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Perceived technological regime, an empirical analysis of the italian wine industry

antonio Stasi
university of foggia
safe
antonio.stasi@unifg.it

Abstract

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Jelcodes:O33,Q00

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Keywords Technological regime; SMEs; Wine industry; Technology adoption; Absorptive capacity.
JEL Codes L20, L66, O31, O33

INTRODUCTION

Innovation is widely recognised as being at the core of companies' competitiveness and growth. Business success in the market depends crucially on the ability to develop, acquire and recombine knowledge from different sources and use it to develop new products and processes. Firms do not rely only on their internal knowledge resources, they need to find efficient ways to manage a complex set of knowledge inflows and outflows within their organisational boundaries (Chesbrough et al., 2006; Amesse and Cohendet, 2001). The ability of firms to innovate, compete and thrive is often crucially determined by their success in coping with their technological environment. However, these dynamics are so complex and uncertain that various early scientific attempts to systematise them have limited applicability. The technological regime approach (Nelson and Winter, 1982; Winter, 1984) would seem to contribute to overcoming these limitations. Assuming that economic agents are endowed with bounded rationality (Simon, 1991), Nelson and Winter claim that firms evolve through local search and, therefore, that a knowledge-based theory of production might explain why organisations may follow different strategies and innovation patterns. This body of research deals with the effect of the sector's technological characteristics on the knowledge building and innovative dynamics of the firms belonging to that sector.

Among the contributions of those scholars that exploit the technological regime model (Dosi, 1982), the characterisations introduced by Malerba and Orsenigo (1993, 1997) and Breschi et al. (2000) are particularly relevant since they add a more pragmatic and operational emphasis to the concept of technological regime. There is empirical evidence that technological regimes determine the pattern of innovative activity (Breschi et al., 2000), varying across different industrial sectors, but being invariant across different geographical contexts, at least if not mediated by the specificities of the national and local systems of innovations (Malerba and Orsenigo, 2000). There is extensive empirical evidence that industries differ in the frequency and intensity of their innovation activity. These evident and significant inter-sectoral differences in firms' innovative dynamics have stimulated the emergence of a rich stream in the economic literature that studies the common and less common characteristics of different economic sectors, and explains distinct patterns of innovative activity.

In this paper we propose an important revision to the technological regime model, by stressing the relevance of the process of firm adaptation to a chosen regime. We argue that the technological regimes described in the literature (i.e. defined by the characteristics of the technology, and invariant within the same sector) should be interpreted and elaborated by each organisation operating in a specific sector in order to be rationally implemented as the *perceived technological regime*. This paper proposes the notion of *perceived technological regime* and tests it empirically. We integrate the theory of technological regimes by including the possibility that the technological environment is differently interpreted and elaborated by each firm operating in a given sector. In this process of adaptation, which can determine a substantial cognitive distance (Nooteboom, 2002; Nooteboom et al., 2007) among firms, absorptive capacity plays a major role. We argue that firms perceive distinct technological regimes differently, and investigate the factors driving the degree of firms' perception of

the relevance of specific technologies within the same industry. We investigate the level of perception taking account of some fundamental technological properties identified in the economic literature, namely: opportunity conditions, appropriability conditions, cumulativeness conditions and knowledge base conditions (Malerba and Orsenigo, 1993). Our empirical analysis is based on emerging evidence from a technology-intensive food sector: the wine industry. On the basis of the results of an original survey of Italian wine producers, we investigate companies' compliance with different technological regimes in a highly competitive market.
The paper is organised as follows. Section 2 sets the theoretical background to technological regimes. Section 3 presents our empirical results and applies descriptive statistics and regression models to analyse the data on wine companies in Italy. Section 4 discusses the results and their implications for policy.

1 THEORETICAL BACKGROUND

1.1 THE RELEVANCE OF TECHNOLOGICAL REGIMES IN INNOVATION

The concept of technological regime defines the technological environment in which innovative and learning activities take place within each sector of the economy. Studies on technological regimes build on the key argument that firms differ in their innovation behaviour. Firms are characterised by bounded rationality and tend to evolve through local search. This dynamic may explain why even firms operating in the same environment may adopt different strategies if the context in which they interact is sufficiently complex and uncertain. In particular, in a 'rugged environment' (Levinthal, 1997), the capabilities and research efforts peculiar to different firms might induce them to follow very different paths and eventually to find distinct local optima. This can happen because firms are not aware of all their possible choices and results; instead, they work within a range of satisfactory options (Simon, 1955).
The notion of technological regime can be ascribed to Nelson and Winter (1982) and Winter (1984), who attribute to the concept primarily a cognitive meaning, by referring to the research heuristics of engineers in an industry in order to determine "what is feasible or at least worth attempting" (Nelson and Winter, 1982: 258). More generally, technological regime refers to the nature of the technology with respect to a knowledge-based theory of production in which innovation is understood as a problem-solving activity drawing on the knowledge base embodied in routines. Nelson and Winter underline that technological regime defines the technological environment in which firms' innovative activity takes place and that, in each sector of the economy, the characteristics of the technology impact on the orientation and on the intensity of the knowledge building and learning processes of the economic agents involved.
Dosi (1982) provides another fundamental contribution to the definition of technological regime by introducing the concepts of technological paradigm and technological trajectory in order to extend the research beyond the interpretation of technological change based on demand-pull and technology-

push theories. According to Dosi, a technological paradigm is a "model and a pattern of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies" (Dosi, 1982: 152). In other words, technological paradigm refers to the concept of progress through the inclusion of prescriptions on the directions of technological change that should be either pursued or ignored. Technological paradigm is analogous to scientific paradigm, which is defined as the pattern of enquiry, the tasks, the procedures and the problems to be addressed. Technological trajectory is instead characterised as a "pattern of normal problem solving activity (i.e. progress) on the grounds of a technological paradigm" (Dosi, 1982: 152), or a pattern of implementation of concrete solutions based on a paradigm.

Nelson and Winter's definition of technological regime and Dosi's definition of technological paradigm and theoretical, which hinders their empirical applicability and verification. Malerba and Orsenigo (1993, 1997) and Breschi et al. (2000) redefined the notion of technological regime in a more pragmatic and operational way that is more easily applied and tested empirically. According to them, a technological regime can be defined as a particular combination of some of the fundamental properties of technology, such as:

- *Opportunity conditions* which refer to the likelihood of a successful innovation from a given financial investment in innovation activity;
- *Appropriability conditions* which refer to the possibilities of protecting innovations from imitation and of reaping profits from innovative activities;
- *Cumulativeness conditions* which reflect the extent to which today's technological innovation depends on past innovation, and the extent to which current innovators are likely to be innovative in the future on the basis of specific trajectories and technologies;
- *Knowledge base conditions* which relate to the nature of the knowledge underlying firms' innovative initiatives.

Malerba and Orsenigo (1993) claim that, generally, the viability and the effectiveness of technology strategies and types of organisations should be favoured by high levels of pervasiveness of technological opportunities, increased levels of cumulativeness, low appropriability and a complex knowledge base. In this context, there is an extensive literature that provides empirical evidence on the pervasiveness of the notion of technological regime. Technological regime has been used to explain the existence of *sectoral differences* in terms of firm competitiveness, intensity and characteristics of research and innovation activity (Malerba and Orsenigo, 1997; Crespi and Katz, 1999), and productivity (Castellacci, 2007, 2008; Castellacci and Zheng, 2010; van Dijk, 2000; Kim and Lee, 2003). The notion of technological regime has been applied to determine firms' *structural and dynamic properties* (van Dijk, 2000) in terms of turbulence or stability in churn rates (Audretsch, 1997; Lin and Huang, 2008), to describe *market structure*, ease of entry into the market, and frequency and type of mergers and acquisitions (Damiani and Pompei, 2008; Kim and Lee, 2011). It has been used in the context of *international technological performance* (Malerba and Orsenigo, 1995), competitiveness and trade dynamics (Laursen, 1999; Laursen and Meliciani, 2002; Lee and Lim, 2001; Park and Lee, 2006). In sum, work on technological regimes highlights that technological change in economic sectors depends heavily on the characteristics defining the technological environment in which the learning activities take place (Castellacci, 2007).

Technological regimes determine the pattern of sectoral innovation activity, which varies across sectors, but tends to be invariant across geographic space, for instance, among firms in the same industry located in different countries. However, little is known about the firm-level process of technology adaptation. The technological regime model provides a good picture of the pervasiveness of homogeneous dynamics in different sectors, but does not explain how firms adapt to a specific regime. Dosi emphasizes that: "a 'disembodied' part of the technology consists of particular expertise, experience of past attempts and past technology solutions, together with the knowledge and the achievements of the 'state of the art'. Technology in this view includes the 'perception' of a limited set of possible technological alternatives and of notional future developments." (Dosi, 1982: 152).

In our view, subsequent developments in the technological regime literature still do not investigate this 'perceptive' dimension of a firm's decision to comply with a given regime, and its determinants. Thus, although we acknowledge that technological regimes drive a number of aspects of industrial change, we argue that there are a number of factors that influence how a firm 'embraces' a technology and how it is adapted by the firm.

1.2 FROM TECHNOLOGICAL REGIMES TO *PERCEIVED* TECHNOLOGICAL REGIMES

The sectoral system of innovation framework (Breschi and Malerba, 1996; Malerba, 2002, 2005) highlights that, in addition to the characteristics of the technology and of the learning process, we need to take account of other variables and trends to fully explain the sectoral pattern of innovation. Authors such as Pender (2010) and Leiponen and Drejer (2007) argue that many industries are characterised by heterogeneous patterns of innovation, which would suggest that technological regimes can vary within the same sector.

In this paper we acknowledge the fundamental properties of technological regimes and their effects on sectoral patterns of innovation, based on analysis and measurement of the technological regimes within a sector, with the aim of integrating their definition and characterisation. We propose that technological regimes, as defined in the literature (i.e. defined by the characteristic of the technology and invariant within the same sector), need to be *interpreted* and *elaborated* by the organisations operating in a given sector. This implies that a specific technology has to be "adapted" to the firm, and this process of adaptation can be affected by substantial cognitive distance between firms and, therefore, by the firms' absorptive capacity.

By interpreted we mean "the process of translating [...] events, of developing models for understanding, of bringing out meaning, and of assembling conceptual schemes" (Daft and Weick, 1984: 286), to give meaning to information before the firm learning process and other actions. In other words, through the process of interpretation, firms try to understand their position in relation to the technology, and decide their direction for the future. Interpreting assumes particular importance in relation to the level of perception of specific technological regimes, since this perception can be influenced by aspects such as the characteristics of the environment in which the firm operates, the firm's previous experience, how this experience was acquired, and the types of problems the firm needs to solve. Thus, we would expect this process of interpretation to vary from firm to firm, and have different effects that influence firms' perceptions in the formation of their particular perceived technological regime.

Another fundamental step in the creation of perceived technological regimes is elaboration of information. The concept of elaboration in this context derives from the notion of sense-making as defined by Weick (1988) and Weick et al. (2005). Sense-making is the process of giving meaning to experience, and creating shared awareness and understanding sufficient to inform the firm's actions (Weick et al., 2005). Interpreting is a component of sense-making since it refers to the effort to understand something that already exists, without creating anything new. Some of the fundamental properties of sense-making defined by Weick are particularly useful for explaining the differences in perceived technological regimes among firms. First, sense-making is grounded in identity construction; thus, the perception of the sense-maker about who he is and is becoming has a strong influence on his interpretation and action behaviours. In the context of perceived technological regimes, the identity construction principle seems to confirm that different firms with distinct backgrounds and competencies, will be likely to interpret the technological regimes in their sector in different ways. Also, sense-making is based on plausibility rather than accuracy. This means that understanding a phenomenon and taking action, may be based more on intuition and perception than on discovering the specific elements of the problem, which is precisely the concept that the notion of perceived technological regime conveys. Finally, sense-making enacts sensible environments, since the particular ways in which organisations interpret the environment lead them to undertake specific actions that in turn shape their environment. Similarly, the innovative behaviours of different firms in a sector, reflect their perception of the technological regime, and tend to determine and strengthen it. In this respect, perceived technological regimes tend to have a self-fulfilling effect.

The existence of different perceived technological regimes in one sector can be traced to the existence of a certain degree of cognitive distance (Nooteboom 1999, 2000; Nooteboom et al., 2007) among organizations. Diversity in knowledge and learning behaviours, in turn, are determined by the firms' environment, development, and different capabilities to understand, evaluate and interpret the problems and situations they are faced with. In line with the resource-based view of the firm (Penrose, 1959), which emphasizes resource heterogeneity as a fundamental source of performance differences among firms, cognitive distance is defined as difference in "a broad range of mental activity, including proprioception, perception, sense making, categorisation, inference, value judgments, emotions, and feelings, which all build on each other" (Nooteboom et al., 2007: 1017). Cognitive distance among firms will be generated by their development in different technological environments. The final effect of cognitive distance on firms' innovative dynamics will be determined by the interactions among a series of factors, the most important being absorptive capacity, measured initially in terms of R&D accumulated as technological capital (Cohen and Levinthal (1990). This has been defined as "a set of organisational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability" (Zahra and George, 2002: 186). Zahra and George (2002) propose two types of absorptive capacity: potential and realised. Potential absorptive capacity refers to the ability of firms to both acquire and assimilate external knowledge and, thus, builds directly on Cohen and Levinthal's (1990) definition of absorptive capability. Acquisition refers to identification and absorption of knowledge that has been developed externally, which is crucial for the firm's operations; assimilation refers to the presence of and adaptations to routines that allow the firm to understand and process the knowledge obtained from external sources. Thus, cognitive distance refers to the case where external R&D is the main source of knowledge needed to acquire or develop a technology. In this case, the firm is heavily dependent on external dynamics and not all firms will have the same access to these sources. It is reasonable to assume infer that each firm will develop its own cognitive and learning processes, which will vary across organisations.

Realised absorptive capacity derives from firms' capabilities to both transform and exploit the knowledge they have acquired. Transformation refers to the creation and refinement of routines that allow the firm to combine and integrate both current and newly assimilated knowledge. Exploitation refers to the routines that allow the firm to leverage existing competencies or to create new competencies to exploit their knowledge. Therefore, firms can demonstrate different ability to create and adjust their routines in order to combine new and assimilated knowledge, and to apply it. A certain degree of cognitive distance could arise from these processes, since the various firms in a sector may learn differently and develop new abilities through the performance of in-firm activities.

At the basis of the arguments in favour of the notion of perceived technological regime, is the idea that technological regime refers on the one hand to the characteristics of the technology in a sector and on the other hand, to the way that firms learn and build their knowledge bases. These cognitive processes may vary across firms with the consequence that they will differentially affect how firms interpret the different technology in their sector in relation to their various activities. In other words, if firms were asked about the opportunities, appropriability, cumulativeness and the characteristics of their knowledge bases in the context of specific technologies, it would be reasonable to expect their answers to vary because each firm will have a different perception of the characteristics and potential of these technologies. Based on these arguments we formulate the following hypotheses:

Hypothesis 1 – Firms in the same industry display heterogeneous levels of perception about the relevance of given technologies.

Along the same lines, we argue that the degree of 'positive' perception of a given technology is influenced by its adoption. The adoption of advanced technologies is closely related to productivity gains and other measures of firm performance (Beaumont and Schroder, 1997). Therefore, the decision to adopt advanced technologies depends ultimately on the benefits provided by the technology and the costs associated with its adoption (Baldwin and Lin, 2002). There is a large stream of literature that investigates the drivers of technology adoption and

highlights the fundamental role of absorptive capacity (Gomez and Vargas, 2009). Rogers (2003) is perhaps the most fundamental contribution to the investigation of the relationship between adoption and perception. Rogers (2003) stresses how firms adopt innovations on the basis of their perceived attributes and in particular their trialability. Therefore, if the degree to which a technology is perceived as being better than an older technology depends on their relative advantage, it can be argued that:
Hypothesis 2 – Firms' adoption of specific technologies influences their perception of the technology.

Finally, it is possible that different firms perceive their sector's technological regime in different ways since, for example, they have different competences and knowledge about the possible application and the future development of given technologies. This refers to the cases of cognitive distance described above. In the first example, the considered firms have developed distinct sets of knowledge, which might derive from external or internal R&D and learning processes, and which are linked to the technologies they employ in their activities. In the second case, the firms' activities are based on the same technologies, but the firms are characterised by different capabilities, which are linked to the way in which they apply their knowledge and build on it. Thus, we hypothesize that:
Hypothesis 3 – The degree of perception is influenced by the firms' absorptive capacity and networking activity.

2 EMPIRICAL ANALYSIS

The research hypotheses discussed above allow the definition of a general model for the empirical application:

$$P_{i,d} = f_d\,(AC_i, AD_i, C_i) \qquad \text{Eq. 1}$$

where,

$$AC_i = \{RD_i, NW_i, HR_i\}$$
$$C_i = \{M_i, S_i, PP_i, R_i\}$$

P is a synthetic measure of the level of perception relative to the dimensions of technological regime; *i = 1,..., N* indicates the specific technology; *d = 1, ..., D* refers to the individual firm; the function *f* refers to a system of *d* seemingly unrelated equations including the same set of independent variables and the set of technologies investigated; *AC* denotes absorptive capacity, which includes: *RD* - internal and external R&D activities, *NW* – networking characteristics, and *HR* – human resource skills; *AD* refers to the adoption of the specific technology; *C are* the control variables, which include: *M* - market and demand orientation, *S* - structural factors, *PP* - product and process characteristics, *R* - regional and geographic characteristics.
In our view, the definition of perceived technological regime completes the concept of technological regime, justifying it and rendering it more

comprehensible on empirical grounds, which often show a remarkable degree of heterogeneity in the innovative activity of firms in the same sector. In addition, specification of the effects of the cognitive distance at the basis of the differences in perceived technological regimes makes it easier not only to verify the existence in an industry of different perceived technological regimes but also to identify the determining firm characteristics.
In order to prove the validity of the notion of perceived technological regime, we conducted an empirical experiment focused on the Italian wine industry. This industry is particularly suited to the analysis of firms' perceptions since Italian wine producers typically are small sized, interact little with other firms, and depend on external R&D and technological progress to introduce major technological innovations.
To set up the experiment, we first identified valuable and promising technologies in the sector based on a review of relevant food sector publications and journals. Based on expert advice from the industry and academia, we selected the technologies to be tested according to their use and potential applications. Table 1 presents the selected technologies.

Table 1 Technologies considered for the empirical analysis

Technology	Description
Innovative Wine Machinery	High level of automatism. Reduction of energy consumption and optimization of specific phases of the wine making process such as: submerged cover fermentation, heated and refrigerated maceration, white-like red wine making, deferred maceration.
Biotechnologies applied to yeasts	Adding selected yeasts that empathize *terroir*, so local wine characteristics
Biosensors	Monitoring wine quality parameters on machineries during the wine making
Alternative wine making techniques	E.g. pre-fermentative chill maceration, through different chilling agents to increase the anthocyanin rate

In order to estimate the drivers of innovation in the wine sector, we constructed a sample of 2,000 wineries and designed a CATI (Computer Assisted Telephone Interview) questionnaire for company managers.[1] The sample wineries were randomly selected, and their number was determined by region, proportional to the number of local companies. Stratification based on company size was applied in order to obtain a more representative sample.
The questionnaire included questions to gather information on the companies, and to analyse the drivers of perception of technological regime, based on those identified in the innovation literature. The survey was available on a web-based platform. Companies were contacted by telephone to invite participation. This was followed by an email to those managers who agreed to participate, which provided our phone contact details and the link to the questionnaire. The average time taken to complete the questionnaire was 14 minutes, and the response rate was 16.8%,[2] providing 334 completed questionnaires.

[1] The universe of Italian wineries companies numbers around 380,000 (ISMEA, 2012)
[2] Sampling choices and stratification were oriented to minimizing selection bias. When compared to national winery data (Source: ISTAT 2011 - Censimento dell'Industria e dei Servizi), the sample is generally representative of all size classes (expressed as numbers of employees) with less than 4% deviation, with the exceptions of wineries with just 1 employee, which are under

The questionnaire asked for respondents' perceptions about the benefits derived from implementing the technologies listed in Table 1, firm collaboration with external agents, and firms' main sources of information for innovation. The questionnaire also collected some general information of the firm (employment, structural characteristics, etc.) and its principal destination markets. Table 2 summarises the information collected via the survey.

Table 2 Variables considered for the analysis

Category	Name	Description	Type
NW	Relationship with Universities	The company has relationship with Universities and other research institutions	Dummy
	Relationship with Winemaker		Dummy
	Relationship with other wineries and consortia		Dummy
	Relationship with Suppliers		Dummy
	Relationship with Customers		Dummy
HR	Share of employees with technical college degree	Human capital source of knowledge to implement new technologies	Number of Employees with technical college degree/number of employees
RD	Investments in R&D (share of sales)	Innovative profile of the company	Share of sales invested in R&D
	Participation to Regional and National R&D Grants		Dummy
M	Sales to foreign market	The company has ability to adapt and sell to different markets and needs	Share of sales to foreign market
	Conducting market analysis		Dummy
S	Sales	Dimension of the firm	Classes: 0-1 Mil. Euro, 1-3 Mil. Euro; 3-5 Mil. Euro; 5-10 Mil. Euro; 10-30 Mil. Euro; More than 30 Mil. Euro
PP	Share of high price wines (>15€)	Quality level of production	Share of products priced higher than 15 € per bottle
	Certification		dummy (organic, ISO 9000 and 14000 classes, EMAS)
R	Regional number of wine firms	Regional specialization	Count
AD	Adoption of Innovative Wine Machines		Dummy
	Adoption of Biotechnologies applied to yeasts		Dummy
	Adoption of Biosensors		Dummy
	Adoption of Alternative wine making techniques		Dummy
	Adoption of Innovation in vineyard		Dummy
P	Technological opportunity 1 (OPP1)	Convenience for the company to invest in this direction	Level of agreement on a 5 point scale
	Technological opportunity 1 (OPP2)		Level of agreement on a 5 point scale
	Appropriability conditions (APP)		Level of agreement on a 5 point scale
	Cumulativeness conditions (CUM)		Level of agreement on a 5 point scale
	Basic knowledge (KBA)		Level of agreement on a 5 point scale
	Applied knowledge (KAP)		Level of agreement on a 5 point scale

represented, and companies with 3-9 employees, which are over represented.

Table 3 presents the general descriptive statistics. On average, about 16% of companies' sales are exports, although some companies produce for export only. The average investment in R&D is 5% of revenue, although a value of 40% was observed in one case. 30% of the companies benefit from regional and national R&D grants; a small percentage have established relationships with a university or other type of research institution. More frequent networking is with external wine-makers, which seem to provide significant contributions to the development of new products with other wine companies and suppliers. On average, half of winery employees have technical college degree, which is the basis for good absorptive capacity in the sector. The limitations to the adoption of new technology are related to cost and uncertainty about the innovation.

Table 3 Descriptive statistics [n. = 334]

Variable		Mean	St. dev.	Min	Max
Sales to foreign market		0.158	0.247	0	1
Conducting market analysis		0.164	0.371	0	1
Investments in R&D		5.528	6.646	0	40
Participation to Regional and National R&D Grants in collaboration with Research Institutions		0.314	0.465	0	1
Relationship with Universities		0.164	0.371	0	1
Relationship with Winemaker		0.336	0.473	0	1
Relationship with other wineries and consortia		0.267	0.443	0	1
Relationship with Suppliers		0.382	0.487	0	1
Relationship with Customers		0.100	0.300	0	1
Share of employees with technical college degree		0.515	0.406	0	1
sales		2.227	1.164	1	5
Share of high price wines (>15€)		0.063	0.185	0	1
certification		0.397	0.490	0	1
Regional number of wine firms		20.215	21.217	1	84
Adoption of Innovative Wine Machines		0.209	0.407	0	1
Adoption of Biotechnologies applied to yeasts		0.242	0.429	0	1
Adoption of Biosensors		0.094	0.292	0	1
Adoption of Alternative wine making techniques		0.239	0.427	0	1
Adoption of Innovation in vineyard		0.130	0.337	0	1
instrumental variables	No adoption - development costs are too high	3.874	1.044	1	5
	No adoption - limited access to funding	4.090	0.942	1	5
	No adoption - low internal skills	2.780	1.183	1	5

No adoption - poor knowledge of the market	2.837	1.083	1	5
No adoption - uncertainty about innovations	3.122	1.045	1	5
No adoption - poor knowledge of innovations	2.805	1.100	1	5
No adoption - poor access to external skills in the neighbourhoods	2.893	1.015	1	5
No adoption - difficulties in collaborating with research institutions	3.112	1.087	1	5
No adoption - difficulties in collaborating with other companies	3.026	1.146	1	5

To test our hypotheses we first run a frequency analysis related to the dimensions of the technological regime and the adoption of technologies reported in Table 4. The figures show that adoption is strongly associated with the perception of different technological regimes. The frequencies of positive values for all technological regime dimensions increase substantially if the technology has already been adopted. For technology that has not been adopted, perceptions differ, but are fairly evenly distributed between positive and negative values. This result confirms the importance of considering adoption in a deterministic model predicting the perception of technology.

We then run an econometric test using the model presented in eq.1. First, we conduct a factor analysis of the dimensions of technological regime. The five dimensions of technological regime relative to five technologies generate a hypothetical set of 25 equations to be estimated. This allowed us to obtain one single measure of perception per technology. The model was then synthesised as a five-equation system.

The econometric specification needs to consider that perception among technologies could be interrelated, which involves the inclusion of seemingly unrelated equations for the estimation. Given the cross-sectional nature of our data, we also take account of the endogeneity of adoption: A technology that is perceived positively has a higher probability of being adopted, while already adopted technology that produces positive results is positively perceived by management. In order to correct estimation distortions due to endogeneity issues, we estimated the model employing 3SLS (3 Step Least Square). The instrumental variables considered in the analysis were derived from the results of our survey and are related to the causes of limited adoption of new technology, and the constraints to and limitations of technology adoption (see descriptive statistics in Table 3).

Table 4 Firms' perception about different technologies

		Innovative wine machines		Biotechnologies applied to yeast		Biosensors		Alternative wine making techniques		innovation in vineyard	
		Not adopted	Adopted	Not adopted	Adopted	Not adopted	Adopted	Not adopted	Adopted	Not adopted	Adopted
Opportunity	1	19%	0%	17%	1%	28%	0%	11%	3%	15%	2%
	2	17%	3%	21%	12%	23%	4%	17%	4%	16%	5%
	3	23%	9%	33%	5%	33%	11%	28%	22%	20%	0%
	4	21%	31%	20%	35%	13%	18%	26%	35%	25%	37%
	5	21%	56%	9%	46%	4%	68%	18%	36%	24%	56%
Appropriability	1	25%	3%	23%	3%	33%	0%	15%	4%	15%	10%
	2	16%	5%	23%	8%	23%	4%	13%	6%	15%	0%
	3	19%	20%	30%	9%	25%	15%	29%	13%	19%	7%
	4	18%	27%	14%	34%	12%	19%	26%	36%	19%	32%
	5	21%	45%	9%	46%	8%	62%	17%	42%	31%	51%
Cumulativeness	1	17%	3%	18%	2%	23%	0%	12%	1%	13%	3%
	2	13%	3%	20%	5%	23%	0%	10%	6%	12%	3%
	3	17%	13%	24%	9%	24%	20%	26%	10%	19%	18%
	4	23%	20%	17%	30%	11%	20%	32%	39%	27%	24%
	5	30%	60%	20%	55%	20%	60%	20%	43%	29%	53%
Knowledge base	1	22%	2%	19%	2%	12%	5%	12%	5%	11%	8%
	2	18%	5%	25%	11%	16%	9%	16%	9%	14%	11%
	3	31%	25%	31%	19%	35%	23%	35%	23%	23%	11%
	4	18%	17%	11%	24%	23%	41%	23%	41%	24%	26%
	5	10%	51%	14%	44%	13%	23%	13%	23%	28%	45%

Table 5 Results of the 3SLS estimation, drivers of technological regime perception

		Innovative Wine Machines	Biotechnologies applied to yeasts	Biosensors	Alternative wine making techniques	Innovation in vineyard
NW	Relationship with Universities	0.142	0.405	0.356	-0.075	-0.018
		[0.479]	[0.397]	[0.379]	[0.500]	[0.508]
	Relationship with Winemaker	0.412	0.459	0.296	-0.205	0.459
		[0.339]	[0.293]	[0.278]	[0.369]	[0.370]
	Relationship with other wineries and consortia	0.523	0.457+	0.282	0.197	0.049
		[0.318]	[0.270]	[0.260]	[0.348]	[0.343]
	Relationship with Suppliers	-0.028	0.013	0.026	-0.21	-0.518
		[0.369]	[0.290]	[0.277]	[0.382]	[0.371]
	Relationship with Customers	0.058	-0.297	-0.116	0.721	-1.16
		[1.072]	[0.949]	[0.850]	[1.119]	[1.127]
HR	Share of employees with technical college degree	0.452	0.561+	0.557+	0.735+	0.965*
		[0.356]	[0.306]	[0.296]	[0.393]	[0.394]

RD	Investments in R&D (share of sales)	0.043	0.037	0.047+	0.087**	0.047
		[0.031]	[0.027]	[0.025]	[0.033]	[0.033]
	Participation to Regional and National R&D Grants	0.348	0.186	0.276	0.48	-0.005
		[0.386]	[0.333]	[0.324]	[0.477]	[0.439]
M	Sales to foreign market	-0.001	-0.007	-0.002	0.008	0.002
		[0.007]	[0.006]	[0.006]	[0.010]	[0.008]
	Conducting market analysis	0.453	0.556+	0.820**	0.414	0.624
		[0.358]	[0.323]	[0.293]	[0.392]	[0.390]
S	Sales	0.378**	0.343**	0.377**	0.513**	0.266*
		[0.105]	[0.090]	[0.085]	[0.121]	[0.116]
PP	Share of high price wines (>15€)	0.016**	0.010+	0.010+	0.011	0.021**
		[0.006]	[0.005]	[0.005]	[0.007]	[0.007]
	Certification	0.691+	0.436	0.473+	0.088	0.749*
		[0.378]	[0.297]	[0.279]	[0.396]	[0.373]
R	Regional number of wine firms	0.003	0.007	0.008+	0.004	0.008
		[0.006]	[0.005]	[0.005]	[0.006]	[0.006]
AD	Adoption of Innovative Wine Machines	0.132				
		[0.479]				
	Adoption of Biotechnologies applied to yeasts		0.851**			
			[0.273]			
	Adoption of Biosensors			0.857*		
				[0.385]		
	Adoption of Alternative wine making techniques				0.305	
					[0.744]	
	Adoption of Innovation in vineyard					1.736*
						[0.793]
R-squared		0.935	0.939	0.956	0.925	0.936

Table 5 presents the results of the econometric analysis. Perception is related to the specific technology; however, our estimates identify some key drivers that are common to all the selected technologies. Firm characteristics have a major influence on level of perception. For example, demand orientation or the commitment of companies to follow market trends (*conducting market analysis*) has a positive and significant influence on perception of innovative technologies. This applies to two of the five technologies probably because not all innovations have an impact on the final product. The level of R&D investments has a positive and significant effect on perception of technological regime. R&D commitment, proxying for technological capital in line with Cohen and Levinthal (1990), likely influences the degree of trust into new technology. Intra-sectoral relationships, and sharing of knowledge and experience among companies can have a positive effect on the perception of some innovative technologies, especially those aimed at product differentiation to maintain competitive position against competing firms. Absorptive capacity plays a major role in understanding convenience and implementability, thus the economic opportunity of investing in innovation confirms the findings in Zahra and George (2002). In the specific case of the wine industry, there is evidence that linkages between firms and universities play a significant role in increasing competitiveness for New World producers in the international market (Aylward, 2003; Morrison and Rabellotti, 2007; Cusmano et al., 2010; Giuliani et al., 2011), and contribute to making firms more technology-push oriented and adopting complex product innovations (Dell'Era and Bellini, 2009).

Firm size has a positive and significant impact on the perception of technology. Large firms able to benefit from scale economies, are more likely to consider adopting an innovation in order to maintain their competitive position in the market through a more complex division of responsibilities, e.g. internal R&D department. The production of high priced, high quality products positively affects the perception of technology. The ability to manage more complex, high quality production leads to a more positive attitude to innovations that provide further quality improvements. Certification of processes and products is related to a positive perception of new technology, confirming the hypothesis that product and process characteristic affect the likelihood of positive expectations about the ability of new technology to provide quality and efficiency improvements. The monitoring activity related to certification provides a deeper understanding of the impact of innovation. As expected, the adoption of the selected technologies has a positive impact on perception. However, our results provide evidence also of the difference highlighted by Olmstead and Rhode (2008) between adoption of mechanical and biological innovations in agriculture. Olmstead and Rhode in their seminal work investigate and compare the sources of technological progress in agriculture in the US suggested by David (1966) and Grilliches (1957). They refer to the debate over land productivity versus labour productivity highlighted in Hayami and Ruttan (1985), and conclude that there is a symbiotic relationship between these two types of innovation. However, they also note that investments in mechanical innovations over most of the 20th century, lagged behind investment in biological innovations.

Our results show also that R&D grants do not affect perception. In contrast to individual investment in R&D, grants provide an incentive to invest in new technology, but do not increase levels of perception. This questions the effectiveness of such policies for increasing the independent choice to adopt new technology. Relationships with universities and research centres should provide better information on technological innovations, but do not increase companies' perceptions of appropriability, cumulativeness and opportunity.

The hypothesis that firms perceive technology differently is confirmed as perceptions related to adoption. Our hypotheses about of firm, process and product characteristics are also confirmed, but the effect of network characteristics on perception is not supported except in the case of intra-sectoral networking. Also, collaboration aimed at participating in national and regional R&D projects does not increase the positive perception of new technology.

3 CONCLUDING REMARKS

To confirm the notion of perceived technological regime we conducted an empirical experiment based on the Italian wine sector. Wine firms are particularly suited to an analysis of firms' perception because of their strong dependence on external sources of innovation for technological and organisational improvements.

Our results confirm the existence of different perceptions among wine companies of the dimensions of technological regime . Based on the relationship between technological regime and patterns of innovation proposed by Breschi et al. (2000), it is plausible to expect that wine firms will follow innovation paradigms in line with those adopted by the other firms in the sector. Our results show that perception varies quite uniformly across the selected technologies. The correlation analysis highlights the link between perception of technological regime and absorptive capacity. Also, structural and market characteristics were shown to be important for the implementation of the technologies considered. Our results have some policy implications related to reducing or eliminating the barriers to innovation in the Italian wine sector. First, government and decision makers more generally, should take account of the strong differences in how firms interpret technological regime. Firms should also work to improve their technological knowledge bases using appropriate information tools and consultancy services, in order to encourage independent innovation initiatives. We found that R&D funding does not affect perception although it can be an important incentive for technology implementation. A positive perception of technology would increase the continuity of the innovation process. This could be achieved in two fundamental and complementary ways. Policy makers could establish means for wine producers to meet and interact regularly which would increase exchanges of knowledge and provide the opportunity to benefit from experience of others in the use of new technology. This is important in the case of wine firms which are highly heterogeneous and often isolated. Government should also encourage the development of absorptive capacity enabled by relations with industry professionals, academic experts and other wine producers. The development of absorptive capacity would allow better exploitation of knowledge and recognition of the opportunities offered by new technology.

Compliance with Ethical Standards:
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