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The age dynamics of vineyards: Past trends affecting the future ☆

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Abstract

The paper introduces a modified version of the demographic balance equation commonly used in human demography in the study of populations of permanent crops. The proposed methodology is then applied to analyzing the evolution of the Italian vineyard.

In short, the study measures different factors that have had an impact on the extension of the Italian vineyard and on its age structure such as the reduced investments in new plantations; the massive early explant and also the extended life of the vineyards since they are kept in production well beyond the conventional limit of their economic life. Results show that the reduction of the area cultivated with grapes in Italy is due to different reasons, some of which relate to the past while others mirror more recent behaviors of vine growers.

The methodology also allows the prediction of tendencies in the future. Three scenarios are built, based on different hypothesis about new investments and explantation rates that account for the wine EU CMO 2013–2030. Projections show, that in the next decades, both the extension of cultivated area and plant age will be deeply influenced by choices that had been made even decades before. Comparing the results obtained under the different hypothesis, helps to assess the range of possible impacts of the new policy framework.

In an increasingly global and competitive market, the analysis proposed provides original insights on some future waves in the wine industry both to policy makers and stakeholders. This awareness is especially needed in order to put in place strategies aimed at avoiding supply-demand mismatches in a sector where supply moves slowly while demand trends are fast and almost unpredictable.

Keywords: Demographic trends; Future scenarios; Italian vineyards

1. Introduction

Over the last few decades, the geography of wine grape cultivation has changed worldwide. The process has had and still has a deep impact on the structure and equilibria of the sector in each producing country. The causes of the upsurges and declines that have taken place in the world wine picture, together with some of their effects, have been extensively analyzed in the economic literature especially in terms of demand trends and of competitiveness drivers (Banks and Overton, 2010; Cassi et al., 2012; Cusmano et al., 2010; Giuliani and Morrison, 2011; Mariani et al., 2012; Pomarici, 2016). Also changes in the policy framework and their effects on the wine sector have been deeply analyzed (Gaeta and Corsinovi, 2014; Meloni and Swinnen, 2016). However, to the authors' knowledge, the effects of such a huge re-localization of the cultivation in terms of the demographic structure of the vineyards and on the subsequent future perspectives of the cultivation have not been explored so far. This paper seeks to fill this gap by proposing a method that can provide insights into the time trends of the area cultivated with vines as it results from the age structure of plantations.

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The analysis proposed is based on a simple index commonly used in human demography, hereby applied for the first time with the goal of analyzing the dynamics of populations of permanent crops. The application of the method shown in this paper relates to viticulture, however, the methodology can be clearly applied to any permanent crop. The goal of the paper is twofold. First, we seek at presenting this new methodology. Second, we aim at analyzing the age dynamics of the Italian vineyard by the mean of the methodology. The Italian case seems particularly interesting thanks to its long history and to the major role played by the country in international wine markets. Besides, Italy provides quite a good example of the potential of the method as the wine sector has undergone a drastic reduction along the last decades while, more recently, it is somehow recovering. Consequently, the demography of the Italian vineyard offers a varied set of situations to be analyzed by the proposed index.

The relevance of the results obtainable with this method can be well understood in relation to different situations, all related to plantation age, that requires a deep knowledge of the demographic structure of the cultivation, both in the present and in the future. The following provides a few examples that are worth pinpointing:

- The expansion, or even only the survival of the sector, relies on the decision to invest in planting young vines to replace the older ones and/or to add new plantations. Hence, the vitality and the competitiveness of the sector are strictly related to investment decisions about planting propagation materials as well as explanting older plants.
- Matching supply with demand. As it is well known, food demand moves much faster than supply and this is particularly true in the case of permanent crops. Referring to the wine sector, let's consider, for example, a new grape variety that has come into fashion and an old variety that does not meet consumer preferences anymore; on the supply side, the switch may take several years and once the new variety is in place any further change will again be slow and costly. In such a context, being able to assess future demographic trends that follow past and present investment decisions is clearly a more relevant task both for producers and policy makers.
- Several aspects of the cultivation of permanent crops are not changeable once the plantation is set. Thus, catching-up with new technologies, requires a renewal. This is the case for training systems, plant varieties, mechanization and other features of the cultivation technique. Also productivity and quality are deeply influenced by plant age and adjustments may require that a new plantation is set in place of the previous one.
- Some diseases are related to plant age (Kovács et al., 2017; Sharabani et al., 2013). When addressing such problems, it is essential to assess the age structure of the cultivation at present but also for future years. This enables to foresee the patterns of development of the disease and allows setting up a contrast strategy.

The study explicitly leaves out of the picture the many complex interactions with the entire primary sector and it does not frame any features of the social and natural environment as well as of the global economy. Although, these aspects clearly have, and will have, significant impacts on the area cultivated with vineyards, the scope of our analysis is much more limited and does not account for this level of complexity (Holman et al., 2017; Tóth and Végvári, 2016; Gomes et al., 2009).

The paper is organized as follows. Section 2 is an overview of world and Italian trends in vine cultivation together with the resulting demographic structure. Section 3 is devoted to presenting the original methodology on which the paper is based and illustrates the sources of the data used. Section 4 presents and discusses Italian grape cultivation past trends. The demographic balances of the vineyards by age classes for the whole Italian sector are calculated with reference to the period 1990–2010. Projections to 2020 and 2030 are discussed in the second part of this section. These help in getting insights on the patterns of change at stake and on their consequences in terms of the extension of the national vineyard and of its age structure in the medium-long run. The projections consider three different scenarios based on different sets of assumptions with respect to the European policy framework (European Union, 2013) and to behaviors possibly adopted by Italian producers. Section 5 discusses potentials and limits of the methods and illustrates further applications and future extensions.

2. Trends in grapevine area and the age structure of vineyards

This section is aimed at providing evidence of the intense changes that took place in the grapevine cultivation over the past three decades both internationally and in Italy. The first Subsection gives a general overview of the global changes while the second one focuses on Italy. This picture helps the reader to understand the background behind the phenomena that will be assessed in Section 4.

2.1. The World and Europe at a glance

During the past three decades, the world grapevine cultivation has progressively decreased even if at non-constant rates (Fig. 1). The reduction was in place even before than that, however the trends in the previous decades were more variable, with phases of reduction alternated with expansions. Fig. 1 shows that the overall reduction is basically due to the decline of the cultivations in traditional producing countries such as Spain, France and Italy, while in the so called “New wine world”, in the same time span, cultivated areas remained approximately constant. As a consequence of these different trends, the role of the traditionally producing countries has significantly reduced from about 42% to about 33% of world area cultivated with vines. Clear enough, despite this reduction these three countries remain major players in the world wine markets. Thus, the inner dynamics of the sector in those areas affect the overall supply and market equilibrium in the present as well as in the future.

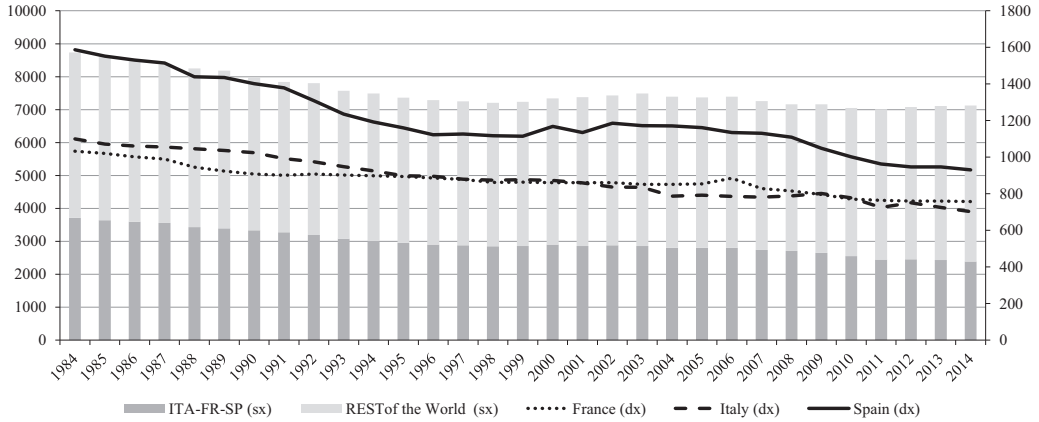

Fig. 1. Long run trends in grape cultivation around the world (000 ha). *Source*: our elaborations on OIV (International Organization of Vine and Wine) data.

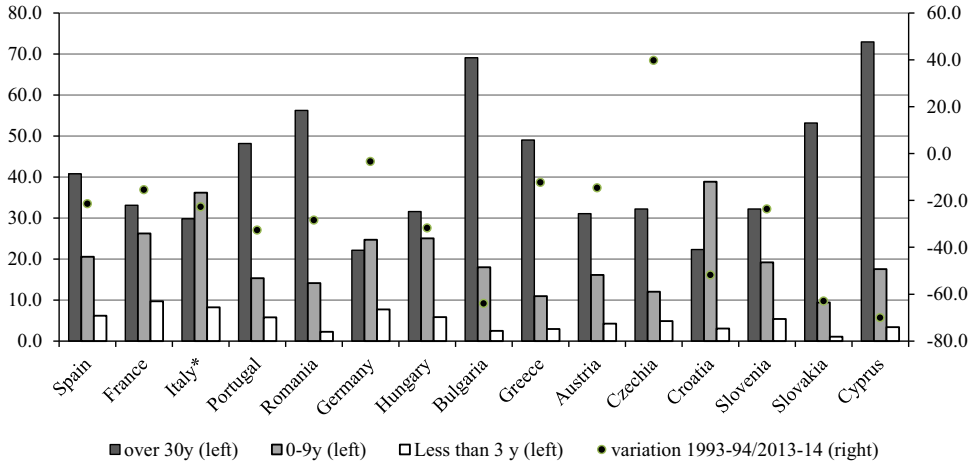

Fig. 2. The age structure (in %) of vineyards in some EU Countries (2015). *Source*: our elaborations on OIV (International Organization of Vine and Wine) data.

With the help of data produced by an *ad hoc* survey conducted by Eurostat in some EU member State, it is possible to explore the age structure of vineyards for these few countries (Fig. 2).[1] These appear in Fig. 2 in a descendent order (from left to right) according to the extension of their wine grape area. At a first glance it is clear how the presence of old vines is widespread almost everywhere: in many countries the share of plants with more than 30 years is at least 30–40% or even more. On the other hand, young vineyards (less than 10 years old) represent shares of less than 20% in many countries and are higher than that only in a few ones. The smaller bars in light gray measure the share of land occupied by new plantations (less than 3 years). These are less than 10% in all the examined countries.

The little dots in Fig. 2 measure the rate of change of total vineyards cultivation in each country in a 20-year time span, that is, from 1993-94/2013-14 (the percent rate of change is measured on the right axe that span from negative to positive values). Data indicate that land is reducing everywhere with the only exception of Czechia, a country with a very limited vineyard area (14 thousands hectares (ha) in 2015). The extent of the reduction is quite remarkable in many countries. It is worthwhile to pinpoint that data clearly suggest a relation between the decline of the cultivation and the ageing of the plants: where the correlation coefficient between the two variables is 0.585. This last evidence confirms that the analysis proposed in this paper addresses an issue that is relevant far beyond the case of Italy.

2.2. Trends in the demographic structure of Italian vineyard

Italy has been chosen as a case study for this first presentation of the methodology. As previously stated, the role of Italy in the global wine sector, the intense decline of the vineyard area in the last decades and the related changes in the age distribution of the vine cultivation, are all aspects that well explain the choice. It is worth presenting a few general figures of the Italian wine grape cultivation before introducing the rationale and algebra of the demographic balances.

The last National Agricultural Census (2010) registered a total wine grapes area of about 600 thousands ha. Table 1 shows the changes in the Italian vineyards across forty years (1970–2010). In this time span, the Italian wine sector has lost a bit less than half a million hectares (-43.6%). Although the

[1] Italian data come from the National 2010 Census.

Table 1
Italy: Vineyards 1970–2010.*Source*: our elaborations on data by ISTAT

time	Cultivated area (000 ha)	Change (000 ha)	Percentage change
1970	1109.6	-46.2	-4.2
1982	1063.3	-200.9	-18.9
1990	862.4	-204.2	-23.7
2000	658.2	-32.5	-4.9
2010	625.7		
1970–2010		-483.9	-43.6

cultivation has been reducing progressively along the entire period, the reduction has been particularly sharp between 1982 and 2000.[2] Then, in the first 10 years of the new millennium, the negative trend slowed down significantly. This long-term decline took place in almost all the diverse Italian regions from North to South.

Fig. 3 shows the age structure of the Italian vineyards and its changes along time. In 2010 the three age classes are similar with about one third of total vineyards each; in other words, plants with 30 years or more occupy approximately the same extension as plants of less than 10 years and of those aged 10–29. Compared to 2000 the age structure has changed. In fact, the increase in the share of younger plants, due to an increase of new investments (Sardone et al., 2012), goes together with a sharp increase of the share of land with old and very old vines (from 26% to 31%). In particular, this increase in the share of cultivation with older plants is continuing since 1990. Clear enough, vine growers are keeping old plants in place instead of investing in renewing the cultivation.

3. Methodology: a proposal for assessing the ageing dynamics of the vineyards

The analysis here proposed illustrates a measure of the ageing dynamics of vineyards. The demographic balancing equation at the core of our proposal is simple and commonly used in the field of human population demographic analysis (Haupt et al., 2011; Livi Bacci, 1984; Rowland 2003). The equations have been, obviously, adapted for being applied to vines population dynamics. Although, biologist and ecologist have extensively studied plant demography so far, their interest has been mainly on individual spontaneous plants and/or on their populations (Franco and Silvertown, 2004; Harper and White, 1974). On the contrary, demographic analyses are less common in the literature with reference to cultivated plants and, to the authors' knowledge, there are no contributions so far devoted to assessing the age structure of cultivations and its evolution over time.

The methodology relies on the calculation of demographic balances by age class of plantations within a definite time span and in a reference area. There are two starting points of the reasoning: i) the longevity of any plantation is related both to the physiology and to economic results (expected costs and revenues); ii) the rate of renewals depends on investments decisions subject to economic incentives, including those eventually set by policy interventions, that change over time.

Now, focusing on the life of vineyards, the following steps can be depicted:

a) It starts at year 0, when the young grapevines are planted, and there are neither grafts nor significant replenishments over the same area.[3]
b) The average economic life of the grapevines is here set at about 30–40 years. Some vineyards are explanted starting at 30 years and some others that may remain in production until about 50 years. Actually, despite in some cases vineyards of 50 years and more can still be well producing, Authors commonly agree that the average life of a vineyard is approximately 25–35 years (Eynard and Dalmasso, 1990; Fregoni, 2013). From that moment onwards, vineyards are considered old and usually start to be explanted.
c) Vines older than that should commonly be considered non-desirable due to different reasons such as: vine varieties may have become out of fashion; training systems and other features of the vineyard itself may not allow new technologies to be adopted; reductions in productivity may be severe and quality drawbacks may arise, even if in some cases older vines provide high quality grape. With respect to this last point researchers as well as practitioners have different views and the influence of the environment as well as of traditions may play a role (Eynard and Dalmasso, 1990; Fregoni, 2013; Todorov, 2012). It is worth recalling that, for example, in Italy the end of vines life is commonly anticipated compared to France where old and very old vineyards (older than 40–50 years) are more frequent and some very old cultivations producing good wine can be found.
d) Commonly, vineyards older than 50 years old are regarded as exceptional for market oriented efficient production units. Such old cultivations may, however, remain in place if farmers are not willing to invest in replanting new vineyards in cases where these do not fully remunerate inputs or in cases where farmers do not have the financial capabilities for making such investments.
e) Explantations that occur to younger grapevines may be justified as follows: i) non-recoverable illnesses; ii) need to change grape varieties and/or to modify the training system; iii) changes in the use of land. This may include: changes in the agricultural crop or switch to non-agricultural uses and/or land set-aside. These changes may be influenced by the market, by farms competitiveness, as well as by sectoral policies.

[2]The National Agricultural Census in Italy has been usually referred to the first year of any decades. However, in the Eighties there was a delay in the implementation of the surveys so that in this case data are refereed to year 1982.

[3]With reference to viticulture, new grafting techniques have been recently developed in order to avoid the necessity of making new plantations for changing variety and/or for any other purposes; however their use is limited and restricted to quite young plants (Zufferey and Maigre, 2008).

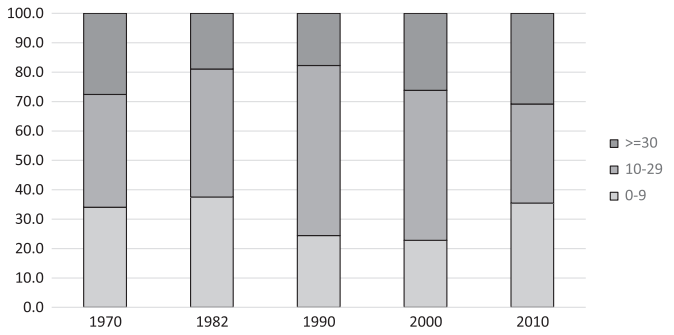

Fig. 3. The Italian vineyard by age class of the plants (%). *Source*: our elaborations on data by ISTAT.

Each of the recalled stages in a vineyard life corresponds to producing decisions that may be influenced by policy incentives and/or by mandatory rules, as it is the case for the EU wine sector in the time span under analysis.

3.1. The demographic balances of vineyards by age class

Following the above considerations, the dynamic equilibrium in a vineyard is defined here as a situation where the total land used for wine grapes is constant over time and the shares of vineyard that falls in the different age classes are equal and time invariant for all the age classes. In this frame, any changes of this balanced demographic structure is a consequence of alterations occurred that brake the equilibrium with effects that will remain for a long time after the perturbing factor itself ceased, as it always is for all long-lived populations.

Formally, in a situation of dynamic equilibrium, we have

$$C_i^{t1} = C_{i+1}^{t2} \tag{1}$$

And, in general terms, any age class Ci at moment t1 changes into the subsequent age class Ci+1 at subsequent moment t2, where the distance between the two moments (t1 and t2) is exactly the same as the width of each age class.

Where:

1) C is the consistency (in terms of hectares) of each 10 years age class.
2) *t1* and *t2* indicate the subsequent moments when the data are recorded. In our case these moments are 10 years distant. In this way we are sure that, in principle (and assuming that the plants are evenly distributed within each age class), all the units (i.e. hectares with vineyards) that where in one age class at moment t1, will be in the subsequent age class at moment t2.
3) *i* indicates the class and it goes from *1* to *u* (the last, or eldest, age class);

In a dynamic equilibrium, at moment t1 the distribution across age class is uniform, so that the entire population is structured as follows:

$$C_1^{t1} = C_2^{t1} = \ldots = C_u^{t1} \tag{2}$$

and:

$$\sum_i C_i^{t1} = POP^{t1} \tag{3}$$

where POP stands for the entire population including all age classes.

Likewise, at moment t2:

$$C_1^{t2} = C_2^{t2} = \ldots = C_u^{t2} \tag{4}$$

And:

$$\sum_i C_i^{t2} = POP^{t2} \tag{5}$$

Where, Eqs. (4) and (5) are, respectively, the same as Eqs. (2) and (3).

Putting together (1)–(5) we also have:

$$POP^{t1} = POP^{t2} \tag{6}$$

Which means that the entire population at moment t1 (POPt1) changes into the entire population at subsequent moment t2 (POPt2), where the distance between the two moments (t1 and t2) is exactly the same as the width of the age classes.

Clear enough, the dynamic equilibrium implies that, in each moment of time the newly planted vineyards C_1 occupy exactly the same area than the ones just explanted:

$$C_1^{t2} = C_u^{t1} \tag{7}$$

In this way,the size and age structure of the population remains unchanged.

Differently, in case we observe that:

$$C_1^{t2} \neq C_u^{t1} \tag{8}$$

the newly planted vineyards C1, at moment t2, do not occupy exactly the same area than the ones just explanted. This means that the population is changing size and age structure:

$$C_u^{t1} - C_1^{t2} \neq 0 \tag{9}$$

Furthermore, if it is, for example:

$$C_3^{t2} < C_2^{t1} \tag{10}$$

This means that all vineyards belonging at the age class C2 at moment t1 are not totally transferred into the subsequent age class C3 at the subsequent moment t2: vineyards in age class C3 at moment t2 are fewer than those belonging to class C2 at moment t1 indicating that early explantations have occurred.

By applying these simple principles (and calculations) to any permanent cultivations, it is possible to detect and measure the presence of demographic unbalances in the population itself.

3.2. The projection scenarios

The demographic balance equations can be also used for getting insights about the development of the age structure and overall size of any permanent crop area. This is done by projecting actual data into the future.[4]

[4]For a conceptually similar exercise applied to populations of farmers and agricultural workers after exodus following the decline of the sector that accompanies economic growth see Carbone (1996) and Carbone and Subioli (2011).

name	first scenario (reduction)	second scenario (stability)	third scenario (expansion)
synthetic description	explores the long-term effects of the 2000-2010 trends	explores the effects of the end of early explants and of new plantations limited to replacing explant of old vineyards.	explores the effects of the end of early explants and of the application of the provisions of Eu Reg. 1308/2013
new entry	by hypotheses they remain the same as those observed between 2000 and 2010	they limit themselves to replacing only the surfaces explanted for old age	the investments for new plants extend up to the maximum limit allowed by the OCM
early explants	follow the trend of 2000-2010	the early explants are canceled	the early explants are canceled
explants of old vineyards	balance rates as in 2000-2010 (44% of the areas aged over 40 and the total surface area over 50 years of age leave production)	balance rates as in 2000-2010 (44% of the areas aged over 40 and the total surface area over 50 years of age leave production)	balance rates as in 2000-2010 (44% of the areas aged over 40 and the total surface area over 50 years of age leave production)
total trend	the total vineyard area reduces	by hypothesis the total surface remains unchanged	the total vineyards area grows
bond 1%	it is not considered	it is considered but does not become effective	it is considered and effective
demographic structure	strongly rejuvenated	unbalanced: few young and many elderly people	substantially balanced, with good presence of young impervious vines and in intermediate classes

Fig. 4. Main features of the three projection scenarios.

Here again it is worthwhile pointing out that the method only provides simple projections based on assumptions on how the life of plants is featured, on producers' investment decisions and on the policy framework. By its very nature, the method cannot provide complex forecasts as it is not a model where the variables interact and/or follow complex patterns of change over time. A number of factors that affect demand trends, dynamics of competitiveness, inter-sectoral linkages, and so forth, are left out of the picture. The method does not seek anyhow at providing a realistic picture of the future features of any permanent crop sector (not even with respect to the dimension of the productive base or to its age structure). Nevertheless, we affirm that the method is valuable. as it allows observing the automatic inevitable transformation over time of the age structure of perennial cultivations. Furthermore, it allows comparing the outcomes of different premises. Even if these premises -and their projected consequences- may seem extremely unrealistic or naïve, they provide useful boundaries to the set of the possible future outcomes. To put it differently and more concretely, what we wish to demonstrate is that our method could be useful to policy makers in case they need to evaluate the effects of the introduction of incentives, or disincentives, to new plantations as it allows them to take into account the future consequences of the measure they seek at introducing presently.

At the second step of the analysis of the Italian vineyards case study, three different scenarios in 2020 and 2030 are built which provide useful indications of possible future consequences of present actions and tendencies. In this way we seek at understanding how the Italian vineyards could possibly develop within the frame of the present set of European rules that will be in place until 2030 and under different sets of hypotheses for producers' behaviors. In particular, the focus is on the resulting overall extension of the vineyards and on their demographic structure. The projections rely on a set of hypothesis regarding the extension of new plantations and of extirpations, for both young and old vines.

The scheme presented in Fig. 4 summarizes these scenarios and allows for easy comparisons:

1) The first scenario simply extends the same tendencies that were observed in 2000–2010 to 2010–2020 and 2020–2030. The new rules introduced by the European regulation EU Reg. 1308/2013 in this case are not taken into account (European Union, 2013). The first hypothesis considered in order to frame this scenario is that trends in new entries for 2010–2020 and 2020–2030 remain just the same, in absolute terms, as those observed for 2000–2010. Please note that new entries (0–9 age class) include young vineyards that replace explantations as well as new cultivations initiated on land not previously used for producing wine grapes. Also with respect to explantations- both early exits and explantations of old vines- the scenario leaves future trends unchanged compared to those observed in 2000–2010. The scenario does not claim any realism as its purpose is to provide insights on what would have been the long run outcomes of the actions undertaken, and of the trends in place, in the recent past.
2) In the second scenario, we explore the consequences of a total halt of early exits. It is supposed that there will not be early exits as a combined effect of the change in the EU policy and of the partial regained competitiveness of Italian wines. It is worth mentioning that early explantations are actually expected to significantly slow down also in the light of the non-marketability of the plantation rights set by the new EU Regulation 1308/2013 (Deconinck and Swinnen, 2015). Only the elderly vines, those in the upper two age class, are supposed to be explanted. In particular, exits involve 80% of grapes that reached 30 years old and 100% of grapes with 40 years old and more (i.e. the same exit rates as in 2000–2010).
3) The third scenario assumes an increased rate of entries: young vineyards expand in each period at the maximum rate theoretically allowed by the Eu Reg. 1308/2013 that rules the wine CMO 2014–2030. This threshold is set each year at 1% of total grapevine area registered in the previous

Table 2a
Italian vineyards by age class (000 ha).*Source*: our elaborations on data by ISTAT-National Institute of Statistics

Age classes/ time	0–9 (I)	10–19 (II)	20–29 (III)	30–39 (IV)	> 39 (V)	total
1990	208.1	313.1	179.8	100.7	50.4	852.0
2000	150.1	155.6	180.4	114.7	57.4	658.2
2010	221.8	126.9	84.2	128.5	64.3	625.7

Table 2b
The demographic balances of Italian vineyards by age classes.*Source*: our elaborations on data by ISTAT-National Institute of Statistics.

Age classes/time intervals	new entries[a]	from I to II	from II to III	from III to IV	from IV to V	out of V age class	total explantations	overall balance
	absolute values (000 ha)							
1990–2000	150.1	-52.5	-132.6	-65.0	-43.4	-50.4	-343.9	-193.8
2000–2010	221.8	-23.2	-71.4	-51.9	-50.5	-57.4	-254.3	-32.5
	percentage values							
1990–2000	72.1	-25.2	-42.4	-36.2	-43.0	-100.0	-40.4	–
2000–2010	147.8	-15.5	-45.9	-28.8	-44.0	-100.0	-38.6	–

[a]new entry rates are in percentage of the newly planted vineyards at the beginning of the decade.

year. In particular, in order to estimate the size of 0–9 age class at 2020 the available official data for years from 2010 to 2017 have been used (SIAN dataset) while for the remaining years the replenishments have been set at 10% of the total 2010–2020 explants (see below for details on this), while the new plantations are assumed to expand to their maximum value (1% of the previous year total vineyard land). For 2020–2030 the estimation is made in the same way as for 2018–2020, but for the entire decade. As for explantations, this scenario works exactly the same way as the previous one.

3.3. Data sources

The analysis presented in Section 4 is based on statistical data on vineyards released by the National Statistical Office (ISTAT). These are Census data collected every 10 years on the whole Italian farm population. Land cultivated with wine vines can be grouped in the following age classes: 0–9; 10–19; 20–29, 30 and more. With respect to the last class, this would be 10 years large only in case vineyards were all explanted at 39. However, this is not the case as elder cultivations occupy significant portion of the whole cultivated land. Detailed data for the elderly vines are released only with respect to 2016–2018 by SIAN (Sistema Informativo Agricolo Nazionale) where are contain updated data of vine sector. Thus, we assumed that the age distribution for wines elder than 30 years old in the past decades was just the same than what we observe nowadays. According to this hypothesis, plants aged 30–39 are two thirds of those elder than 30 while plants 40–49 years old represent the remaining third. Last, all grapes are supposed to be explanted when they are over 50 years old. The data from ISTAT and MIPAAF used for the present analysis are freely available and downloadable by the websites of these Institutions; while data released by SIAN are available only upon request. We used MIPAAF data relatively at the new plant system as required by Reg. 1308/2013. This system fixes the maximum annual limit of new plants authorization at 1% of entire Italian vineyard area.

4. Results and discussion

4.1. The age dynamics of Italian vineyards 1990–2010

Data presented in Tables 2a and 2b and in Fig. 5 show that the sharp reduction of the overall cultivated area with vines between 1990 and 2000 (−193.8 thousand ha) was accompanied by significant inner modifications of the vine population. Specifically, tables show that the extension of the younger vineyards reduced from 208.1 to 150.1 thousand ha in the decade 1990–2000 and raised again in the decade 2000–2010 to 221.1 thousand ha. At the same time, elder plantations enlarged progressively: vines of age class 30–39 and those with more than 39 years extend to about 151 thousands

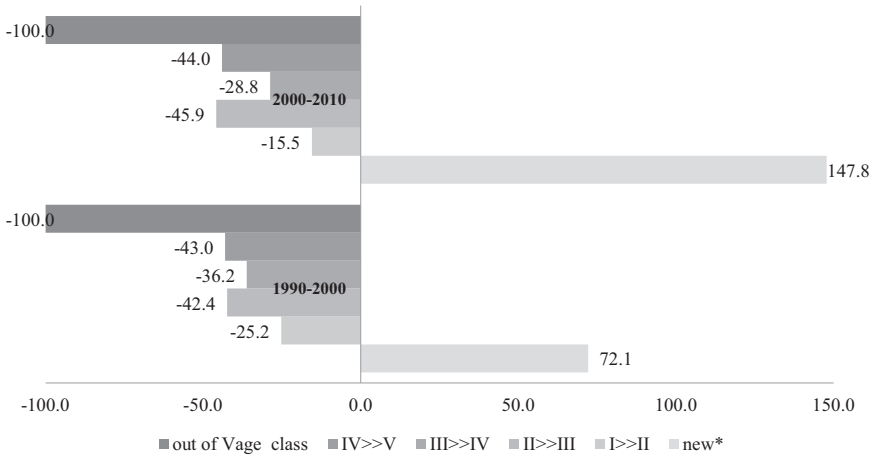

Fig. 5. The demographic balances (%) by age class of vineyards 1990–2000 and 2000–2010. *Source*: our elaborations on data by ISTAT (National Institute of Statistics).

Table 3
Projection Scenarios: demographic balances (2020 and 2030).*Source*: our elaboration on ISTAT, SIAN, Mipaaf data.

time intervals/ age classes	2000-10	2010-20	2020-30	2000-10	2010-20	2020-30
	balances (000 ha)			balances (% values)		
	first scenario (reduction)					
new	221.8	221.8	221.8	147.78401	100	100
from I to II	-23.2	-34.3	-34.3	-15.5	-15.5	-15.5
from II to III	-71.4	-58.2	-86.0	-45.9	-45.9	-45.9
from III to IV	-51.9	-24.2	-19.8	-28.8	-28.8	-28.8
from IV to V	-50.5	-56.5	-26.4	-44.0	-44.0	-44.0
out of V age class	-57.4	-64.3	-72.0	-100.0	-100.0	-100.0
	secondo scenario (stability)					
new	221.8	120.8	109.0	147.8	54.5	90.2
from I to II	-23.2	0.0	0.0	-15.5	0.0	0.0
from II to III	-71.4	0.0	0.0	-45.9	0.0	0.0
from III to IV	-51.9	0.0	0.0	-28.8	0.0	0.0
from IV to V	-50.5	-56.5	-37.0	-44.0	-44.0	-44.0
out of V age class	-57.4	-64.3	-72.0	-100.0	-100.0	-100.0
	third scenario (expansion)					
new	221.8	162.7	172.9	147.8	73.3	106.3
from I to II	-23.2	0.0	0.0	-15.5	0.0	0.0
from II to III	-71.4	0.0	0.0	-45.9	0.0	0.0
from III to IV	-51.9	0.0	0.0	-28.8	0.0	0.0
from IV to V	-50.5	-56.5	-37.0	-44.0	-44.0	-44.0
out of V age class	-57.4	-64.3	-72.0	-100.0	-100.0	-100.0

hectares. The early explantations reduced from 1990–2000 to 2000–2010. In the same time span, vineyards 10–19 and 20–29 years old drastically reduced from 492.8 to 221.1 thousand ha.

The drivers of these changes were, basically three: i) the reduction of investments in new vineyards compared with the previous two decades; ii) the massive explantation of relatively young plants; iii) the extirpation of about 93 thousand elderly vines.

The decade 2000–2010 brings a general smoothing of the overall decline of the Italian vine cultivation (-32.5 thousands ha): a much smaller reduction than the one observed in 1990–2000. Furthermore, in this time span, also internal demographic changes followed a different pattern. In particular, vines explanted before the end of their economic life where much less compared to the previous decade (146.5 thousands ha), while extirpation of elderly vineyards accounted for a larger area (107 thousand ha).

Fig. 5 helps in visualizing the relative dimension of early explantations along the entire time span observed. It appears clearly that these extirpations have been more relevant than the "physiological" removal of older vines (Fig. 5 shows in the same data included in the bottom part of Table 2b).

All in all, the observed dynamics and the resulting changes in the demographic structure of vineyards in the study period, indicate that, although still unbalanced, the sector has started to rebalance. Its size is definitely smaller as a consequence not only of present decisions (i.e. early explants) but it is also the result of reduced investments in previous years as well as the ageing of plantations that enlarged the production base many decades before.

In the next sub-section, the results of the projections at 2020 and 2030 will help understanding under which conditions the rebalancing process will possibly continue and what the pace of the process will be.

Table 4
Projection scenarios: Size of vineyard and age by class.*Source*: our elaboration on ISTAT,SIAN, Mipaaf data.

time /age classes	2010	2020	2030	2010	2020	2030
	000 ha			%		
	first scenario (reduction)					
0–9 (I)	221.8	221.8	221.8	35.5	36.4	37.4
10–19 (II)	126.9	187.5	187.5	20.3	30.7	31.6
20–29 (III)	84.2	68.7	101.5	13.5	11.3	17.1
30–39 (IV)	128.5	60.0	48.9	20.5	9.8	8.2
> 39 (V)	64.3	72.0	33.6	10.3	11.8	5.7
total	625.7	610.0	593.4	100.0	100.0	100.0
	second scenario (stability)					
0–9 (I)	221.8	120.8	109.0	35.5	19.3	17.4
10–19 (II)	126.9	221.8	120.8	20.3	35.5	19.3
20–29 (III)	84.2	126.9	221.8	13.5	20.3	35.5
30–39 (IV)	128.5	84.2	126.9	20.5	13.5	20.3
> 39 (V)	64.3	72.0	47.1	10.3	11.5	7.5
total	625.7	625.7	625.7	100.0	100.0	100.0
	third scenario (expansion)					
0–9 (I)	221.8	162.7	172.9	35.5	24.4	23.6
10–19 (II)	126.9	221.8	162.7	20.3	33.2	22.2
20–29 (III)	84.2	126.9	221.8	13.5	19.0	30.3
30–39 (IV)	128.5	84.2	126.9	20.5	12.6	17.3
> 39 (V)	64.3	72.0	47.1	10.3	10.8	6.4
total	625.7	667.6	731.5	100.0	100.0	100.0

4.2. *Projection scenarios: hints on possible future trends*

Tables 3 and 4, together with Figs. 6 and 7, help understanding and comparing the outcomes of the different scenarios designed as described in Section 3, both in terms of total area and of age structure:

The first scenario can be considered as a *reduction setting*. In fact, leaving future trends unchanged compared to 2000–2010 brings the consequence that the overall vineyard area would continue to reduce progressively. In 2030 it would be less than 600 thousand ha. However, it is worthwhile to pinpoint that the age structure of the cultivation would significantly improve thanks to different dynamics: i) the relatively abundant new entries; ii) the hypothesized extirpation of a large quota of elder vineyards. Differently, the dynamics within the central age classes are more mixed, with a pick of exits for plants between 20 and 29 years in both decades.

The second scenario brings *stability* by construction. In fact, the hypothesis underlying this scenario (see 3.2) is basically that of a stable overall extension of the vineyard area that remains at the 2010 value of 625.7 thousand hectares. As for

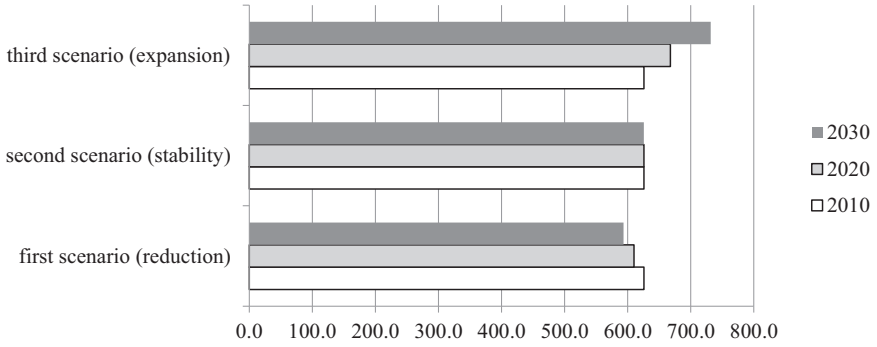

Fig. 6. Total vineyards area in Italy under different scenarios (000 ha).

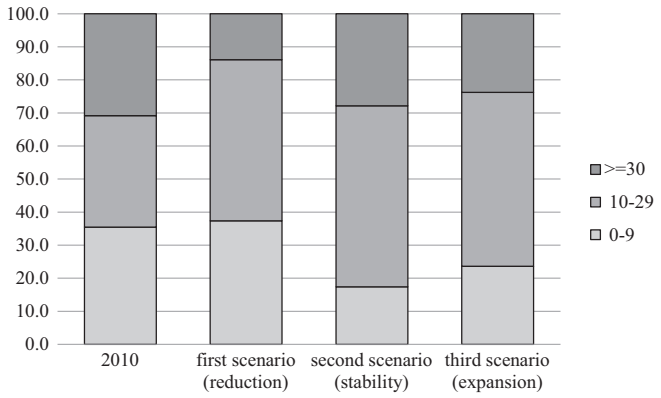

Fig. 7. The Italian vineyard by age class: 2010 and projections at 2030.

the new entries, these are limited to 120.8 and 109 thousands hectares for 2020 and 2030, respectively. These figures correspond to shares of 19.3 and 17.4% of 2020 and 2030 total cultivated area. The 10–19 and 20–29 age classes represent about 55% of 2030 area, while the shares of elder classes reduces a bit (from 30.8 in 2010 to 27.8% in 2030). However, the scenario is somehow pessimistic due to the hypothesis concerning the new entry rate; in fact, this is limited to allow exact replacement of extirpations of old wines. In other words, in this case producers are supposed not to have resources for investing in the expansion of the cultivation and/or these investments are considered not to be worth. Despite the production base is, by construction, unchanged, age structure is the worst possible among the alternatives set, with a smaller proportion of new plantations and a very large share of elderly vineyards. All indicates a situation in which producers have low interest in investing in the sector and the future vitality is questioned.

Last, the third scenario depicts a completely different situation featured by the expansion of the cultivation. This picture is to be regarded as well optimistic as it assumes that producers will continue to push the Italian vineyard to expand further. In fact, new vineyards expand in each period at the maximum rate theoretically allowed by the Eu Reg. 1308/2013 that rules the wine CMO 2014–2030. The outcome of these tendencies in a twenty-year time span is an overall sharp increase of the cultivated area that would be around 730 thousand ha, with an almost balanced age structure. Clear enough, this scenario would be only compatible with a further reinforcement of the competitive advantages of Italian wines in a context of robust positive trends of world wine demand.

It is also worth making a comparison of the results delivered by the three scenarios and discussing their economic and policy implications. As for the first scenario, this helps understanding how long is the time length in which the consequences of the past policy framework (basically at work between the sixties and nineties of the last Century) together with the stakeholders' behaviors, do impact on the sector due to its inherent inertia. This scenario also shows to what extent the new plantations that farmers started to put in place in the new Century can contribute to rebalancing the production base.

Differently, the second scenario shows that also a framework of stability of the cultivated area is not capable to contribute to rebalancing the age structure of the Italian vineyard; on the contrary, this would continue to shift towards an elderly population where aligning supply with demand in terms of vines varieties and production techniques will be increasingly tough. Additionally, this progressive ageing will, in turn, be the premise for further reduction of the production base.

The third scenario is totally different compared to the others. Its relevance mainly resides in its capacity to show that, under the actual European policy framework, the Italian wine sector can still regain its vitality and it is not "condemned" to reduce even more than what we witness presently. The production base can enlarge, and the age structure can improve, with significant implications in terms of aligning vine varieties to demand and of introducing innovations in the production process. Clear enough, the entity of the investments required at farm and processor level as well as along the whole complex chain is extremely relevant. The necessary investments involve capital, technical and managerial know-how and governance capacity for the alignment of the whole chain.

5. Concluding remarks

This paper proposes a methodology for assessing the demographic dynamics of trees cultivations. The method is based on the adaptation of the demographic balance index commonly used to analyze human populations for the study of the demography of perennial plant populations. It presents an

application to grapevine cultivation; however, any other perennial cultivation may be analyzed likewise. Also, it has been shown how the methodology can help detecting the long run effects of planting and of explanting decisions. It can be applied to the analysis of past trends and on how these affect the extension and demography of present cultivation. It can also provide projections of the future demographic structure depending on present cultivation investment and/or disinvestment decisions.

It is, useful to repeat once more that the method, when used for projecting tendencies into the future, provides only a mechanical tool for assessing how the present population will evolve under a set of assumptions on producers and policy makers behaviors. These assumptions represent the necessary frame that feeds and defines the scenarios. Clearly, the assumptions to be made can be different according to different interests of the researcher and/or according to different focuses of the analysis. The comparisons of the results obtained under these different sets of assumptions add interest in the method. However, it shall be never forgotten that these is not a forecast model and it does not account for inter-sectoral relations, competitive factors and so forth. The design stands all in the assumptions about planting and explanting decision and in the design of the lifetime of the cultivated plants.

The insights provided by the method can be useful under a number of circumstances and for different kinds of stakeholders. Producers may be interested in assessing the medium-long run effects of their present actions (e.g. enlarging/renovating their plantation or reducing it, changing the varieties they cultivate or keeping old varieties, old plants, old training systems) in terms of expected productivity, quality and possible matching with demand trends. It is worth underlining that these are key goals especially for producers acting in fast changing markets like those for wines. In addition, policy makers may find the method much useful in case they shall consider introducing measures targeted at modifying the investment behaviors of producers in the field of perennial crops that need to project the consequences over time of present actions. We argue that such a tool wood have been highly beneficial to the European policy maker at the time when many structural measures within the wine sector were introduced in the past.

After presenting the methodology, the paper provides an application to the Italian vineyard area. The case-study assesses past and present age unbalances as a combined effects of three circumstances: i) a progressive reduction of investments in new plantations; ii) a massive extension of early explantations; and iii) a widespread behavior of vine growers who keep in place old and very old vineyards, well beyond the commonly set limits of their economic life.

The resulting picture in 2010 is complex as it presents both shades and lights. This complexity stems from a mix of present effects of past behaviors, as well as, of present behaviors influenced by expectations for the future evolution of Italian wine competitiveness.

In particular, the exercise shows that: i) new plantations increase thanks to the regained competitiveness of the Italian wine sector (Carbone and Henke, 2010; Sellers and Alampi-Sottini, 2016); ii) at the same time, total vineyard area still faces a reduction trend. This is the result of the extreme ageing of the large area invested in the past under the strong incentives set by the CAP, especially in the sixties and seventies of the last Century. These old plantations have not been explanted (later on) due to: i) a lack of investing capacity at farm level; ii) a lack of competitiveness that featured the Italian wine sector short after the investments were made (until the nineties). The lack of competitiveness is explained by many structural and organizational features of the sector and was also enhanced by the rigid system set up within the CAP, from 1980 onward, that was basically aimed at limiting the excessive production capacity. Summing up, the complexity and patchy nature of the Italian vine cultivation along the last decades is reflected in the extension of explants of relatively young plants (that was favored by the premia given under the CAP for early explantations), while at the same time, old and very old vines are kept in production despite grape varieties and the cultivation systems may not be any more up-to-date.

The hypothesis made for building the projection scenarios at 2020 and 2030, somehow set the boundaries of the possible future development of the production base of the wine sector in Italy. This is particularly true for the two scenarios that have been labelled as *expansion* and *stable*. Differently, the *reduction* scenario is more to be interpreted as a way for visualizing where the past set of rules and incentives have led the sector with respect to the present and to the near future. This scenario also shows how long is the time required to reabsorb the unbalances generated in the past.

The comparison of the three different situations depicted gives an idea of how open the picture is in terms of future developments. However, one point seems to be clearly made by the projections: the steep reduction that characterized the past decades and that still influences the present and, partly, the future trends, is not to be seen again in the near future as the regained competitiveness of the sector is pushing producers to invest significantly and is inducing a higher degree of flexibility in the European policy maker. Both the set of EU rules and the capacity of investing of the private sector will be major drivers of the evolution of the productive base. In this sense, the proposed analysis provides meaningful hints to policy maker,s producers' associations and all stakeholders along the chains who should undertake action in order to facilitate the modernization process in the sector.

New applications of the index focused on international comparisons, as well as on regional detailed comparisons that may include looking at single vine varieties, will add meaningful insights. For example, in-depth analysis at vine variety level may help to understand whether the evolution of the production base is in line with demand trends and, particularly, with the evolution of consumers' preferences in terms of grape varieties (e.g international varieties or native ones). The long time required for adjusting supply makes it relevant to be able to timely detect future potential supply-demand mismatches. The awareness of these mismatches is the base for undertaking action at farms and firms level, as well as for a better

coordination and alignment along the whole chain from the nurseries to the processors.

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Authorship declaration

All authors have contributed significantly to the research and they all are in agreement with the manuscript.

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