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**PROXIMITY AND SCIENTIFIC
COLLABORATION: EVIDENCE FROM
THE GLOBAL WINE INDUSTRY**

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Proximity and scientific collaboration: Evidence from the global wine industry

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Abstract

International collaboration among researchers is a far from linear and straightforward process. Scientometric studies provide a good way of understanding why and how international research collaboration occurs and what are its costs and benefits. Our study investigates patterns of international scientific collaboration in a specific field: wine related research. We test a gravity model that accounts for geographical, cultural, commercial, technological, structural and institutional differences among a group of Old World (OW) and New World (NW) producers and consumers. Our findings confirm the problems imposed by geographical and technological distance on international research collaboration. Furthermore, they show that similarity in trade patterns has a positive impact on international scientific collaboration. We also find that international research collaboration is more likely among peers, in other words, among wine producing countries that belong to the same group, e.g. OW producers or newcomers to the wine industry,

Proximity, International scientific collaboration, Wine industry, Gravity model, Scientometrics; Emerging countries

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1. Introduction

The worldwide scientific community is more strongly interconnected now than ever before, because many impediments to international collaboration and knowledge transfer have been reduced in the last thirty years or so. Information and knowledge exchanges have been facilitated by the lower costs of travel and long distance communications, and by the diffusion of tools such as videoconferencing. Nevertheless, knowledge transfer remains an uncertain and complex task that can be hampered by a range of frictions, knowledge leakage risks, cultural distances or failures in transmission and absorption (Cowan and Jonard, 2004; Picci, 2010). This makes international collaboration among researchers a far from linear and straightforward process.

Scientometric studies provide a good way of understanding why and how international research collaboration occurs and what are its costs and benefits (Katz and Martin, 1997). There is a stream of literature that focuses on a comprehensive theoretical framework to study the determinants of research collaborations between different countries, as a way of investigating the spatial diffusion of scientific knowledge (Frenken et al., 2009). This approach is based on the concept of proximity, which has been shown to be an insightful analytical device to disentangle different forms of distance – geographical, social, cognitive, institutional and organizational – all of which play a role in the spatial distribution of economic activities (Boschma, 2005; Torre and Rallet, 2005). As suggested in Frenken et al. (2009), in its different dimensions the concept of proximity can be used to test the unevenness of knowledge diffusion on different geographical scales, identifying the main drivers of research collaboration.

In line with this literature, our study investigates patterns of international scientific collaboration in a specific field: wine related research. In recent years, the wine industry has experienced increased globalization in its trade flows, making it a particularly interesting case for investigating whether international research collaboration has also increased and encompassed new exporting countries (Cassi et al., 2011). Recent evidence suggests that emerging countries, such as Chile, Argentina and South Africa are rapidly

catching up in terms of knowledge production, as shown by their increasing share in international scientific publications in wine related disciplines (Glänzel and Veugelers, 2006; Cassi et al., 2011). This process of technological and scientific modernization has been spurred on by consistent investments in research by newcomers and by the support provided to new specialized research institutions (Giuliani et al., 2011). Cusmano et al. (2010) highlight the phenomenon of new players in the global wine market becoming dynamic adapters and adopters of the new institutional models and promoting research-driven transformation of the wine industry.

In this paper, we focus on a selected group of countries active both as producers and consumers in the global geographical wine business, and investigate their mutual research collaborations and the factors that might hinder/facilitate these interactions. The analysis is based on bibliographical data covering a period of 13 years (from 1992 to 2004), extracted from the Web of Science (WoS) edition of the *Science Citation Index Expanded*TM (SCIE) of the *Institute for Scientific Information* (ISI, Philadelphia, PA, USA) according to some selection criteria proposed in Cassi et al. (2011). We test a gravity model that accounts for geographical, cultural, commercial, technological, structural and institutional differences among a group of Old World (OW) and New World (NW) wine producers and consumers.

In line with previous studies (Hoekman et al., 2010; Picci, 2010; Montobbio and Sterzi, 2012), our findings confirm the problems imposed by geographical and technological distance on international research collaboration. Our empirical analysis provides a novel and interesting finding that similarity in trade patterns has a positive impact on international scientific collaboration. In the case of the wine industry, the globalizations of trade and of science do not occur as independent processes but they have a mutual influence. We also find that international research collaboration is more likely among peers, in other words, among wine producing countries that belong to the same group, e.g. OW producers or newcomers in the wine industry.

The paper is organized as follows. Section 2 discusses the relevant literature, provides some background information on the wine industry and introduces the research questions. Section 3 describes the data and methodology and Section 4 presents the empirical results. Section 5 concludes by summarizing

the contributions of this paper and suggesting some directions for future analysis.

2. The internationalization of research

2.1. The literature

Scientific collaboration among researchers is an increasing phenomenon as shown by a striking increase in the number of co-publications over the total number of scientific publications (Wagner-Doebler, 2001). According to Wuchty et al. (2007), collaborative research accounts for well over 50% of all research activities in many countries. Katz and Martin (1997) identify four main reasons for this: 1) in several different fields, increasing interdisciplinarity requires combinations of knowledge sources; 2) the costs of research facilities are leading to a pooling of resources; 3) the increasing need for specialization requires ever more complex instrumentation; and 4) funding, particularly at the EU level, encourages international research collaborations.

Among the key topics of internationalization of research, there is spatial scientometrics, a growing field that explores the globalization of science and the location of scientific activities in specific places (Frenken et al., 2009). In studies on the geography of innovation (Breschi and Lissoni, 2001; Gertler, 2003; Boschma, 2005; Torre and Rallet, 2005), there is a small number of empirical contributions that focuses on the role played by different types of proximity – geographical, cognitive, organizational, social, institutional and technological – in research collaborations (Ponds et al., 2007; Hoekman et al., 2010; Picci, 2010; Paier and Scherngell, 2011; Scherngell and Hu, 2011; Montobbio and Sterzi, 2012).

With regard to geographical proximity, there is a general consensus on its facilitating role in knowledge exchange (see among others Jaffe et al., 1993; Audretsch and Feldman, 1996). It has been claimed that geographical proximity benefits research collaboration because it facilitates face-to-face contacts and thereby the exchange of tacit knowledge. In an empirical analysis of co-publication intensity among 313 regions in 33 European countries for the period 2000-2007, Hoekman et al. (2010) show that physical distance has a negative effect on co-publication activity, although this

decreases over time and a gradual convergence towards a more interconnected European science system is taking place.

In a different context, Scherngell and Hu (2011) analyze knowledge flows among Chinese regions proxied by co-authorship, and find robust evidence suggesting that even more than physical distance, cognitive distance hampers bilateral research collaboration.

As far as institutional distance is concerned, Hoekman et al. (2010) suggest that the existence of institutional barriers to cross-border collaboration makes it: *'more difficult to align incentives among researchers due to difference in for instance funding schemes, institutional frameworks and norms and values'* (p. 663). They distinguish between institutional differences at three different spatial levels: regional science systems in which policy initiatives commonly support collaborative projects (Cooke et al., 1997), the national science system, since researchers in different countries are subject to different incentive schemes, and linguistic areas with a common language that facilitates communication among researchers. Their empirical findings confirm that co-publication activities are more likely to occur within the same region, the same country and the same linguistic area: *"suggesting a mixture of simultaneous processes driven by a 'distance logic' and a 'territorial logic'"* (Cooke et al., 1997: 472).

Ponds et al. (2007) show that institutional differences can influence collaboration patterns. In their study on the Netherlands, they find that geographical proximity is more relevant in collaborations between academic and non-academic organizations than pure academic collaboration. This suggests that institutional similarity helps to overcome the barriers to long distance interactions.

In a recent study on international technological collaboration among patent inventors in advanced and emerging countries, Montobbio and Sterzi (2012) introduce technological proximity alongside geographical, cultural and institutional distances, as a factor impacting on the likelihood of co-patenting activity. They find that the probability of technological collaboration between inventors based in two different countries is higher if companies and institutions are active in similar technological fields. The higher marginal benefit derived from collaboration with a technologically similar partner

partially offsets the costs of collaborating with a geographically distant partner. Similarly, Picci (2010) analyzes patterns of inventive activity in Europe using patent data and concludes that inventive proximity is a strong determinant of bilateral collaboration. Technological and cognitive proximity facilitates collaboration also in the case of formal research cooperation, such as European Framework Program projects (Paier and Scherngell, 2011).

In applied scientific fields, such as the case of research on wine related disciplines, common industry characteristics (i.e. foreign investors, trade flows, climatic and soil conditions) may also influence collaboration among researchers in different countries. The following section provides some background information on the wine industry and the role of science in its recent development.

2.2. Scientific research in the wine industry

Global patterns of wine production and trade have been changing fundamentally since 1980. Up to the end of the 1980s, OW countries, and particularly France and Italy, dominated the international wine market. From the beginning of the 1990s, their supremacy began to be challenged by new international players that have recorded some spectacular performances in terms of both exported volumes and values. These NW producers include affluent countries that are relatively new to the wine sector, such as the USA and Australia, and less developed, but rapidly growing emerging economies, such as Chile, Argentina and South Africa (Giuliani et al., 2011). Whereas OW producers (France, Italy, Spain, and Portugal) still lead in the production, export and consumption of wine, NW producers are gaining market share among consumers around the world, from only 2.5% of world exports in the early 1980s to more than 28 % in 2010 (OIV, 2012). Increasingly, NW producers are gaining recognition in the high-end segments of the market that once were dominated by an elite group of OW producers. Also, NW producers have been quick to adapt their wines to new expanding markets, playing a major role in establishing and strengthening the emergence of a new paradigm based on a market-driven scientific approach to wine production. As documented in Giuliani et al. (2011), in the NW, intermediary organizations, universities and research centers have been restructured and strengthened to

adapt to intensified international competition.

In this changing global context, Cassi et al. (2012) investigated the joint evolution of trade and scientific collaboration networks. They argue that investment in science is both a precursor to changes in the production and trade of wine and that developments in international trade are changing the direction of investment and international collaboration in science. Their results indicate that a strong interdependence between science and trade is affecting how the dynamics of globalization unfold, and developments in networks of trade and scientific collaboration are increasingly occurring in parallel. Based on these findings, in our analysis of the determinants of international collaboration we introduce a measure for commercial proximity. This assumes that two countries targeting the same final market face similar technical problems (e.g. regulations on sulfites) and need to satisfy similar consumer tastes, and hence are likely to collaborate more.

In line with the recent literature on proximity in research collaboration, and on the basis of some industry peculiarities characterizing the wine industry, in this paper we address the following research questions:

- Do geographical, technological and cultural distances matter for establishing scientific collaborations?
- To what extent do bilateral patterns of wine trade affect the extent to which countries collaborate in science in the wine field?
- Does being an OW or a NW producer or mainly a wine consuming country, contribute to explaining the patterns of international scientific collaborations?

In order to answer these questions, we construct a country-level dataset that combines trade and scientific publication data for a 15-year period (1990-2004). We test a gravity model that includes geographical, cultural, commercial and technological distances as well as differences among groups of wine exporting and importing countries.

3. Data and methodology

3.1 Data

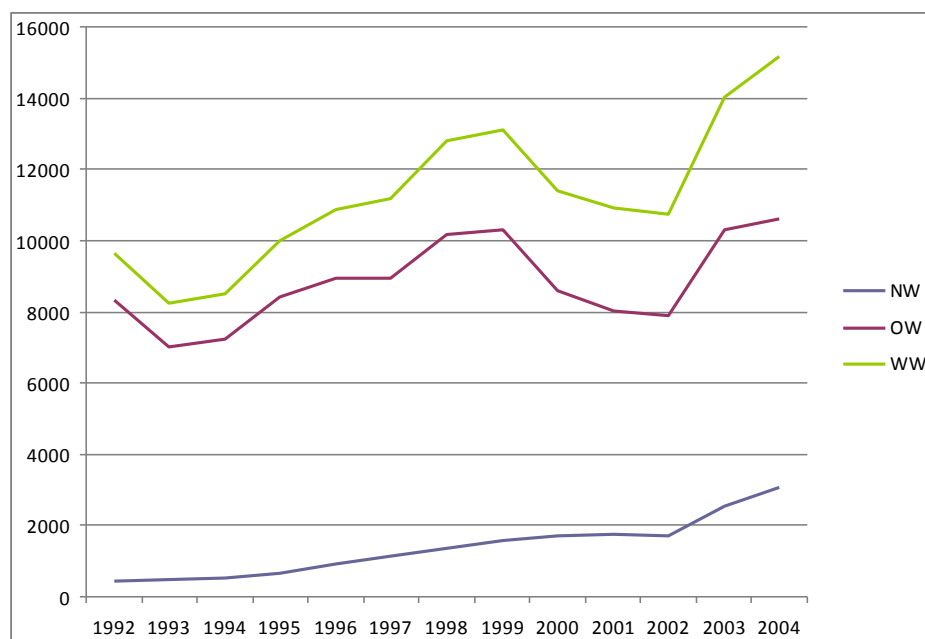
The empirical analysis is based on three main data sources: bilateral trade flows, scientific co-publications and geographical, linguistic and historical relations between countries. Trade data come from the NBER-United Nations Trade Data (NBER, 1962-2000) and the COMPENDIUM (Anderson and Norman, 2006) datasets. The first database provides trade-bilateral flows at the 4 digit SIC sector level from 1962 to 1999. The second database is specific to the wine sector and provides information on international trade-bilateral flows (values) between the main wine importing and exporting countries for 1994 to 2004. In order to extend the period of analysis, we merged these two data sources. In our final dataset, data from 1970 to 1993 are from NBER¹ and data from 1994 to 2004 are from the COMPENDIUM.² The empirical analysis includes the 24 countries in the COMPENDIUM dataset, which register an annual share of at least 1.5% of world global wine trade flows during the period 1980-2004.³ All the countries considered account for more than 95% of worldwide wine export flows and more than 97% of wine related international co-publications in 2004.

Figure 1 shows patterns of trade for the period 1993-2004. Overall, international trade between countries has grown, with both OW and NW countries experiencing positive trends. However, NW countries have grown much faster than OW countries, with Australia and Chile the top performers among wine exporters.

1 In the SIC classification we select Code 1121.

2 The COMPENDIUM dataset is chosen for the overlapping period, which allows us to check for discrepancies.

3 The selected countries are: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Chile, Denmark, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Japan, the Netherlands, New Zealand, Portugal, South Africa, Spain, Sweden, Switzerland, and the United States. We excluded the former Communist countries (e.g. USSR/Russia, FM Yugoslavia, the Republic of Moldova, and the Czech Republic) because of lack of territorial consistency along the period of analysis, and also some Asian countries (e.g. Singapore and Taiwan) because the COMPENDIUM dataset provides only regional aggregated data for them.



Source: Authors' elaboration of NBER trade and Compendium data

Figure 1 Wine exports by group of countries (1992-2004)

Data on scientific co-publications are extracted from the WoS edition of the ISI and cover a period of 18 years from 1989 to 2006. The number of publications is a measure of research activity (for a critical appraisal see Katz and Martin, 1997). In order to define the field of *wine research*, we adopt the same criteria as in Cassi et al. (2011), which builds on Glänzel and Veugelers (2006).

The dataset contains 12,373 publications selected on the basis of three search criteria:

- lexical criterion including specific search strings applied to publication keywords, titles and abstracts;⁴
- journal criterion including all articles in the three top journals – *American Journal of Enology and Viticulture*, *Australian Journal of Grape and Wine Research*, and *Vitis*;⁵

4 We used the search terms: GRAPEVIN* OR WINES OR WINE GRAP* OR WINE PRO* OR RED WINE* OR WHITE WINE* OR WINEMAKING OR ENOLOG* OR VITICULT* OR OENOLOG* OR WINE CELL* OR WINE YEAST* OR WINERY OR WINERIES OR VITIS. In line with Glänzel and Veugelers (2006), we defined and tested the set of search terms. We started our search with the term *wine*, which ultimately was excluded because it produced significant noise in the results. Also, in most of the extracted publications, the word wine appears in the title or abstract or as a keyword.

5 In line with Cassi et al. (2011) and different from Glänzel and Veugelers (2006), we include the journal *Vitis*.

- exclusion criterion excluding all articles where at least one of the authors is affiliated to a hospital or a medical school because these articles are related not to wine production but to research on the health benefits of or damage caused by wine consumption.

Figure 2 depicts co-publication patterns by groups of countries. We group 24 countries following Cassi et al. (2012): the OW group includes traditional producers, the NW group includes emerging exporters, the Core Consumers (CONS) group comprises the major international importers, and Peripheral Exporters and Consumers (PER) is a mixed group including peripheral producers and emerging importers with little or no production.⁶ Overall, international bilateral collaboration increases over the period. All groups show positive growth rates. However, unlike the case for trade flows, we observe that OW countries have grown faster than any other group. In particular, the figures suggest that the OW countries are driving the worldwide growth in co-publication and that the NW countries are only marginal contributors, their share remaining stable from 1996 to 2001.⁷ After 2001, NW and the other groups show a steep growth path.

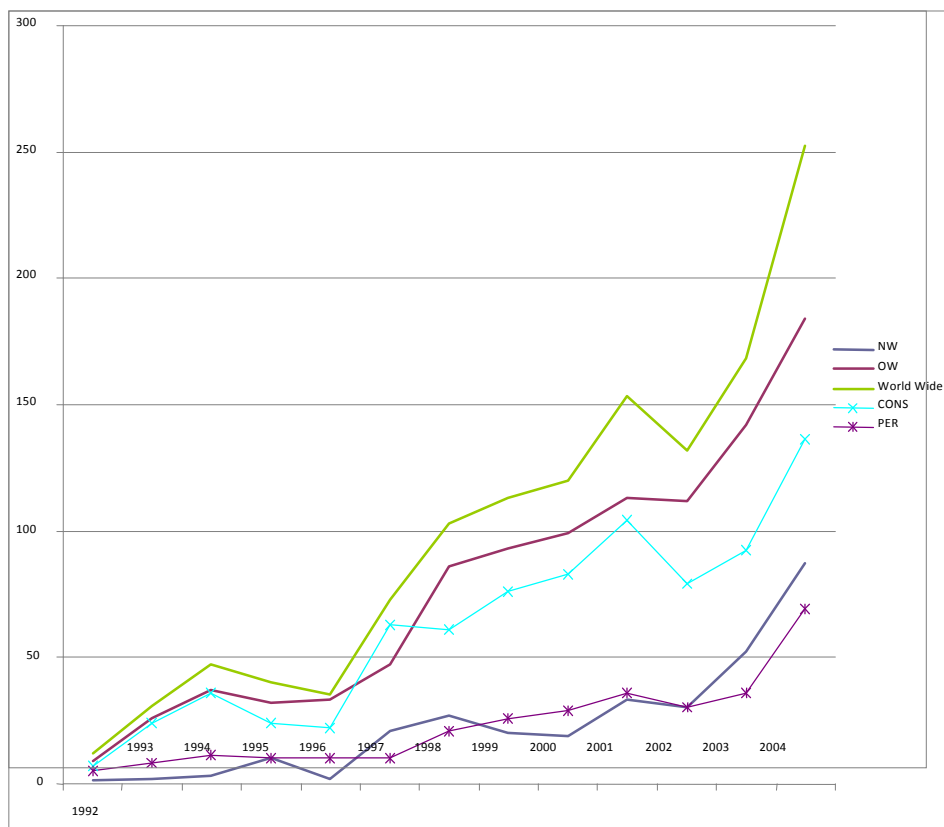
Other information, such as geographical, linguistic and historical relations between countries is retrieved from the CEPII gravity dataset.⁸ Finally, GDP data were obtained from the US Department of Agriculture Economic Research Service.⁹

⁶We classify Bulgaria, France, Greece, Hungary, Italy, Portugal and Spain as OW producers; Argentina, Australia, Chile, New Zealand and South Africa as NW producers; Belgium, Canada, Great Britain, Ireland, Japan, the Netherlands, Switzerland and the United States as CONS; Austria, Denmark, Germany, and Sweden as PER.

⁷Note that the positive trend in CONS is due to the inclusion of the USA.

⁸Data retrieved from <http://www.cepii.fr/anglaisgraph/bdd/gravity.htm> (last accessed 24 September 2012). See Appendix for a detailed description.

⁹Available at <http://www.ers.usda.gov/data/> (last accessed 24 September 2012).



Legend: Old World (OW); New World (NW); Consumer countries (CONS); Peripheral Exporters and Consumers (PER)

Source: Authors' elaboration of ISI-Web of Knowledge data

Figure 2 Wine co-publications by groups of country (1992-2004)

3.2 Model and variables

To model scientific collaboration between countries we exploit a gravity model, widely used in the trade literature to explain inter-country trade flows (Anderson, 1979; Bergstrand, 1985). The gravity model resembles the Newtonian law of gravitation, where masses are proxied by the country's economic size and distance is measured by their geographical position. The model implies that trade between two countries increases with their economic size (i.e. their mass) and decreases with their geographical distance. Previous examples of the gravity framework in the scientific (Ponds et al, 2007; Hoekman et al., 2010; Scherngell and Hu, 2011) and technological collaboration (Peri, 2005; Picci, 2010; Paier and Scherngell, 2011; Scherngell and Hu, 2011; Montobbio and Sterzi, 2012) literature were aimed at explaining the intensity of knowledge flows between countries or organizations. Overall,

these empirical studies (see Section 2) show that collaboration is positively related to actors' size (mass) (e.g. number of publications) and negatively related to the distance between them. In line with this literature, our gravity model is based on the following equation:

$$\ln(IntCopub)_{ijt} = \beta_0 + \beta_1 A_{it} A_{jt} + \beta_2 \ln(geodist)_{ijt} + \beta_3 L_{ijt} + \beta_4 T_{ijt} + \beta_5 C_{ijt} + \delta W_{ij} + \varepsilon_{ijt} \quad [1]$$

where $IntCopub_{ijt}$ is the natural log of the number of co-publications between authors affiliated to organizations in country i and their co-authors affiliated to organizations located in country j , at time t . As usual, we define a research collaboration involving at least two countries as a co-authorship (see Katz and Martin, 1997) if their respective scholars co-author at least one scientific article.

A_{it} and A_{jt} respectively capture the mass of countries i and j at time t . Since the co-publication relationship is undirected (unlike trade where there is a *source* and a *destination*), the coefficients of the two countries are assumed to be equal and the effect of their two masses is captured by β_1 . In our analysis, mass is measured as the economic size of the country proxied by the natural log of the annual GDP ($Ingdp$) and the share of wine exports ($Inexport$), and scientific relevance, proxied by the log of the country's annual publications ($Inpub$). Overall, a country's economic and scientific relevance indicates the level of absorptive capacity and the scientific infrastructure. Hence, in line with the literature, we can expect a country's international scientific collaboration to be positively influenced by its economic and scientific size. However, it should be noted that size could have a negative effect on international collaboration. Indeed, if a country's national scientific community is well developed, there might be fewer incentives for its scholars to search for foreign partners. On the other hand, scholars that belong to small national scientific communities are likely to be highly motivated to establish collaborations abroad in order to avoid isolation. Although the above arguments hold in general, it is worth highlighting that in the wine sector a sizable group of small countries has a large domestic wine industry (e.g. Austria, Portugal, Greece, Moldova, Armenia). In these cases, despite their relatively small economic size, such strong specialization might entail intensive international scientific collaborations.

In our model, the distance terms refer to different types of proximity. The trade literature focuses mostly on geographical distance and on its negative effect for trade relations. The underlying hypotheses are that transportation and communication costs increase with distance. Similarly, gravity studies on knowledge flows confirm the negative effect of geographical distance on technological collaboration (Hoekman et al., 2010; Picci, 2010). A large part of scientific and technological knowledge is tacit; hence it is more effectively transferred and absorbed if the actors are physically close. These latter hypotheses matter even more in the wine case, which is an applied scientific field where researchers usually need to conduct experiments on the field in order to gather data and investigate local-specific plant or vineyard conditions. In our model, the geographical distance between two countries (*geodist*) is measured as the log of the distance in kilometers between their capital cities (*Indist* in the econometric model).¹⁰

However, as discussed in Section 2, other types of distance can hinder scientific interactions (Katz and Martin, 1997; Hoekman et al., 2010) and general knowledge exchanges (Boschma, 2005). In our gravity model, we account for the technological, commercial and cultural distance between two countries, defined as explained below.

Technological Distance (T) is measured as the complement of Jaffe's (1988) index, using the 25 *ISI-Web of Science* sub-categories:

$$Dist_tech_{ijt} = 1 - (P_{it}P'_{jt} / [(P_{it}P'_{it}) (P_{jt}P'_{jt})])^{1/2}$$

where P_t is the distribution vector of country I 's stock of publications at time t for the 25 sub-categories identified as wine-related.¹¹ We expect two countries to collaborate more if they are technologically close, i.e. they are active in similar scientific fields. The Jaffe index ranges between 0 and 1; it is equal to 1 if the pairs of countries have the same distribution of scientific activities, and 0 if they do not share any of these activities.

¹⁰ For a detailed description of the Geodist dataset from which the gravity variables are taken, see the Appendix.

¹¹ Different classifications might lead to discordant results due to the granularity of the measure 'technological distance', as pointed out in Savorelli and Picci, 2013. Unfortunately we are unable to test different measures of technological distance. In the wine scientific field there is no other classification available in the literature, the one derived from ISI being the most reliable.

For *Commercial Distance* (C) we introduce two measures. First, and similar to *Technological Distance*, the complement of Jaffe's index ($Dist_comm_{ijt}$) is computed using export quotas for year t for the 24 potential partner countries. This variable is equal to zero if two countries are competing in the same foreign market, that is, exporting the same proportions to the same countries, and tends to its maximum value (i.e. 1) the more these two countries export to different countries. Following Cassi et al. (2012), we hypothesize that the *Commercial Distance* between two countries is negatively correlated with their scientific collaboration. Indeed, winemakers who target the same markets usually sell to customers with similar consumption habits and tastes and this implies that they often adopt similar oenological practices (i.e. oxygenation) and face the same technical barriers (e.g. regulation about sulfites). Therefore, we might expect a more intense collaboration than among winemakers targeting very different markets.

Another indicator introduced into the model is the *Salton Index*, which captures the relative importance of market j for country i :

$$Salton_{ijt} = X_{ijt} / ((X_{it} * M_{jt})^{1/2}).$$

where X_i and M_j respectively represent the total value of exports of country i and imports of country j and X_{ij} measures the value of the exports of country i to country j (in 2000 US Dollars). By construction, it is:

$$0 \leq Salton_{ij} \leq 1 \text{ and } Salton_{ij} \neq Salton_{ji}.$$

Therefore we know that $Salton_{ij} = 0$ if country i does not export to country j ; $Salton_{ij} = 1$ if country i exports only to country j and this latter does not import wine from any other country.

Different from *Commercial Distance*, which considers each country relation to any other country, the *Salton Index* captures the importance of country i 's export to country j 's market (i.e. imports). Since we only take account of non-directed relations, we compute this indicator as the average value of $Salton_{ij}$ and $Salton_{ji}$. The obtained measure captures the (average) reciprocal importance of the two countries' markets. As for the indicator of *Commercial Distance*, even in this case we expect that the scientific collaboration between two countries increases together with their commercial dependence, since

exporters tend to adapt their wines to local tastes and scientific research might facilitate this adjustment process (Giuliani et al., 2011).¹²

Cultural and historical differences, such as a shared language or being a former colony, also influence the likelihood of scientific collaboration among researchers in different countries. These latter factors certainly have a role also in the wine sector, where there are examples of colonial linkages (e.g. Spain and Chile or Argentina) and language similarities (e.g. the UK and Australia or New Zealand, the Netherlands and South Africa). Hence, in line with the existing gravity literature and in order to capture such time invariant features (L), in the econometric model we include:

- a dummy equal to 1 if the pair of countries has an official language in common (*Comlang_off*) and 0 otherwise;
- a dummy equal to 1 if the pair of countries had colonial ties before 1945 (*Colony*) and 0 otherwise.

To take into account the differences discussed in Section 2.2 among groups of wine countries, a set of control dummies (W) is included in the model. We expect that producing countries with similar histories in wine production (either NW or OW wine producers) have closer research collaborations. In particular, over time OW countries have set up well-established institutions supporting the development of their wine industries. Hence, we expect deep-rooted linkages among them, which are likely to strengthen the scientific collaboration among researchers, specialized in the wine field. For NW countries, we can expect intense research collaboration based on common problems and similar institutional frameworks.¹³

At the same time, since NW countries are latecomers in the sector, their knowledge base in wine might be less extensive than that of the OW countries. Also, some NW countries, such as South Africa, Chile and Argentina, are emerging economies, hence their scientific institutions might be less advanced compared to those in OW countries (Kunc and Tiffin, 2011). These arguments suggest that scientific organizations in NW countries may

¹² Note that, by construction, the expected sign of the *Salton Index* is the opposite of the *Commercial Distance* indicator.

¹³ For instance, Cusmano et al. (2010) stress that South Africa first and Chile more recently have built systems of supporting institutions inspired by the successful Australian wine system.

interact more intensively with established research centers located in OW countries rather than with other countries within their group. Based on what has been said so far, our prediction about the NW country (*NW*) dummy is open.

For consumer countries (*CONS*), *ceteris paribus* we might expect that they would collaborate more intensively with either NW or OW producer countries than among themselves since they are likely to lack specific expertise in the sector. The same expectation holds for the *PER* group.

The gravity model in equation [1] can be estimated using different econometric techniques. Studies by Santos Silva and Tenreyro (2006) and Burger et al. (2009) show that standard techniques, such as Ordinary Least Squares (OLS), generate biased estimates due to a number of different econometric problems (e.g. heteroskedasticity, excess zeros). Also, unlike the gravity models that investigate the determinants of bilateral trade, analysis of scientific collaborations implies the use of count data, which makes OLS an even less suitable method of analysis.

A 'natural' solution to these shortcomings is to use the Poisson Pseudo-Maximum Likelihood (PPML) estimator or the related Negative Binomial or Zero Inflated Negative Binomial (Santos Silva and Tenreyro, 2006; Burger et al., 2009). We chose the PPML estimator as particularly suitable since in our case the dependent variable (i.e. co-publications) is a count variable and its distribution is skewed. All econometric specifications use robust standard errors that are clustered to control for error correlation in the panel (Cameron and Golotvina, 2005). We also include country and time dummies to control for unobservable characteristics. A detailed description of the variables introduced in the econometric analysis is included in the Appendix (Table A1).

4. Empirical results

We test the gravity equation [1] using panel data on bilateral scientific co-publications for a set of 24 countries. Table 1 presents our results under different econometric specifications; all of them include time and country dummies. Country dummies control for unobservable factors (e.g. macroeconomic or political instability, cultural differences not accounted for by other variables, institutional factors, government policies or differences in

stocks of human capital) in both countries i and j . Time dummies capture unobservable time-varying factors that may affect bilateral relations between countries (e.g. changes in political conditions and in public policies).

The first column in Table 1 shows the estimates of the basic gravity model, which include mass and geographical distance. We find that the *Geographical Distance* is strongly significant and with the expected sign, showing that geography hinders international collaborations. This is in line with other studies that use co-authorship as a proxy for scientific collaboration and find that geography matters in disciplines as different as physics, biotechnology and humanities, and in areas as diverse as European and Chinese regions (Ponds et al., 2007; Hoekman et al., 2010; Scherngell and Hu, 2011). We also investigate whether the impact of *Geographical Distance* on bilateral collaborations changes over time. The coefficient of the parameter does not follow a clear trend and it does not decrease,¹⁴ on the contrary it slightly increases over time. This finding confirms findings in similar studies on bilateral knowledge flows (Hoekman et al., 2010; Montobbio and Sterzi, 2012) and is generally in line with evidence in the trade literature on the ‘missing globalization puzzle’ (Coe et al., 2002; Disdier and Head, 2008).

As expected, the mass indicator has a positive effect on bilateral collaboration between countries, but not on export, which is not significant although it has a positive sign. Both GDP and number of publications are positive determinants of international co-authorship, which confirms that the logic of the gravity equation works also in the context of science-based relations between countries. In line with the literature, we find that the economic and scientific sizes of countries are strong attractors.

In Table 1, Columns 2 and 3 present the augmented versions of the gravity model. Column 2 includes the measures for different distances and the results confirm most of our expectations. The Salton Index is positive and significant suggesting that tight trade interdependence among countries is an important

¹⁴In the basic gravity model (see Column 1) we interacted the time dummies with the geographical distance indicator to estimate the effect of distance in different years. Results do not show a clear trend. Since we have a rather small time series, we also tested the distance effect on two sub-periods. We find that the coefficient (-0.21) is not significant in the first period (1992-1998), while it is higher and significant (-0.33) in the second period (1999-2004).

determinant of scientific collaboration. As expected, the *Commercial and Technological Distances* both have a negative impact on bilateral collaboration between countries. The elasticity is particularly high for the *Technological Distance* indicating that collaboration in science requires both actors to be active in similar fields. Indeed, actors with a common scientific background can more easily communicate, understand each other and eventually fully master the knowledge diffused.¹⁵ This result is supported by empirical work on the determinants of international knowledge exchange (see Picci, 2010; Montobbio and Sterzi, 2012).

In contrast to most of the existing empirical work, the indicators of cultural similarity (*Comlang_off* and *Colony*) are insignificant and this might signal some peculiarities of the sector under investigation. If we examine the network of collaborations between countries (Figure A1), we observe that former colonies or countries with a common language are often weakly connected or not connected at all. For example, Chile has links with France but not with Spain, despite the common language and the colonizing history. Argentina collaborates only with Spain. South Africa is linked with the USA and Australia and also collaborates with the Netherlands, which colonized the country, but it does not have links with the UK, which ruled the country for centuries. The same applies to former British territories, such as Australia and New Zealand. These peculiarities may be explained by the inclusion of dummies to control for the type of wine country (i.e. OW, NW, CONS, PER) as in Column 3 of Table 1.

Our findings indicate that countries belonging to the same group, that is, OW, NW, PER, show higher intensity of bilateral collaborations. The dummies also capture an additional dimension of similarity: wine industry incumbents (OW) tend to collaborate more with their peers, latecomers (NW) have stronger interactions among the NW group and inter-group collaborations between OW and NW (see NOW variable in Table 1) are not significant. These findings

¹⁵ We have also tested the non-linearity relation between the probability of collaboration and the technological distance, considering this latter also in square terms. Doing so, we check for the existence of an inverted U-shape curve that can be interpreted as a research for diversity (i.e. complementarity) constrained by the costs of communication and collaboration. However, the square term is not significant. For the sake of readability, this specification has not been reported in the paper.

confirm that countries within the same group face similar problems (e.g. climate conditions) and are characterized by similar institutional settings (e.g. trade agreements, health and environmental standards). Therefore, intra-group collaborations might offer more opportunities to solve problems or promote new ideas for innovation, than relations with researchers located in countries that belong to a different group. In non-producing countries similarity reduces collaboration.¹⁶

5. Conclusions

The barriers to international research collaboration represented by geographical and technological distances are the focus of several empirical studies in different scientific disciplines and diverse geographic contexts (Hoekman et al., 2010; Picci, 2010; Scherngell and Hu, 2011; Montobbio and Sterzi, 2012). Our study confirms that geography and a common scientific background are important for international collaboration. Our evidence also shows that the importance of physical distance does not decline over time. This finding suggests that globalization generally is constrained by geography, despite the increase in international scientific collaborations and sustained growth in international trade.

Empirical analysis provides a novel and interesting result showing that similarity in trade patterns has a positive impact on international scientific collaborations. Economic globalization (through trade) and knowledge globalization (proxied by scientific co-publication) are not independent processes but they rather influence each other. This means that international scientific collaboration could facilitate the adaptation of wines to local tastes and therefore might increase when countries are connected through trade relations.

A peculiar and original result is that intra-group collaborations are favored by the occurrence of similar problems (e.g. climate conditions) and analogous institutional settings (e.g. trade agreements, health and environmental

¹⁶ Note that the inclusion of dummies does not affect the sign or significance level of distance (other than commercial distance).

standards). This confirms the existence of two different patterns in wine production: a NW paradigm based on a market-driven scientific approach and an OW model characterized by an emphasis on *terroir* and regional specificities, and by a strict regulatory framework imposing additional constraints and reinforcing regional differences (Giuliani et al., 2011).

The importance of *terroir* or special characteristics of each different agricultural local soil, weather conditions and farming techniques, has a strong influence on the characteristics of the wines produced and on the oenological and viticulture competencies required to grow vines. In future analyses, the introduction of a variable to test the importance of *terroir* would contribute to improving our understanding of the specificity of this industry.¹⁷ Territorial specificities would become more evident in analyses at a regional level. This might be particularly interesting in the case of EU countries for capturing the richness and extreme variety of old producing countries such as France, Italy and Spain.

¹⁷In a previous version of this analysis, we made an attempt in this direction including the distance of the capital city from the equator, to capture the climate conditions of each country assuming that wine producers facing similar weather conditions share common problems (e.g. weather conditions, diseases). However, due to the roughness of the measure used, the variable is not significant in the econometric test and therefore is not included in the current econometric model.

Table 1 PPML estimation findings

	(1)	(2)	(3)
Lndist	-0.305*** [0.0596]	-0.233*** [0.0578]	-0.224*** [0.0593]
Lnpub	1.131*** [0.102]	0.910*** [0.117]	0.940*** [0.115]
Lngdp	1.324* [0.702]	1.394** [0.705]	1.344* [0.708]
Salton		1.740*** [0.560]	2.014*** [0.550]
Dist_comm		-0.355* [0.188]	-0.251 [0.198]
Comlang_off		-0.0966 [0.244]	-0.249 [0.241]
Colony		-0.0268 [0.152]	0.0754 [0.122]
Dist_tech		-1.439*** [0.287]	-1.297*** [0.298]
OW			0.685*** [0.207]
NW			0.500* [0.271]
NOW			0.127 [0.384]
CONS			-0.627*** [0.218]
PER			0.558** [0.276]
Lnexp	0.0331 [0.0448]		
Constant	-17.02** [7.193]	-16.80** [7.136]	-16.60** [7.039]
Observations	3,446	3,446	3,446
Year dummy	YES	YES	YES
Country dummy <i>i</i>	YES	YES	YES
Country dummy <i>j</i>	YES	YES	YES
Pseudo log-likelihood	-1819.2938	-1794.4781	-1781.2097
R-squared	0.581	0.593	0.598

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Appendix

Table A1: List of Variables

<i>IntCopub_{ijt}</i>	Log of the number of co-publications between one author affiliated in an organization localized in country <i>i</i> and another author affiliated to an organization in country <i>j</i> at time <i>t</i>
<i>Lngdp</i>	Log of GDP of countries <i>i</i> and <i>j</i>
<i>Lnexp</i>	Log of exports of countries <i>i</i> and <i>j</i>
<i>Lnpub</i>	Log of publications of countries <i>i</i> and <i>j</i>
<i>Lndist</i>	Log of the Geographical Distance between each pair of countries in km
<i>Dist_tech</i>	Technological Distance (see Section 3.2)
<i>Dist_comm</i>	Commercial Distance (see Section 3.2)
<i>Salton</i>	Salton Index (see Section 3.2)
<i>Comlang_off</i>	Dummy variable which is 1 if the pair of countries has an official language in common, 0 otherwise
<i>Colony</i>	Dummy variable which is 1 if the pair of countries shares a colonial past, 0 otherwise
<i>OW</i>	Dummy variable which is 1 if the pair of countries is OW (OW), 0 otherwise
<i>NW</i>	Dummy variable which is 1 if the pair of countries is NW (NW), 0 otherwise
<i>CONS</i>	Dummy variable which is 1 if the pair of countries is Consumer (CONS), 0 otherwise
<i>PER</i>	Dummy variable which is 1 if the pair of countries is Peripheral Consumer or Producer (PER), 0 otherwise
<i>NOW</i>	Dummy variable which is 1 if the pair of countries is OW (OW) and NW (NW), 0 otherwise

Gravity variables

GeoDist made available an exhaustive set of gravity variables provided by Cepii (see Mayer and Zignago (2011) for more details). The dataset is available at the following web address:

<http://www.cepii.fr/anglaisgraph/bdd/distances.htm>

The GeoDist provides two distinct files:

- a country-specific one: *geo_cepii*
- a dyadic one: *dist_cepii* including a set of different distance and common dummy variables used in gravity equations to identify particular links between countries such as colonial past, common languages, contiguity.

In our exercise, we used the following variables taken from the dyadic dataset

- *Geodist* measures the distance in Km between two countries. Geodesic distances are calculated following the great circle formula, which uses latitudes and longitudes of the most important cities/agglomerations (in terms of population);
- *Comlang_off* indicates if two countries share a common official language;
- *Colony* indicates if two countries have ever had a colonial link.