal willingness to pay for wine, conditional on output. Note that removing quantity controls from the regression will not qualitatively change our estimate of β.

Our identifying assumption is that within a *vignoble*, treated and untreated departments would have followed parallel price movements after the AOC reform if not for the reform itself. Given the limited geographical span of our *vignobles*, we find it unlikely that remaining unobservables correlated with the AOC share within a *vignoble*-year could confound the effect of regulation. Controlling for *vignoble*-by-year fixed effects means that our identification relies on differences, within a *vignoble*, in the share of vineyards eligible for an AOC in a given year following the reform. Such differences arise from different shares of a department's vineyard area being eligible for a given appellation and, to a lesser extent, from different dates of adoption of decrees for different appellations. For instance, if two departments in the same *vignoble* are only eligible for one and the same appellation, they will nonetheless participate in identification as long as they have different shares of vineyards eligible for that appellation. Conversely, if two departments in the same *vignoble* have the same share eligible, but this share relates to two distinct appellations with decrees taken at different dates, they will participate in identification as well. Assuming that decree adoption does cause an increase in wine prices, we expect departments within a *vignoble* with larger shares of vineyards eligible to have higher price increments upon AOC recognition; we also expect eligible departments within a *vignoble* to experience price increases sooner if their decrees are enacted sooner. Violation of our identification assumption would require the existence of unobservable factors systematically correlated with AOC status

[33] Milhau (1948, 1949) uses a similar argument and a similar regression to identify the demand for wine during the period 1919–1933 at the national level, treating aggregate realized output as exogenous to price.

within a vignoble in the many years we observe following the reform. In support of our identification assumption, we use 30 years of pre-reform data to rule out such systematic differences across departments with differing eventual AOC status.

5.2. Inference

Our specification includes *vignoble*-by-year fixed effects. These fixed effects flexibility control for annual shocks common to departments located in the same *vignoble*, notably those due to weather shocks that could affect quality independently of quantity (which is explicitly controlled for). On average, there are fewer than five departments in each *vignoble*. Our preferred standard errors assume that, conditional on these geographically differentiated yearly shocks and other included regressors, there is no residual correlation in errors across departments. Nonetheless, we allow for serial correlation across years within a department through the use of department-level clusters. We believe that this is important because we observe outcomes in many years, and treatment is correlated across years before and after the reform. We view department-clustered standard errors as conservative enough, particularly given the small number of departments within each *vignoble*.[34] Further, because we sample all departments in all *vignobles*, there is no sampling design justification for clustering at the *vignoble* level (there are no relevant *vignobles* absent from our data set that we wish to draw inference about). Instead, we view our sampling as occurring in the time dimension, in which case department-level clusters should be appropriate (Abadie *et al.*, 2017).

For comparison purposes, we also report two other types of standard errors: (i) standard errors computed using the method of Conley (1999) adapted for panel data,[35] and (ii) standard errors clustered at the level of a *vignoble*. Unlike the department- and *vignoble*-clustered standard errors, Conley errors do not account for serial correlation of the error term.

5.3. Results

Before discussing our main results and considering competing explanations for the observed price effect, we present suggestive evidence that AOC recognition positively affected the trajectory of wine prices at the department level. A detailed heterogeneity analysis is provided in Appendix C.

[34] As a point of comparison, Jensen and Miller (2008) report standard errors clustered at the level of the treatment unit (a household) in a panel regression that includes county-by-year fixed effects, even though the number of households per county in their study is 100–150.

[35] The Conley errors are to spatial data what Newey-West errors are to time-series data. We apply the Newey-West weighting scheme to neighboring relationships when calculating our standard errors.

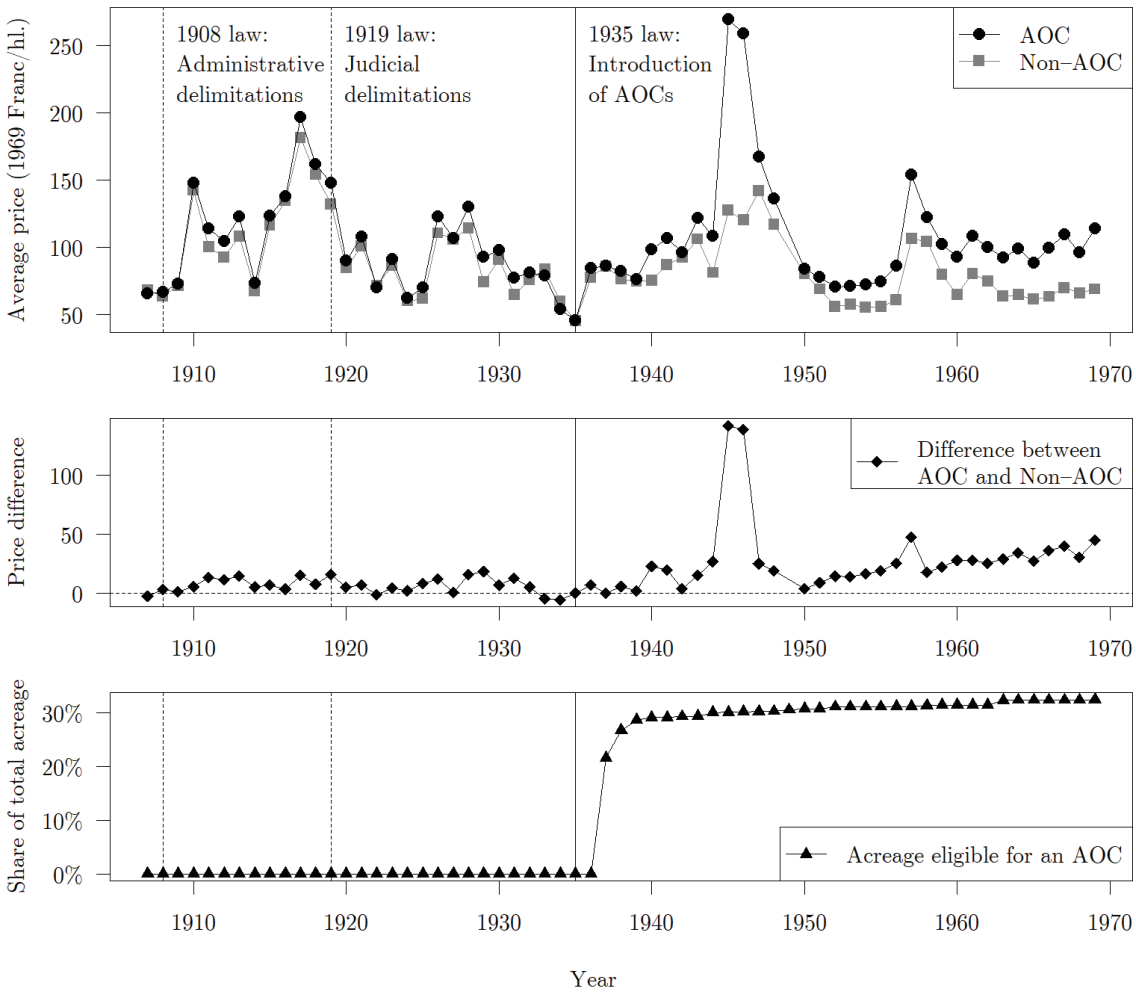


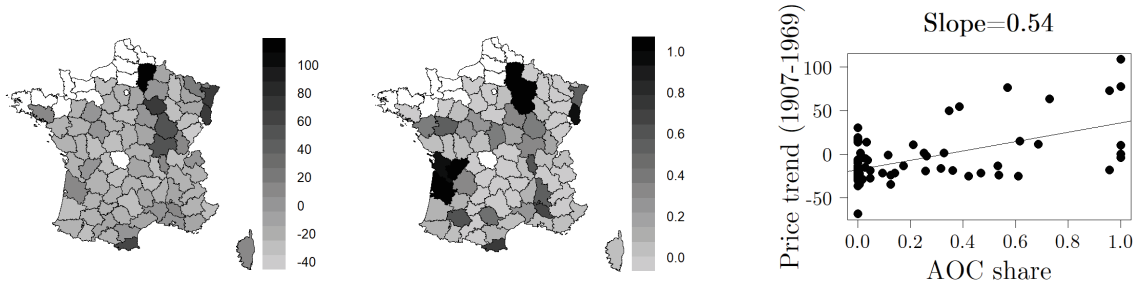
Figure 6: Average real wine prices in AOC and non-AOC departments

Notes: Average real wine prices are calculated using production weights and conditioning on departments without missing data. Prices deflated by CPI. Production weights are constant over time and calculated as the average departmental wine production over the pre-reform period from 1907 to 1936. AOC departments (23) have a 1969 share of vineyards eligible for AOC larger than 20%. Non-AOC departments (29) have a 1969 share of vineyards eligible for AOC smaller than 2.5%. Departments with an intermediate share (11) not represented.

5.3.1. Suggestive evidence

The top panel of Figure 6 plots a time-series of average real wine prices across two categories of departments: those with high eventual AOC share (with an eligible share of AOC vineyards larger than 20% by 1969) and those with low eventual AOC share (with an eligible share lower than 2.5%). A few departments with intermediate share are not represented. The middle panel of the figure plots the evolution of the difference between the two averages, and the bottom panel shows the evolution of the share of acreage eligible to an AOC.

Figure 6 shows that the two categories of departments had very similar prices before the AOC reform, even after the appellation laws of 1908 and 1919 were passed. The two price series only start to diverge after the AOC reform, with higher values in departments with high eventual AOC



(a) Price trend (b) AOC share (c) Correlation

Figure 7: Trends in departmental real wine prices over the period 1907-1969

Notes: Price trends are computed using changes in 25-year averages from the endpoints of the period and are expressed in relative terms. The share of vineyards eligible for AOC is calculated as of 1969. White departments: no data available.

share, particularly in the immediate aftermath of WWII.[36] As depicted in the bottom panel, the implementation of the 1935 law only started with the first set of AOC decrees published in 1936, which we consider affected the eligible acreage, in practice, one year later.

The figure provides visual support for the "parallel trends" assumption implicit in difference-in-differences designs.[37] What the figure does not capture, but our main regression will, is any differential price trends *within* the two broad categories defined here according to the AOC eligible share and the behavior of prices in departments with intermediate share (that is, the intensive margin of treatment along the AOC share dimension), as well as the fact that recognition did not happen simultaneously in all treated departments (the intensive margin of treatment along the time dimension).

Figure 7 depicts trends in real wine prices over the period 1907 to 1969 at the departmental level, using changes in 25-year averages from the endpoints of the period to compute the relative increase in price. It also depicts the share of vineyards eligible for AOC recognition by department as of 1969. Qualitatively, Figure 7 tells a similar story as the previous figure: price trends over the period 1907-1969 appear to be stronger in departments with higher AOC shares.

One may be worried that departments with eventually high shares of AOC recognition may have been on a steeper price trend for reasons unrelated to regulation. For instance, one could perhaps imagine that producers in departments with steeper price trends lobbied harder for AOC recognition. To investigate this possibility, we compare two simple price trend regressions based on different subsamples of years: 1907–1936 (pre-reform) and 1927–1956 (pre-post-reform), where price trends are computed using 10-year averages from the endpoints of each period and

[36] In a robustness check, we show that our estimates are not driven by data from that period. See Table 9.

[37] Average prices in the departments with intermediate eventual AOC share do not contradict this story: prices in those departments were consistently below those in non-AOC departments before the reform, and caught up after it.

Table 2: Trends regressions

	Price trend				Output trend	
	1927–1956		1907–1936		1927–1956	
	(1)	(2)	(3)	(4)	(5)	(6)
AOC share	74.16	71.96	-6.93	-3.92	5.79	-13.25
	(27.07)	(26.28)	(6.56)	(6.93)	(11.68)	(22.86)
Vignoble FE		✓		✓		✓
Observations	72	72	72	72	72	72

Notes: The sample is limited to departments with enough information to compute price and output trends over the two periods 1907–1936 and 1927–1956. Heteroskedasticity-robust standard errors are reported in brackets. The *vignoble* control includes 16 different wine regions.

are expressed in relative terms. The results are reported in Table 2. Column (1) of the table reports the coefficient on the AOC eligible share (by 1956) from a regression of the price trend calculated over the period 1927–1956. Column (2) controls for *vignoble* to purge the regression of effects common to all departments located in the same wine region. In both columns, the coefficient on the AOC share is highly significant, suggesting that AOC eligibility had a positive effect on price trends, even after controlling for *vignoble* effects. In contrast, columns (3) and (4) show that if we focus on price trends during the pre-reform period, the AOC share does not have any explanatory power, that is, eventual AOC eligibility (as of 1956) is irrelevant to explaining price trends prior to regulation. Finally, columns (5) and (6) show that AOC eligibility also had no clear effect on wine output, suggesting that the effects of regulation on price trends were not the result of a reduction in volumes.

5.3.2. Panel analysis

The results from the estimation of Equation (4) appear in Table 3 and Appendix Tables B.1 and B.2. Each table uses a different window of time to identify the effects of AOC recognition, from the widest (1907–1969, the entire data set) to the narrowest (1921–1950). We show results with different sets of controls. Every regression includes department and year fixed effects. Except for column (6), all columns control for production in some way. For a given time window, estimates of the effect of the AOC eligibility share are quite similar across specifications, even when omitting production controls.

We do not necessarily expect coefficient estimates to be stable across time windows. One basic reason is that as periods change, so does the set of appellations that are recognized in the sample. For instance, appellations in the Alsace region were recognized relatively late, in 1962. Because AOC recognition may cause different price increases in different regions, our coefficient estimate, which captures an average effect, may vary according to the period used. In

Table 3: Effect of the AOC eligible share on the real price of wine, 1907–1969

	Dependent variable: log average real price of wine					
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share	0.395	0.427	0.417	0.424	0.413	0.409
	(0.043)	(0.044)	(0.044)	(0.045)	(0.045)	(0.044)
	[0.088]	[0.083]	[0.083]	[0.084]	[0.083]	[0.085]
	{0.109}	{0.130}	{0.133}	{0.134}	{0.136}	{0.136}
log(Production)	-0.041	-0.042				
	(0.011)	(0.012)				
	[0.012]	[0.015]				
	{0.013}	{0.018}				
log(Production$_{-1}$)			-0.024			
			(0.011)			
			[0.016]			
			{0.015}			
log(Production)×*vignoble*				✓		
log(Production$_{-1}$)×*vignoble*					✓	
Year×*Vignoble* FE		✓	✓	✓	✓	✓
Observations	4,572	4,572	4,483	4,572	4,483	4,572

Notes: All regressions include year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

addition, it may take time for reputations to build. Despite these considerations, our results show a statistically significant and economically meaningful effect of AOC recognition on the average wine price in all periods, even after conditioning on quantity produced. In the largest sample, the regression with the richest set of controls implies a 42% increase in the average departmental wine price associated with full AOC eligibility (column (4) of Table 3, using contemporaneous rather than lagged quantity). The estimate is statistically significant in all cases, except when simultaneously considering the most conservative standard errors (clustered at the *vignoble* level), the narrowest time period (1921–1950), and the most flexible specifications (with *vignoble*-by-year fixed effects and production effects differentiated by *vignoble*).

Our identifying assumption is that conditional on *vignoble*-by-year effects and quantity, there are no unobserved determinants of price correlated with the AOC eligible share. One could be concerned however that departments eligible for AOC recognition were on a different price trajectory than control departments. That is, although our *vignoble*-by-year fixed effects control for trends common to all departments within a *vignoble*, unobserved factors that would have systematically propped up prices in treated departments after the reform could be confounding the effect of regulation. For instance, an increasing taste of foreign markets for *bordeaux* wine

Table 4: Effect of the later AOC eligible share on the real price of wine, pre-treatment periods

	Dependent variable: log average real price of wine								
	1907–1936					1907–1926		1917–1936	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
AOC Share	-0.054	-0.006	-0.023	-0.004	-0.023	0.067	0.037	-0.129	-0.120
	(0.056)	(0.054)	(0.054)	(0.055)	(0.054)	(0.061)	(0.064)	(0.069)	(0.069)
	[0.069]	[0.084]	[0.085]	[0.084]	[0.083]	[0.083]	[0.079]	[0.060]	[0.066]
	{0.059}	{0.084}	{0.084}	{0.084}	{0.080}	{0.053}	{0.051}	{0.084}	{0.093}
log(Prod)	-0.054	-0.064							
	(0.016)	(0.015)							
	[0.014]	[0.015]							
	{0.010}	{0.016}							
$\log(\text{Prod}_{-1})$			-0.046						
			(0.013)						
			[0.018]						
			{0.023}						
log(Prod) ×*vignoble*				✓		✓		✓	
$\log(\text{Prod}_{-1})$ ×*vignoble*					✓		✓		✓
Year ×*Vignoble* FE		✓	✓	✓	✓	✓	✓	✓	✓
Observations	2,249	2,249	2,138	2,249	2,138	1,493	1,389	1,498	1,482

Notes: All regressions include year fixed effects (FE). *Prod* denotes production. Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years.

occurring after the reform could affect identification since the share eligible for the *bordeaux* AOC increased from zero to almost one upon recognition.[38]

In order to rule out such possibility, we first run a falsification test of the relationship between AOC recognition and average wine price using data from the pre-reform period. Specifically, we artificially set the share of AOC vineyards to its value fifteen years later. Since we begin counting AOC recognition the year after the decree is enacted, and the first decrees were enacted in 1936, from 1907 to 1921 (15 years) our AOC share remains equal to zero and the artificial treatment period goes from 1922 to 1936 (15 years). Results are shown in Table 4 and confirm that eventual AOC recognition was uncorrelated with price patterns before the actual treatment period began. That is, AOC and non-AOC departments do not appear to have been following different price trends prior to the reform. The table also shows results obtained from models where the share of eligible vineyards is artificially set equal to its value 20 years later (columns (6) and (7)) or 10 years later (columns (8) and (9)). If anything, the results in columns (8) and (9) suggest a negative correlation between eventual AOC recognition and pre-reform price trends right before the reform, although statistical significance is dependent on which standard

[38] In order to confound our effect, such a taste would have to be unrelated to AOC recognition, however.

Table 5: Effect of the AOC eligible share on the real price of wine, 1938–1969

	Dependent variable: log average real price of wine					
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share	0.234	0.352	0.355	0.365	0.352	0.362
	(0.096)	(0.136)	(0.137)	(0.144)	(0.141)	(0.136)
	[0.078]	[0.145]	[0.135]	[0.161]	[0.145]	[0.140]
	{0.094}	{0.065}	{0.055}	{0.059}	{0.049}	{0.056}
log(Production)	✓	✓				
log(Production$_{-1}$)			✓			
log(Production)×*vignoble*				✓		
log(Production$_{-1}$)×*vignoble*					✓	
Year×*Vignoble* FE		✓	✓	✓	✓	✓
Observations	2,267	2,267	2,261	2,267	2,261	2,267

Notes: All regressions include year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

error is used. This relative erosion of wine prices in departments ultimately eligible for AOC recognition is consistent with historical accounts of increasing abuses in the appellation wine market in the years leading to the reform (the "appellation scandal," see Capus (1947)).

As a second piece of evidence that our estimated effects are not driven by unobserved correlated factors, we restrict the sample to the post-1937 period: by that date, the most important AOCs had already been defined, so that the residual variation in the AOC eligible share, conditional on the departmental fixed effects, comes from later rounds of AOC recognition, notably that of Alsatian wines. Results are displayed in Table 5. Although the point estimate is slightly smaller than in the full sample, the effect of the AOC share remains large (37% in column (4)) and statistically significant. For the estimated effects to be spurious, unobserved factors would thus need to be systematically correlated with waves of AOC recognition.

Finally, we investigate whether the set of departments used as controls is a significant driver of our results. If unobserved factors unrelated to AOC recognition affected wine prices in AOC departments differently than in non-AOC departments within a *vignoble* after the reform, we would expect that removing non-AOC departments from the sample would change the estimated effect of AOC recognition. We thus remove all departments for which the eventual AOC share (by 1969) lies below 2.5%, as well as all departments with missing data. There are 42 such departments out of 76 used in the full sample, therefore this procedure removes more than half of the departments. Because departments with zero or very small eligible share are excluded, identification now relies on comparisons of price changes across moderately and more intensively treated departments within the same *vignoble*, which are plausibly more similar to

Table 6: Effect of the AOC eligible share on the real price of wine, AOC departments only

	Dependent variable: log average real price of wine					
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share	0.383	0.385	0.373	0.363	0.363	0.371
	(0.053)	(0.047)	(0.047)	(0.047)	(0.046)	(0.045)
	[0.111]	[0.106]	[0.106]	[0.109]	[0.107]	[0.106]
	{0.134}	{0.126}	{0.122}	{0.140}	{0.133}	{0.118}
log(Production)	✓	✓				
log(Production$_{-1}$)			✓			
log(Production)×*vignoble*				✓		
log(Production$_{-1}$)×*vignoble*					✓	
Year×*Vignoble* FE		✓	✓	✓	✓	✓
Observations	2,108	2,108	2,074	2,108	2,074	2,108

Notes: The period is 1907–1969. All regressions include year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is balanced.

each other and less likely to be differentially affected by factors unrelated to AOC recognition after the reform. Results are displayed in Table 6 and show that the coefficient estimates on the AOC eligible shares are still statistically significant and of similar magnitudes as those obtained using the entire sample of departments.[39] For instance, column (4) shows an average effect of AOC recognition equal to 36%, as opposed to 42% in the full sample.

Taken as a whole, these results clearly suggest that AOC recognition caused a sizeable appreciation in average wine prices at the department level. Our preferred estimate indicates a rate of increase of the average wine price with respect to the share eligible for AOC of 42%. This estimate implies that in a department where 100% of vineyards became eligible for at least one AOC (like Gironde), the average wine price increased by 42%.

5.3.3. Ruling out alternative explanations

The results of Section 5.3.2 suggest a clear effect of AOC recognition on the departmental wine price. Whether the increase in the wine price was indeed related to quality enhancements that failed to be incentivized prior to the reform remains to be established. Perhaps one of the biggest threats to identifying whether the AOC reform had any effect on the supply of quality is its potential for affecting the volumes of wine produced. There are at least two potential channels to consider. First, the reform could have reduced overall wine acreage and/or yields in regulated areas, and therefore the quantity of wine produced. Second, the reform could have reshuffled volumes of wines away from the appellation market into the ordinary wine market.

[39] The results still hold if we include departments with missing data in the regression.

Table 7: Effect of AOC recognition on production acreage and yield

	Dependent variable: log acreage		log yield		log production	
	(1) 1916–1955	(2) 1907–1969	(3) 1916–1955	(4) 1907–1969	(5) 1916–1955	(6) 1907–1969
AOC Share	0.163	0.376	-0.037	0.042	0.131	0.438
	(0.040)	(0.048)	(0.051)	(0.042)	(0.064)	(0.063)
	[0.136]	[0.117]	[0.080]	[0.088]	[0.150]	[0.161]
	{0.062}	{0.115}	{0.089}	{0.112}	{0.084}	{0.147}
Observations	3,007	4,653	3,006	4,647	3,009	4,681

Notes: All regressions include year by *vignoble* fixed effects. Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years.

Acreage and yield effects

It is difficult to imagine how acreage in vineyards could have been reduced by the reform because it did not force producers to uproot existing vineyards. One could easily expect, however, that maximum yields specified in many appellation decrees may have resulted in yield (and therefore production) reductions. In fact, we do not detect any negative effects of the reform on either acreage or yield in the data. Instead, regressions reported in Table 7 show that the share of AOC recognition had a positive and statistically significant effect on productive vineyard acreage, at least when estimated over the period 1907–1969.[40]

This effect is consistent with the view (confirmed by Figure 5) that wine acreage has decreased more over time in non-AOC regions than in AOC regions. One potential explanation for the observed differential trends in acreage may be that the AOC reform increased the profitability of wine making in treated areas and therefore had an effect on the extensive margin of wine production. If this were the case, this additional supply of wine would be direct evidence of the increase in market size attributable to the resolution of the lemons problem, as described in Akerlof's original model of adverse selection whereby high-quality sellers do not sell product in equilibrium. As appealing as this explanation may seem, we are unwilling to entirely attribute the relative acreage increase in AOC departments to the resolution of the lemons problem, the main reason being that AOC vineyards were largely exempt from restrictions on new plantings applicable to the ordinary wine market starting in 1953 (Humbert, 2011).

Table 7 also shows that there is no clear effect of AOC recognition on yield. Estimates are small and statistically insignificant, with fluctuating signs according to the period considered.

[40]The *Statistique agricole annuelle* reports both productive (harvested) acreage and planted acreage. We use the productive acreage variable. Results are similar if we use the planted acreage variable.

Although many AOC decrees specify maximum yields, it thus appears that reducing yield was not the principal channel through which quality improvements were achieved. In a way, the absence of a negative effect of AOC recognition on average departmental yield is consistent with available information. For instance, the large regional *bordeaux* and *bourgogne* AOCs, when created, imposed a maximum yield of 50 and 45 hl/ha, respectively. The average yield over the ten years prior to regulation were 32 hl/ha in Gironde – the department where *bordeaux* is produced – and 28 hl/ha in the departments covered by the *bourgogne* AOC.

Finally, Table 7 shows that the combined effects of AOC recognition on acreage and yield resulted in a positive effect on quantity produced, which is statistically significant when considering the period 1907–1969. Therefore, the increase in wine price observed in departments with higher eligible share cannot be attributed to a decrease in wine output following the reform.

Reshuffling

The second main effect that the reform could potentially have had on wine quantities is redistributive. It is conceivable that some wines that used to be sold under appellation before the reform were later denied the use of the AOC and thus had to be sold either under a less prestigious name, if available, or as ordinary wine (an effect known as *déclassement*). Initially, the "double appellation" regime allowed wines to be sold under a plain appellation *of the same name* as a recognized AOC, as long as they met the geographical requirements associated with the use of the denomination (that is, the rules already applicable prior to the reform). During that initial period, it is thus unlikely that the reform led to significant *déclassement* as wines could continue to be marketed pursuant to the old rules. This tolerance was formally abolished in 1942 however, which implies that wines not meeting the more comprehensive AOC requirements could no longer claim the appellation, even if they originated in an eligible region. It is therefore likely that the reform ultimately resulted in the reallocation (or "reshuffling") of some volume of wine away from the appellation market into the ordinary wine market.

If consumers are homogenous with respect to their taste for quality, such movements from one segment of the wine market to another should leave the average price of wine at the department level unchanged as consumers update their valuations of ordinary and appellation wines based on the average quality present in each market segment. In that case, the reshuffling effect should not confound our finding that average prices increased due to AOC recognition through an increase in the quality of AOC wines.

However, we formally show in Appendix A.2 that if consumers are heterogenous with respect to their taste for quality, average price could increase as a result of the *déclassement* of wines alone, *even if the reform has no effect on quality*. In that case, we show that welfare increases as well through a reallocation effect, as higher-quality wines are more selectively chosen by quality-valuing consumers. However, the relationship between the relative increase in price

and the relative increase in welfare is much less straightforward than in the case where the price increase is due to an increase in the quality of AOC wines. In addition, while reshuffling *could* cause a price increase, it could also cause a price decrease, so the net contribution of the reshuffling effect to our overall effect remains ambiguous.

In order to assess whether the positive and significant effect of AOC recognition on the average wine price found above is driven by reshuffling, rather than quality improvements, we leverage additional data to assess the extent to which appellation wines were forced into the ordinary wine market after the reform.

France's *Journal Officiel* for the year 1936 reports the volumes of wines declared under appellation in the year 1935, by department. We pair these data with production data from the *Statistique agricole annuelle* to construct a measure of the volume share of wines sold under (plain) appellation right before the reform. (We only have data for 1935, but this year, together with 1934, had historically high shares of appellation wines because producers were trying to escape the constraints of the new *Statut Viticole* applicable to ordinary wines (Capus, 1947). Therefore this approach overestimates the share of wines sold under appellation over the entire pre-reform period.) We compare these departmental appellation shares to the average departmental share of wines sold under either AOC or plain appellation in the post-1942 years, after the "double appellation" regime ended.[41] We then identify departments for which the share decreased by more than 5% (that is, for instance, a share going from 40% to 37% or less), and exclude these from the sample if the share of vineyards eligible for AOC during the post-reform years (our regressor of interest) was nonzero.[42] The idea is that in departments with AOC recognition, a post-reform appellation share lower than the pre-reform appellation share could have plausibly been caused by *déclassement*. The 5% tolerance is meant to account for variations in volumes due to weather, as well as for the fact that the 1935 share likely overstates the share that prevailed during the broader pre-reform period. As such, we believe that this approach is conservative.

Table 8 shows estimation results for two different sample periods: 1916–1955 and 1907–1969. In each case, departments included in the regression are selected based on a post-reform appellation share computed over years present in the sample, that is, 1942–1955 or 1942–1969. For comparison purposes, the table also reports coefficient estimates for the full sample of departments over the same time periods. The decrease in sample size once we remove departments with a decline in the appellation share indicates that our procedure removes a sizable portion of the initial sample. Indeed, this leads to excluding from the 1916–1955 sample key departments, which cover the *bordeaux* region (Gironde department), most of the *bourgogne* and *côtes-du-*

[41] This information is available starting in 1942 from France's *Statistique agricole annuelle*.

[42] All departments with a decreasing share of appellation wines actually had a positive share eligible for AOC during the post-reform years, so this second filter is not selective.

Table 8: Effect of the AOC eligible share on the real price of wine, excluding departments with plausible reshuffling

	Dependent variable: log average real price of wine							
	1916–1955				1907–1969			
	Selected departments		All departments		Selected departments		All departments	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AOC Share	0.405	0.397	0.244	0.250	0.657	0.641	0.424	0.413
	(0.109)	(0.112)	(0.055)	(0.055)	(0.061)	(0.062)	(0.045)	(0.045)
	[0.138]	[0.145]	[0.077]	[0.077]	[0.087]	[0.089]	[0.084]	[0.083]
	{0.160}	{0.183}	{0.128}	{0.130}	{0.135}	{0.141}	{0.134}	{0.136}
log(Prod) ×*vignoble*	✓		✓		✓		✓	
$\log(\text{Prod}_{-1})$ ×*vignoble*		✓		✓		✓		✓
Observations	1,819	1,802	2,910	2,893	3,147	3,081	4,572	4,483

Notes: All regressions include *vignoble*-by-year fixed effects. *Prod* denotes production. Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the department level. Standard errors in {} are clustered at the *vignoble* level. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years.

rhône regions, as well as a large share of the *champagne* region.[43] Nonetheless, irrespective of the period considered, the estimates in Table 8 suggest that if anything, the estimated effect is stronger when removing those departments with plausible reshuffling. Therefore, it is unlikely that our estimated positive effect is driven by the mere reallocation of wines across market segments following the reform.

The results of Table 8 also enable us to investigate the hypothesis that the relative price increases in AOC departments were driven by the sorting of wines along departmental boundaries, rather than by quality improvements. Indeed, if some departments were denied the use of an appellation to the benefit of others, so that the reform merely served to signal pre-existing quality differences across departments, we would expect that excluding departments with decreasing appellation share would reduce the estimate of the effect of eligibility on price. Our results do not support this hypothesis and instead give credence to our interpretation that the relative price increase we observe was due to quality improvements for eligible wines.

[43] Fewer departments are excluded when looking at the longer time period as the share of wines sold under AOC increased over time. The 1935 data on appellation wine production are missing for Charente and Charente-Maritime, the main producers of *cognac*. We suspect these data are not reported due to the nature of that appellation, which is not a wine but a brandy, obtained by distilling wine. Since we cannot rule out that *déclassement* had an important effect in these departments, we remove them from the regressions reported in columns (1), (2), (5), and (6). We also remove the other two departments with parcels eligible for the appellation *cognac*, namely Dordogne and Deux-Sèvres, as well as the departments producing the other brandy appellation *armagnac*.

Table 9: Other robustness checks, selected years

	Dependent variable: log average real price of wine					
	w/o 1940–45		w/o 1945–47		w/o 1941–1947	
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share	0.479	0.460	0.406	0.395	0.450	0.436
	(0.047)	(0.046)	(0.046)	(0.046)	(0.048)	(0.048)
	[0.099]	[0.099]	[0.084]	[0.085]	[0.100]	[0.100]
	{0.158}	{0.162}	{0.140}	{0.142}	{0.162}	{0.166}
log(Prod)×*vignoble*	✓		✓		✓	
$\log(\text{Prod}_{-1})\times$*vignoble*		✓		✓		✓
Observations	4,133	4,049	4,344	4,258	4,054	3,970

Notes: All regressions include *vignoble*-by-year fixed effects. *Prod* denotes production. Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in { } are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

Other robustness checks

Tables 9 and 10 provide results for samples that exclude selected years or selected departments. Table 9 investigates the robustness of our estimated effects to the removal of (i) the German occupation years 1940–1945, (ii) the post-war years 1945–1947, during which there was a sharp increase in wine prices in AOC departments (*e.g.* Gironde), and (iii) the years 1941–1947, during which ordinary wines as well as certain AOC wines were subject to administered prices (a regime known as *taxation*) and requisition.[44] Table 10 shows results for samples that exclude (i) the four departments of the *champagne* appellation, which had production requirements enacted (without official control) as soon as 1927, and (ii) Gironde, the department where *bordeaux* wines are exclusively produced and the home department of Joseph Capus, the assemblyman who promoted the 1935 law.

Results obtained when removing selected years are in line with those for the full sample, irrespective of the window of time omitted from the sample.

Results without *champagne* departments make sense to us. Unlike other appellations, *champagne* does not have sub-regional appellations, therefore the vast majority of eligible vineyards are only eligible for one appellation, *champagne*. Despite this fact, *champagne* is perhaps the most prestigious of all wine appellations and the one that commands the highest prices per hectoliter. To the extent that *champagne* wine benefited relatively more than other appellations from AOC recognition, which is plausible, this effect would entirely be captured by the AOC eligibility share capturing the first layer of recognition, s_{it}^1. Including *champagne* departments

[44] Taxation lasted after the liberation and ended with a decree of 4 September 1947, see Milhau (1949) and Humbert (2011).

Table 10: Other robustness checks, selected departments

	Dependent variable: log average real price of wine			
	w/o *champagne* dpts.		w/o Gironde	
	(1)	(2)	(3)	(4)
AOC Share	0.293	0.283	0.455	0.441
	(0.037)	(0.037)	(0.047)	(0.047)
	[0.080]	[0.081]	[0.087]	[0.087]
	{0.109}	{0.112}	{0.135}	{0.139}
log(Production)×*vignoble*	✓		✓	
log(Production$_{-1}$)×*vignoble*		✓		✓
Observations	4,324	4,239	4,510	4,422

Notes: All regressions include *vignoble*-by-year fixed effects. Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

in estimation would then tend to pull the estimate on the AOC eligible share towards a slightly higher value than when these departments are omitted.

Finally, results without *bordeaux* wines are very similar to the results for the full sample, suggesting that the reform was effective at promoting quality well outside of Gironde.

5.3.4. Effect on gross welfare and implied appreciation of AOC wine

At the end of our study period, the overall share of vineyards eligible for at least one AOC was 32% across all French departments. Together with an estimated effect of AOC recognition of 43%, this figure implies a relative increase in gross welfare in the French wine market (inclusive of ordinary wine) of about 13%, ignoring potential increases of production costs for wines sold under AOC after the reform. Furthermore, the increasing effect of the AOC eligible share across time, exhibited in Table C.3, implies even larger gains at the end of the period.

As indirect evidence that the additional costs of supplying AOC wines were generally smaller than the price premium, we collected supplementary data to evaluate the share of eligible producers who found it profitable to produce AOC wines. A technical report by INAO gives the shares of total vineyards cultivated for the production of AOC wines from 1949 through 1969 (INAO, 1978). Over that period, the share of total acreage producing AOC wines increased from 13% to 19%, while we estimate that the share of the eligible area relative to the area in vineyards increased from 32% to 36%.[45] These figures imply that the share of eligible area where

[45]The figure of 36% in 1969 differs from the 32% mentioned above because the share is here computed relative to the area in vineyards *in the current year*, as opposed to the *maximum* of the area in vineyards across all sample years.

AOC wine production was found to be profitable grew from 40% to 51%. This widespread and increasing adoption of AOC denominations suggests that the price premium for AOC wines exceeded the additional production cost for the inframarginal units supplied, and thus that the reform was welfare-enhancing.

Retrieving the price increase for AOC wine from our estimate is less straightforward. Because not all eligible parcels claim an AOC, our estimated coefficient $\hat{\beta}$ on the share of vineyards eligible for AOC recognition underestimates the effect of the reform on the price of wines actually sold under an AOC. However, using additional assumptions, our data allow us to size this effect. Using the notation of Section 3, the average price can be written as $p_m = p_0 + s_1(p_1 - p_0) + s_2(p_2 - p_1)$ with s_2 denoting the share of production sold under AOC. Since our empirical model regresses $\log p_m$ on σ_2, the share of acreage eligible for AOC, it is useful to express p_m as a function of σ_2 rather than s_2. Let κ be the share of eligible acreage actually cultivated for AOC wine production, and let y_1 and y_m denote the appellation yield and the average yield, respectively.[46] We then have $s_2 = \sigma_2 \kappa \frac{y_1}{y_m}$. Therefore,

$$p_m = p_0 + s_1(p_1 - p_0) + \sigma_2 \kappa \frac{y_1}{y_m}(p_2 - p_1).$$

Since our empirical model explains average price by the share of eligible acreage, it estimates $\hat{\beta} = \frac{\partial \log p_m}{\partial \sigma_2} = \frac{p_2 - p_1}{p_m} \kappa \frac{y_1}{y_m} = \frac{p_2 - p_1}{p_m} \frac{s_2}{\sigma_2}$. Therefore, we have

$$\frac{p_2 - p_1}{p_m} = \hat{\beta} \frac{\sigma_2}{s_2}.$$

Between years 1942 and 1969 (and excluding 1948 and 1950), the agricultural yearbook reports the volume of wines sold under an AOC for each department, allowing us to compute the share s_2 for each department and each year over this period. Using our proxies of σ_2, we calculate a geometric mean ratio for $\frac{\sigma_2}{s_2}$ equal to 2.7 over all treated departments and all years where s_2 is observed. Assuming that this mean holds over the whole study period, the price effect relative to the mean price, $\frac{p_2 - p_1}{p_m}$, is estimated to be 119%. This figure implies an average appreciation for AOC wines roughly equal to the size of the average wine price.

6. Conclusion

This article provides empirical evidence that the quality of wines sold under appellation prior to a pioneering 1935 law was below the social optimum, and that the reform allowed producers to profitably adopt quality-enhancing practices. Using a panel approach with fixed effects, we

[46] As in Section 3, it is assumed that yields are unaffected by the reform. In addition, here we assume that κ and $p_2 - p_1$ do not depend on σ_2.

estimate that the price of wines ultimately sold under an AOC increased by a value roughly equal to the average wine price.

In order to interpret this remarkable appreciation as stemming from an increase in wine quality, we first rule out that AOC recognition negatively affected the quantity of wine produced in treated departments. We then show that the reshuffling of previous appellation wines towards the ordinary wine market did not contribute to the observed price increase. In the end, the most parsimonious explanation for the large and significant price increase in treated departments is that the reform had the intended effect: it provided incentives to atomistic producers to supply costly quality that was ultimately valued by consumers.

Although treated departments are different from control departments in the sense that they benefit from natural factors that are conducive to producing higher-quality wine, we provide several arguments in support of the counterfactual comparability assumption necessary for a causal interpretation of our results. First, we show that eventual AOC status was uncorrelated with price patterns during the pre-reform period. Second, we show that the estimated effect survives the elimination of the pre-reform years from estimation. That is, exploiting only the period after the first wave of AOC recognitions yields a comparable estimate of the effect of AOC recognition. Finally, the estimated effect is robust to eliminating from the sample the set of control departments, defined as those with incomplete data or an eventual AOC share lower than 2.5%. That is, exploiting only the intensive margin of AOC eligibility to identify the effect does not change our overall estimate.

We provide a simple theoretical framework to underscore the welfare implications of our estimated price effect. If consumers are homogenous, then the relative price increase can be directly interpreted as a relative increase in consumers' average valuation of wine, or gross welfare. If consumers are heterogenous, then the estimated effect still constitutes a lower bound to the valuation increase relative to market value.

More work is needed to assess the effect of AOC adoption on production costs, but the evidence presented here, together with the observation that the AOC designation was widely and durably adopted wherever available, suggests that the reform was welfare-enhancing. Ignoring increases in production costs, our estimate implies that welfare increased by 13% in the French wine market due to the AOC legislation. This effect is consistent with the existence of a lemons-type market failure prior to the reform and resonates well with historical accounts of widespread abuse in the appellation wine market during the first decades of the 20th century.

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A. Models with heterogenous consumers

We consider a Mussa-Rosen model of vertical differentiation (Mussa and Rosen, 1978) whereby consumer tastes for quality are parameterized by an index $\theta \in [0,1]$ and $F(\theta)$ denotes the c.d.f. of θ. Each consumer consumes at most one unit of wine. The mass of consumers is set to $M > Q$, where Q denotes the fixed quantity of wine produced, including ordinary and appellation wine. Therefore, some consumers are not served in equilibrium. When consuming wine of quality μ sold at price p, a consumer of type θ enjoys utility $U^\theta(\mu, p) = \bar{u} + \theta\mu - p$, where $\bar{u} > 0$, and zero if the consumer purchases nothing.

A.1. Model with quality enhancement

This model is an alternative to the model presented in Section 3 whereby consumers are allowed to differ in their taste for quality. As in the main text, we assume that the effect of the reform is to increase the quality of a share of wine production previously sold under an appellation.

Wine quality is denoted $\mu_0 = 0$ for ordinary wine, $\mu_1 \geq \mu_0$ for an appellation that does not end up being recognized as AOC (*i.e.* a plain appellation), and $\mu_2 \geq \mu_1$ for an AOC.

Given that $M > Q$, the equilibrium price of ordinary wine must be equal to $\bar{u}$ ($p_0 = \bar{u}$) so that low-θ consumers are indifferent between purchasing nothing and purchasing ordinary wine.

Denote by $\tilde{\theta}$ the index of the consumer indifferent between purchasing ordinary wine and appellation wine. It must be that $\tilde{\theta} = \frac{p_1 - p_0}{\mu_1} = \frac{p_1 - \bar{u}}{\mu_1}$. Similarly, denoting by $\hat{\theta}$ the index of the consumer indifferent between purchasing plain appellation wine and AOC wine, we have $\hat{\theta} = \frac{p_2 - p_1}{\mu_2 - \mu_1}$. Market clearing implies that $M \int_{\tilde{\theta}}^{1} dF(\theta) = Qs_1$ and $M \int_{\hat{\theta}}^{1} dF(\theta) = Qs_2$ under full information. Under asymmetric information, all appellation wine has quality μ_1 and only the first market-clearing condition applies.

The relationship $M \int_{\tilde{\theta}}^{1} dF(\theta) = Qs_1$ determines $\tilde{\theta}$ given the exogenous values of Q, M, and s_1, and given $\tilde{\theta} = \frac{p_1 - \bar{u}}{\mu_1}$ it further determines p_1, which is then independent of the information regime. Similarly, the relationships $M \int_{\hat{\theta}}^{1} dF(\theta) = Qs_2$ and $\hat{\theta} = \frac{p_2 - p_1}{\mu_2 - \mu_1}$ determine $\hat{\theta}$ and p_2 under full information.

The increase in gross welfare (ignoring the additional costs of quality provision) when moving from the asymmetric to the full information scenario is simply the added gross utility of consumers with value index between $\hat{\theta}$ and 1, that is, those with the highest tastes for quality who

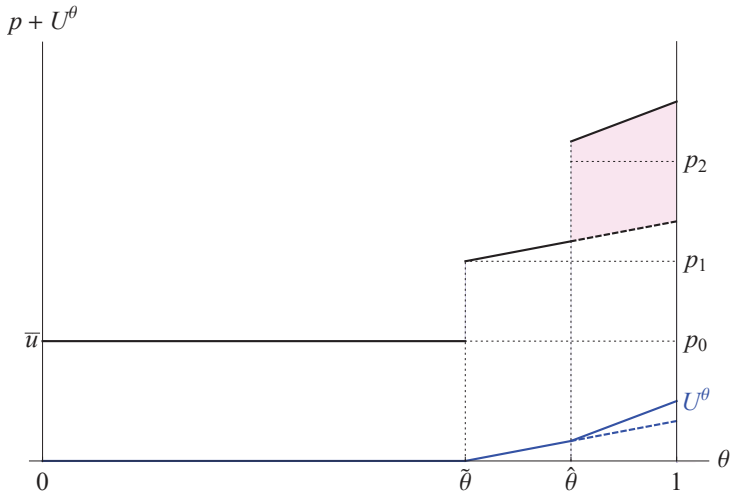


Figure A.1: Consumer utility and welfare under full information and asymmetric information

Notes: Full information equilibria are represented with solid lines. Dashed lines represent outcomes, under asymmetric information, for consumers purchasing controlled appellation wine under full information.

end up purchasing AOC wine:

$$\begin{aligned}
\Delta\text{GW} &= M\int_{\hat{\theta}}^{1}(\mu_2-\mu_1)\theta dF(\theta)\\
&= M(\mu_2-\mu_1)\int_{\hat{\theta}}^{1}\theta dF(\theta)\\
&= Qs_2(\mu_2-\mu_1)\times\frac{\int_{\hat{\theta}}^{1}\theta dF(\theta)}{\int_{\hat{\theta}}^{1}dF(\theta)}\\
&= Qs_2(p_2-p_1)\times\frac{\int_{\hat{\theta}}^{1}\theta dF(\theta)}{\hat{\theta}\int_{\hat{\theta}}^{1}dF(\theta)}.
\end{aligned}$$

Since $\frac{\int_{\hat{\theta}}^{1}\theta dF(\theta)}{\hat{\theta}\int_{\hat{\theta}}^{1}dF(\theta)} > 1$, it is clear that the gross welfare measure $Qs_2(p_2-p_1)$ that holds with perfectly elastic demands (see Section 3) represents a lower bound to the gross welfare increase in the more general model.

Figure A.1 illustrates the gross welfare calculation in the special case where $s_1 = 0.50$, $s_2 = 0.25$, $M = \frac{3}{2}Q$ and consumer taste parameters are uniformly distributed on $[0,1]$. In this case, market clearing implies that $\tilde{\theta} = \frac{2}{3}$ and $\hat{\theta} = \frac{5}{6}$. Setting $\bar{u} = 1$, $\mu_1 = 1$, and $\mu_2 = 2$, we obtain the equilibrium prices $p_1 = \frac{5}{3}$ and $p_2 = \frac{5}{2}$. In the figure, blue lines are used to represent consumer utility (net of the price paid) as a function of the taste parameter. Black lines represent the resulting gross welfare (ignoring supply costs) in equilibrium. Dashed lines depict utility and gross welfare for high θ consumers under asymmetric information. The shaded area represents the increase in gross welfare resulting from regulation.

A.2. Model with exogenous quality

A competing explanation as to why the average price rises after the reform (besides an increase in quality) is that the quantity of wine sold under appellation decreases as some wines are subject to *déclassement* (keeping constant the total quantity of wine sold). Indeed, wines previously sold under an appellation that did not meet the requirements for the AOC had to be sold either under a less prestigious appellation, if available, or as ordinary wine. If massive quantities of wines previously sold under appellation were redirected to the ordinary wine market due to the reform, the average price could change without any change in quality.

Here we thus assume that wine quality (and quantity) are fixed. We denote by $\mu_0 = 0$ the quality of ordinary wines, and by μ_1 the intrinsic quality of "true" appellation wines. The share of true appellation wines is s_1, but some of the ordinary wine is sold under appellation. The share of wine sold under appellation is thus $s_2 > s_1$. Therefore, the average quality of appellation wine is $\bar{\mu}_1 = \frac{\mu_1 s_1 + \mu_0(s_2 - s_1)}{s_2} = \frac{\mu_1 s_1}{s_2}$. We assume the reform reduces the share of appellation wines by removing some of the low-quality wine from the appellation and forcing it to be sold as ordinary wine (its true quality).

At a market equilibrium, it must be that $p_0 = \bar{u}$ so that low-θ consumers are indifferent between consuming ordinary wine and consuming nothing. In addition, the index of the consumer who is indifferent between ordinary and appellation wine must satisfy $\bar{u} - p_0 = \bar{u} + \tilde{\theta}\bar{\mu}_1 - p_1$, which implies that $p_1 = \bar{u} + \tilde{\theta}\frac{\mu_1 s_1}{s_2}$. Market-clearing further implies that $M \int_{\tilde{\theta}}^{1} dF(\theta) = Q s_2$, which implicitly defines $\tilde{\theta}$ as a function of s_2. The average price of wine is then

$$\begin{aligned} p_m &= p_0(1 - s_2) + p_1 s_2 \\ &= \bar{u} + \mu_1 s_1 \tilde{\theta}(s_2). \end{aligned}$$

It is clear that $\tilde{\theta}$ decreases with s_2, so if the reform decreases s_2 to $s_2' < s_2$, we would expect $\tilde{\theta}$ to increase and the average price to increase. Note that this result critically depends on the presence of consumer heterogeneity: if all consumers are the same and wine quality does not change, then average price (and welfare) do not change in equilibrium, even if there is a redistribution of volumes towards the ordinary wine category. Let us now show that welfare also increases (in this case there is no reason to distinguish gross from net welfare as we assume away any quality enhancement). Denoting by $\tilde{\theta}'$ the index of the indifferent consumer after the reform, we have

$$\begin{aligned} \Delta \mathrm{W} &= -M \int_{\tilde{\theta}}^{\tilde{\theta}'} \theta \frac{\mu_1 s_1}{s_2} dF(\theta) + M \int_{\tilde{\theta}'}^{1} \theta \mu_1 s_1 \left(\frac{1}{s_2'} - \frac{1}{s_2} \right) dF(\theta) \\ &= Q \mu_1 s_1 \left[\frac{\int_{\tilde{\theta}'}^{1} \theta dF(\theta)}{\int_{\tilde{\theta}'}^{1} dF(\theta)} - \frac{\int_{\tilde{\theta}}^{1} \theta dF(\theta)}{\int_{\tilde{\theta}}^{1} dF(\theta)} \right] \\ &> 0 \end{aligned}$$

while the change in price is simply $\Delta p_m = \mu_1 s_1 \left(\tilde{\theta}' - \tilde{\theta}\right) > 0$. Therefore, in this case both price and welfare increase. But without further restrictions on the cumulative density function $F(\theta)$, it is not possible to determine whether the observed relative price increase attributable to the reform under- or -overstates the associated change in welfare, although both have the same sign. Also note that the only source of the welfare increase here is allocative efficiency as lower-quality (ordinary) wine is being redirected towards low-θ consumers.

Of course, the reason behind the welfare increase here is that the reform is able to sort out low-quality wine from the appellation market and redirect it to the ordinary wine market, so information improves. What if instead the reform arbitrarily redirects high-quality wine towards to ordinary wine market? To investigate this scenario, we now assume that before the reform $s_2 = s_1$ but after the reform $s_2' < s_1$, that is, only a portion of the high-quality wine has a right to the appellation. Average quality in the ordinary wine market is $\mu_0 = 0$ before the reform and $\bar{\mu}_0 = \frac{\mu_0(1-s_1)+\mu_1(s_1-s_2')}{1-s_2'} = \frac{\mu_1(s_1-s_2')}{1-s_2'}$ after the reform.

Market-clearing in the wine market determines the taste parameter of the lowest-θ wine consumer, $\underline{\theta}$, through the equality $M\int_{\underline{\theta}}^{1} dF(\theta) = Q$. Market-clearing in the appellation market determines the taste parameter of the consumer indifferent between ordinary and appellation wine: $M\int_{\tilde{\theta}}^{1} dF(\theta) = Qs_1$, and similarly after the reform: $M\int_{\tilde{\theta}'}^{1} dF(\theta) = Qs_2'$, so that $\tilde{\theta}' > \tilde{\theta}$. Consumers with taste parameter above $\tilde{\theta}'$ are consuming high-quality wine before and after the reform. Consumers with taste parameter between $\tilde{\theta}$ and $\tilde{\theta}'$ switch from high-quality wine to a mixture or low- and high-quality wine of quality $\bar{\mu}_0$. Low-θ wine consumers switch from low-quality wine to that same wine mixture. Therefore, the effect on net welfare is

$$\begin{aligned}
\Delta \mathrm{W} &= M\int_{\underline{\theta}}^{\tilde{\theta}} \theta \frac{\mu_1(s_1 - s_2')}{1 - s_2'} dF(\theta) - M\int_{\tilde{\theta}}^{\tilde{\theta}'} \theta\mu_1 \left(1 - \frac{s_1 - s_2'}{1 - s_2'}\right) dF(\theta) \\
&= Q\mu_1(s_1 - s_2') \left[\frac{\int_{\underline{\theta}}^{\tilde{\theta}'} \theta dF(\theta)}{\int_{\underline{\theta}}^{\tilde{\theta}'} dF(\theta)} - \frac{\int_{\tilde{\theta}}^{\tilde{\theta}'} \theta dF(\theta)}{\int_{\tilde{\theta}}^{\tilde{\theta}'} dF(\theta)}\right] \\
&< 0
\end{aligned}$$

so that welfare decreases. It is possible (though not necessary) that average price decreases as well. For instance, if the distribution of the taste parameter is assumed to be uniform, then it is easy to show that $\Delta p_m = -\frac{Q}{M}(s_1 - s_2')(1 - s_1) < 0$. For an example where average price increases, consider the case where the density of θ is given by $f(\theta) = \frac{\theta^{0.1}(1-\theta)^{0.1}}{\int_0^1 \theta^{0.1}(1-\theta)^{0.1} d\theta}$, $\frac{Q}{M} = 0.99$, $s_1 = 0.5$, and $s_2' = 0.4$.

B. Results with shorter time windows

Table B.1: Effect of the AOC eligible share on the real price of wine, 1911–1960

	Dependent variable: log average real price of wine					
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share	0.282	0.307	0.304	0.303	0.300	0.298
	(0.050)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
	[0.076]	[0.078]	[0.080]	[0.079]	[0.080]	[0.082]
	{0.100}	{0.126}	{0.131}	{0.132}	{0.135}	{0.134}
log(Production)	-0.070	-0.069				
	(0.011)	(0.013)				
	[0.014]	[0.016]				
	{0.014}	{0.016}				
log(Production$_{-1}$)			-0.042			
			(0.013)			
			[0.016]			
			{0.015}			
log(Production)×*vignoble*				✓		
log(Production$_{-1}$)×*vignoble*					✓	
Year×*Vignoble* FE		✓	✓	✓	✓	✓
Observations	3,644	3,644	3,627	3,644	3,627	3,644

Notes: All regressions include year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

Table B.2: Effect of the AOC eligible share on the real price of wine, 1921–1950

	Dependent variable: log average real price of wine					
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share	0.222	0.209	0.207	0.189	0.195	0.201
	(0.066)	(0.068)	(0.067)	(0.067)	(0.066)	(0.067)
	[0.071]	[0.081]	[0.083]	[0.083]	[0.084]	[0.082]
	{0.078}	{0.112}	{0.116}	{0.118}	{0.121}	{0.116}
log(Production)	-0.069	-0.068				
	(0.017)	(0.020)				
	[0.019]	[0.025]				
	{0.024}	{0.032}				
log(Production$_{-1}$)			-0.024			
			(0.019)			
			[0.023]			
			{0.029}			
log(Production)×*vignoble*				✓		
log(Production$_{-1}$)×*vignoble*					✓	
Year×*Vignoble* FE		✓	✓	✓	✓	✓
Observations	2,172	2,172	2,164	2,172	2,164	2,172

Notes: All regressions include year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

C. Heterogeneity analysis

C.1. Heterogeneity across time

We would expect that the new regulatory apparatus introduced by the 1935 reform took some time to generate discernable effects on the French wine market. Such expectation is grounded on both supply-side and demand-side considerations. First, some of the production requirements introduced in AOC decrees could have required sizable upfront investments, notably grape varietal requirements for vineyards that were previously planted in unapproved varieties. This could imply a lag between AOC recognition and the actual increase in wine quality. Second, even if producers were able to adjust rapidly to the newly mandated requirements, it could have taken time for consumers to update their beliefs regarding the underlying quality of AOC wines as wine quality is subject to the vagaries of climate, making quality assessment difficult within just a few years.[47] Finally, some eligible but perhaps high-cost producers may have chosen to delay changes in production practices until they could better assess the extent to which the market would reward their investments towards quality. This last point would be consistent with the AOC eligibility and acreage trends shown in Figure 3, which clearly suggest that the compliance rate for eligible producers (*i.e.* the AOC acreage relative to the AOC eligible acreage) increased over time.

In order to test the proposition that the effect of AOC eligibility on wine prices increased over time, we estimate a variant of Equation (4) where we interact the AOC eligible share with a linear time trend. Results are shown in Table C.3 and suggest that the effect of AOC recognition on the wine price started at about zero in 1937, the year immediately following the first round of AOC decrees, and then increased at a rate of about 2.3% per year in our preferred specification (column (4)). The slope coefficient is precisely estimated.[48]

C.2. Heterogeneity across space

Given the diversity of wines across France's *vignobles*, one may expect that the effect of the reform on the wine price could differ geographically. Indeed, reputable regions differ in their propensity to produce red vs. white wines, still vs. sparkling wines, but also in the way that appellations themselves are organized, with many idiosyncratic factors like the use of *châteaux* to identify prestigious wines in Gironde, the widespread use of municipal appellations in Burgundy, *etc.*

In order to investigate heterogeneity in the effect of AOC recognition across *vignobles*, we estimate a variant of Equation (4) where we interact the AOC eligible share with regional dummy

[47] See Macchiavello (2010) and Macchiavello and Morjaria (2015) for empirical evidence on the progressive nature of reputation building.

[48] We also estimated a model with a quadratic, rather than linear, trend but the coefficient on the quadratic interaction term was not statistically significant.

Table C.3: Time-varying effect of the AOC eligible share on the real price of wine

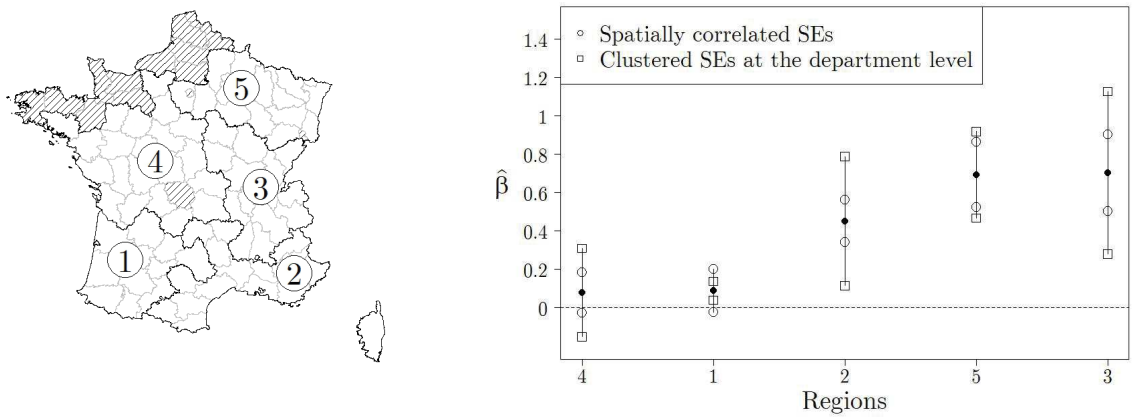
	Dependent variable: log average real price of wine				
	(1)	(2)	(3)	(4)	(5)
AOC Share	0.035	0.036	0.035	0.034	0.036
	(0.064)	(0.062)	(0.062)	(0.060)	(0.061)
	[0.060]	[0.068]	[0.069]	[0.068]	[0.069]
	{0.066}	{0.081}	{0.084}	{0.080}	{0.083}
AOC Share×(t-1937)	0.022	0.023	0.023	0.023	0.023
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]
	{0.007}	{0.006}	{0.006}	{0.007}	{0.007}
log(Production)	-0.053	-0.056			
	(0.011)	(0.011)			
	[0.014]	[0.015]			
	{0.012}	{0.015}			
log(Production$_{-1}$)			-0.037		
			(0.011)		
			[0.016]		
			{0.013}		
log(Production)×*vignoble*				✓	
log(Production$_{-1}$)×*vignoble*					✓
Year×*Vignoble* FE		✓	✓	✓	✓
Observations	4,572	4,572	4,483	4,572	4,483

Notes: All regressions include year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

variables. In order to keep the model tractable and well identified under our rich set of geographically differentiated year effects, we choose to group *vignobles* according to geographical proximity. This leads us to defining five broad groups of *vignobles*, represented in panel (a) of Figure C.2. The spatial heterogeneity of the effect is represented in panel (b) of Figure C.2. Although all coefficients are positive, two out of five regions (regions 1 and 4) show small effects that are not always statistically significant, whereas the other three regions show large and significant effects, in excess of 45%.

C.3. Heterogeneity across eligibility layers

As mentioned in Section 2, in many wine regions the AOC system is highly hierarchical and recognizes, besides broadly defined regional or sub-regional appellations, the specificity of communal (municipal) or even sub-communal appellations with prestigious place names. In order to investigate whether recognition of sub-regional, communal or finer appellations commanded



(a) *Vignoble* groupings

(b) Estimated effects

Figure C.2: Heterogeneity of the effect across space

Notes: Estimates are obtained using the specification with Year×*Vignoble* fixed effects and demand flexibilities with respect to contemporaneous production differentiated by *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949. The bounds of the intervals are $\pm\Phi^{-1}(0.975)$ times the chosen standard error of the estimate, with Φ being the cumulative distribution function of the standard normal.

an additional premium relative to recognition of broad regional appellations like *bordeaux* or *bourgogne*, we run price regressions that include the share of a department's vineyard acreage eligible for at least k AOCs ($k > 1$), in addition to our main regressor.

Conceptually, it is not clear whether the official recognition of geographically limited and prestigious sub-appellations should influence the departmental wine price to the same extent as the recognition of broad regional appellations. On the one hand, prestigious place names may command a sizable price premium over broad regional appellations. On the other hand, narrowly defined vineyards may not have suffered as much from free-riding problems as larger appellations prior to the reform, as they involved fewer producers who may also have had more to lose from the erosion of the vineyard's reputation. In that respect, it is noteworthy that during the short period of time during which the "double appellation" regime was in effect, many broad regional appellations – unlike small, prestigious vineyards – did not gather enough support amongst their members to voluntarily eliminate plain appellation designations in favor of the exclusive use of the AOC (Humbert, 2011). This suggests significant heterogeneity in vineyard practices, and attendant wine quality, across producers claiming a broad regional appellation prior to the reform.

Indeed, Table C.4 shows that the estimate of the effect of multi-layer AOC recognition on the departmental wine price, although positive and sometimes large, is not statistically significant.

Table C.4: Heterogeneity across eligibility layers

	Dependent variable: log average real price of wine					
	(1)	(2)	(3)	(4)	(5)	(6)
AOC Share: 1 layer	0.365	0.379	0.357	0.392	0.403	0.390
	(0.055)	(0.055)	(0.053)	(0.046)	(0.046)	(0.045)
	[0.096]	[0.097]	[0.098]	[0.085]	[0.086]	[0.086]
	{0.176}	{0.172}	{0.179}	{0.142}	{0.141}	{0.141}
AOC Share: 3 layers	0.214	0.201	0.230			
	(0.085)	(0.085)	(0.084)			
	[0.206]	[0.204]	[0.209]			
	{0.308}	{0.304}	{0.306}			
AOC Share: 5 layers				0.931	0.932	0.864
				(0.313)	(0.316)	(0.306)
				[0.760]	[0.762]	[0.761]
				{1.208}	{1.223}	{1.197}
log(Production)×*vignoble*	✓			✓		
log(Production$_{-1}$)×*vignoble*		✓			✓	
Observations	4,483	4,572	4,572	4,483	4,572	4,572

Notes: All regressions include *vignoble*-by-year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949.

C.4. Linearity of the AOC eligibility effect

Our regression model in Equation (4) assumes a linear total effect of AOC eligibility on the log-price of wine. To test whether this linearity assumption is justified by the data, we estimate flexible models that nest the linear model and perform post-estimation specification tests of the linearity assumption. Specifically, we estimate a model where the eligible share enters quadratically on the right-hand side, and a model whereby we discretize the AOC share using three categories: $0 < s_{it} \leq 0.07$, $0.07 < s_{it} \leq 0.40$, and $0.40 < s_{it} \leq 1$. The cut-off points are chosen in order to ensure a balanced number of observations falling in each category. The categorical model estimates coefficients on dummy variables for each category. For the quadratic model, the linearity test is simply the t-test on the quadratic coefficient. For the model with categorical share variables, the linearity test is a set of linear restrictions involving the mean shares within each category. We report tests statistics constructed using the department-clustered variance-covariance matrix.

Table C.5 shows that the linearity assumption cannot be rejected at standard levels of statistical significance for most specifications, the exception being the test based on a quadratic model using the less conservative spatial-robust standard errors that ignore serial correlation.

Table C.5: Tests of the linearity assumption

	Dependent variable: log average real price of wine							
	quadratic model				categorical model			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AOC Share	0.123	0.085	0.203	0.129				
(β_1)	(0.113)	(0.113)	(0.118)	(0.118)				
	[0.295]	[0.297]	[0.285]	[0.293]				
	{0.432}	{0.438}	{0.428}	{0.442}				
(AOC Share)^2	0.348	0.380	0.253	0.326				
(β_2)	(0.132)	(0.133)	(0.137)	(0.137)				
	[0.335]	[0.336]	[0.330]	[0.335]				
	{0.499}	{0.501}	{0.498}	{0.508}				
$I_{0<s\leq 0.07}$					0.025	0.028	0.040	0.038
(β_1)					(0.021)	(0.021)	(0.021)	(0.022)
					[0.060]	[0.060]	[0.059]	[0.058]
					{0.032}	{0.032}	{0.030}	{0.030}
$I_{0.07<s\leq 0.40}$					0.147	0.140	0.168	0.152
(β_2)					(0.031)	(0.030)	(0.032)	(0.032)
					[0.050]	[0.050]	[0.049]	[0.049]
					{0.050}	{0.053}	{0.055}	{0.056}
$I_{0.40<s\leq 1}$					0.263	0.256	0.278	0.265
(β_3)					(0.036)	(0.036)	(0.037)	(0.037)
					[0.083]	[0.084]	[0.080]	[0.081]
					{0.132}	{0.136}	{0.133}	{0.136}
log(Prod)	✓				✓			
log(Prod$_{-1}$)		✓				✓		
log(Prod)								
×*vignoble*			✓				✓	
log(Prod$_{-1}$)								
×*vignoble*				✓				✓
Joint significance								
test: $\beta_1 = \beta_2 = 0$	27.564	26.616	26.208	25.395				
Linearity test:								
$\frac{\beta_1}{\mu_1} = \frac{\beta_2}{\mu_2} = \frac{\beta_3}{\mu_3}$					2.56	2.23	4.53	3.26
Observations	4,572	4,483	4,572	4,483	4,572	4,483	4,572	4,483

Notes: All regressions include *vignoble*-by-year fixed effects (FE). Standard errors in () allow for spatial correlation up to the fourth neighboring departments and assume no time correlation. Standard errors in [] are clustered at the level of the department. Standard errors in {} are clustered at the level of the *vignoble*. The panel is unbalanced and includes all departments for which price data is available for at least half of the sample years. Price data is missing for the year 1949. In the categorical model, the Wald test of linearity uses the mean AOC shares across observations within each category (μ_i). The two specification tests use the department-clustered covariance matrix. The critical value for both tests is $\chi^2_{95\%}(2) = 5.991$.

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