A New Forecasting Model for the Diffusion of ISO 9000 Standard Certifications in European Countries

NEW RESEARCH

A new forecasting model for the diffusion of ISO 9000 standard certifications in European countries

Fiorenzo Franceschini, Maurizio Galetto and Giovanni Giannì
Dipartimento di Sistemi di Produzione ed Economia dell'Azienda, Politecnico di Torino, Torino, Italy

Keywords *Quality, ISO 9000 series, International standards, Diffusion, Logistics, Modelling*

Abstract *ISO 9000 standards for quality system management are involving a higher and higher number of enterprises and organizations. This paper presents a detailed analysis of certification diffusion in Italy and in some European countries with similar economic structures. Benchmarking and evolution forecasts are based on the "logistic model", traditionally used for studying biological growth phenomena. The presentation is supported by many empirical data, which show that, in many countries, the phenomenon is going to be close to saturation. Finally, some considerations about new developments, after the present "certification era", are proposed.*

Introduction

The demand for ISO 9000 quality standard certifications is continuously increasing and involving a higher and higher number of enterprises and organizations, both public (no-profit) and private (ISO 9000, 1994, 2000). The

The authors wish to thank the Agencies and Organizations that gently supplied the data utilized in the present research: ISO, EUROSTAT, Organization for Economic Co-Operation and Development Statistics Directorate (OECD) (Luxemburg), European Co-Operation for Accreditation (EA), SINCERT (Italian National System for the Accreditation of Certification and Inspection Bodies) (Italy), Italian Institute for Foreign Trade (ICE) (Italy), ISTAT (Italy), UK National Statistics (UK), Standards and Technical Regulations Directorate (UK), The United Kingdom Accreditation Service (UKAS), Centraal Bureau voor de Statistiek (CBS) (The Netherlands), The Dutch Council for Accreditation (RVA) (The Netherlands), TGA Accreditation Body and DQS GmbH (Germany), Deutsche BundesBank (Germany), Statistisches Bundesamt (Germany), The German Accreditation Council (DAR), Sweden Board for Accreditation and Conformity Assessment (SWEDAC), Sweden Statistics (SCB), Asociation Espanola de Normalizacion y Certificacion (AENOR), Instituto Nacional de Estadistica (Spain), Entidad Nacional de Acreditation (ENAC) (Spain), Association Francaise de Normalisation (AFNOR), Comite Francaise d.Accreditation (COFRAC), Ministere de l'economies (France), Mouvement DES Enterprises de France, (MEDEF), Ministry of Economic Affairs Division Accreditation (BELCERT) (Belgium), National Bank of Belgium, Central Balance Sheet Office (Belgium).

latest ISO survey (ISO, 2001) gives an updated photograph about the state of development of this process in several countries in the world.

In general, there are many reasons that "push" an enterprise toward quality certification, both exogenous and endogenous. Sometimes, certification is explicitly required by customers; in other cases it is necessary in order to concur as a contractor in national or international tenders, otherwise, it is simply used to show a real advantage on competitors (Anderson *et al.*, 1999). In addition, quality certification can become the tool by which a company operates a more organic management of its resources, on line with the continuous market changes (Mann and Kehoe, 1994; Weston, 1995; Zhu and Scheuermann, 1999).

Without exploring further the reasons for getting a certification, it is interesting to analyze the diffusion of ISO 9000 certifications over time. The phenomenon is extremely complex as a result of a large variety of factors that can influence the strategies of an organization: economic/entrepreneurial structure, merchandise sector, incentives and pushes by central Governments, and so on.

Many authors tried to analyze the effects of ISO 9000 certifications over performances and quality improvement in order to obtain effective competitive advantage (Rayner and Porter, 1991; Withers *et al.*, 1997; Beattie and Sohal, 1999). In detail, Withers *et al.* (2000) used the eight dimensions of quality (Garvin, 1987) to evaluate the impacts of ISO 9000 certification on companies' product quality. Many results indicated that quality seems to improve as a result of ISO 9000 certification, and it can also be argued that the reason for seeking certification can influence the degree to which quality is improved (Withers *et al.*, 2000).

Despite some authors tried to make an interpretation of ISO 9000 registrations and define a new perspective for their implementation (Ebrahimpour *et al.*, 1997; Docking and Dowen, 1999), an exhaustive analysis of ISO 9000 diffusion is still lacking.

In order to describe the certification diffusion process, in the present paper a detailed analysis of certification growth in Italy and in some other European countries is reported. A particular attention is devoted to those countries where the phenomenon is close to arrive at a saturation level. The methodology utilized for the analysis can be easily extended to other countries where the certification growth is still far from a stable and definitive level. Finally, some indications about new developments after the present "certification era" are reported.

The ISO survey is the starting point of the analysis (ISO, 2001). Available data concur to trace a synthesis of what has happened and what is in progress all over the world. One of the purposes of this research is to make country/regional/local governments sensible to the dynamics and times of certification, especially when certification is interpreted as a tool for stimulating enterprises competitiveness.

The paper starts with a description of the certification process in general terms. Then, from the analysis of empirical data we discuss about the strict analogy between the diffusion of certifications and the bio-systems population growth. On the basis of this association, we propose a general forecasting model to explain the diffusion of certifications in Italy and in some other European countries. The paper proceeds analyzing the tight link between the number of certifications and the entrepreneurial structure of each country. At the end, some cues about the future of ISO 9000 standard quality certifications are argued.

The model

Data analysis of the countries which firstly started certification process highlights a behavior very similar to that of a bio-population growth in a limited resource habitat, or to a diffusion process of new technologies (Pearl, 1978; Cherruault, 1983; Edelstein-Kesher, 1988; Murray, 1993; Stoneman, 1995).

Quality certification diffusion began when some companies, with the aim of distinguishing themselves in the business competition, manifested a wish to give an external and formal evidence of their organizational efforts towards quality practice. Achieving success in a more and more careful market, their number has progressively grown up with a trend almost exponential. This dissemination was promoted by central governments and by quality national system bodies, reducing administrative features and supporting the diffusion of the certification bodies in the countries. As a result of these joint actions an increasing attention of the enterprises towards the certification was manifested: inside of the organization itself, in order to increase the resource involvement; outside, to give their own customers the evidence of excellence achievement. But the increasing process does not go on without end. Caught up the interest apex, the driving push slowly begins to attenuate under the effect of some concomitant factors: the reduction of the competitive gap between certified and not certified companies, and the limited number of enterprises potentially interested to certification. So, the growth tends slowly to a gradual saturation.

Figure 1 shows the evolution of the number of certifications in some European countries (SINCERT, 2001; ISO, 2001). The curves highlight the different evolutionary stage of each country. The diffusion process is very close to the behavior of the so-called logistic systems, firstly introduced by the Belgian mathematician Pierre Verhulst (1838) in order to describe the phenomena related to a bio-population growth.

Under a set of well defined conditions (see the Appendix), the "modified-logistic-curve" for a "certus-population" (i.e. the ISO 9000 standards certified companies, hereinafter called "certus-population") is the following:

$$N(t) = \frac{N_0 \cdot K}{N_0 + (K - N_0)e^{-r_0 t}} - N_0, \tag{1}$$

where the parameters have the following meaning:

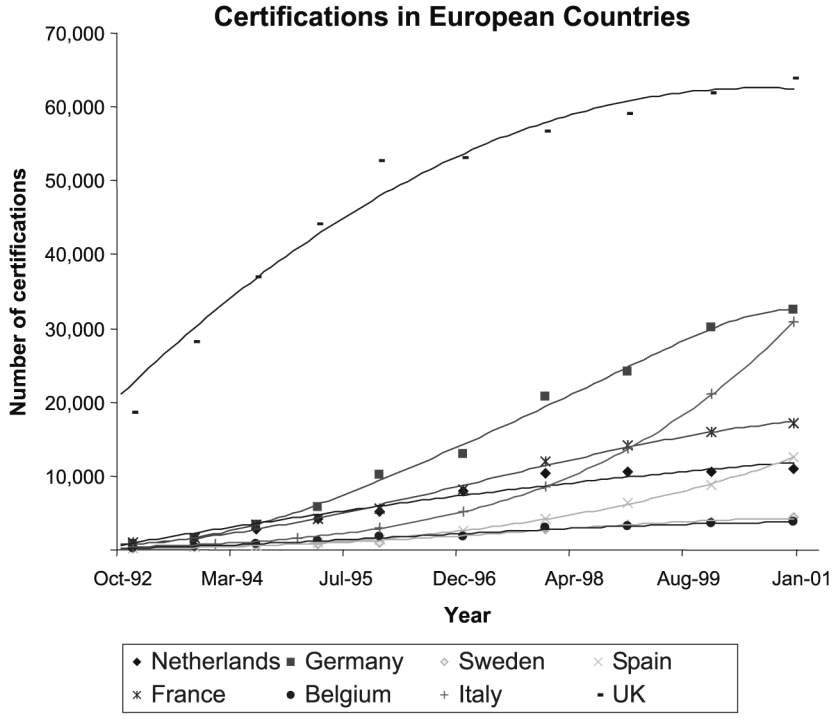


Figure 1.
The evolution of certifications in the main European countries since October 1992

Sources: ISO (2001) and SINCERT (2001)

- $N(t)$ is the number of ISO 9000 standards certified companies over time;
- r_0 is the population growth rate in the absence of intra-specific competition;
- N_0 represents the translation value to assure the condition $N(0) = 0$;
- $N(\infty) = (K - N_0)$ is the certus-population saturation level, that is the total number of companies that will be interested in the certification process.

The logistic model is also widely utilized to model the diffusion process of new technologies (Stoneman, 1995).

Forecast of the Italian certus-population growth

In this section, we will try to describe the diffusion of quality certifications by means of the logistic model. The empirical data allow making a forecast about certification growth for those countries where the phenomenon has yet to arrive at the saturation level. Looking, for example, at the certification growth in Italy (see Figure 1 and Table I), we can observe that the evolution is close to the end of the preliminary exponential growth. In this situation it is interesting to

Year	Number of certifications
1991	161
1992	348
1993	810
1994	1,589
1995	3,033
1996	5,097
1997	8,513
1998	13,690
1999	21,069
2000	30,895
2001	40,000

Table I.
Numbers of ISO 9000 standard certifications in Italy from year 1991 up to 2001

Source: SINCERT (2001)

provide a forecast of the total number of enterprises that will be involved in the certification process (saturation level), and when it will happen (saturation time).

A first consideration, that comes out from this preliminary data analysis, is that the number of certified enterprises is much smaller than the total number of potential ones. As well as for Italy, British and Dutch growths confirm this assertion (see Figure 1 and Tables II and III). Referring to the logistic model, the saturation level value $N(\infty)$ is only a limited fraction of the number of potentially interested companies.

The analysis of ISO survey data shows that the certus-population growth appreciably depends on the economic and productive structure of each country (ISO, 2001). With the aim of identifying some common evolutionary aspects of certus-populations, it is useful to consider in a deeper detail the entrepreneurial mix of each country. In accordance with a typical enterprise classification, Table IV shows the Italian entrepreneurial macro-composition from 1995 to 2000. From these values, we observe the dominant presence of sole traders category. A substantial balancing of the ratio over time of the four macro-categories – corporations, partnerships, sole traders and others – emerges too. This aspect is not only true for Italy, but also for the other European countries considered in this analysis (see Table II).

With the aim of defining a common way for reading the certus-population evolution, we suggest to compare the number of certified enterprises with the total number of corporations. These last represent the category with the larger number of certified enterprises, constituting the natural catchment for the certification issues. Table V shows the percentage rate of Italian companies that achieved the ISO 9000 standard quality certification (SINCERT, 2001).

In order to carry out a homogenous comparison among the various European countries, we applied the modified logistic model (equation (1)) on the percentage rate of certified companies (see Tables III and V). Figure 2 shows

Table II.
Entrepreneurial macro-structures of UK, The Netherlands, Germany, Spian and France

	UK (2001)		The Netherlands (2000)		Germany (1999)		Spain (2001)		France (2001)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Sole traders	578,505	35.6	272,285	47.0	2,037,230	70.6	1,651,265	62.4	1,182,352	48.4
Partnerships	358,330	22.1	122,375	21.1	357,009	12.4	105,876	4.0	38,859	1.6
Corporations (CC)	657,215	40.5	162,445	28.0	442,036	15.3	796,790	30.1	943,191	38.6
Others	28,970	1.8	22,150	3.8	49,993	1.7	91,386	3.5	278,960	11.4

Sources: Eurostat (2002), UK National Statistics (2001) (UK), Centraal Bureau voor de Statistiek (CBS) (2000) (The Netherlands), Deutsche BundesBank (Germany), Statistisches Bundesamt (1999) (Germany), Instituto Nacional de Estadistica (2001) (Spain) and Ministere de l'economie de France (2001) (France)

Table III.
Certus-population growth rate of UK, The Netherlands, Germany, Spain and France and related percentage on total corporation companies (CC)

Year	UK		The Netherlands		Germany		Spain		France	
	Number of certifications	Rate on total CC (%)	Number of certifications	Rate on total CC (%)	Number of certifications	Rate on total CC (%)	Number of certifications	Rate on total CC (%)	Number of certifications	Rate on total CC (%)
December 1986	0[a]	0.00								
December 1987										
December 1988			0[a]	0.00	0[a]	0.00	0[a]	0.00	0[a]	0.00
December 1989			58[a]	0.04	8[a]	0.00	1[a]	0.00		
December 1990			144[a]	0.09	217[a]	0.05	15[a]	0.00		
December 1991	14,000	2.13	250[a]	0.15	234[a]	0.05	59[a]	0.01		
December 1992	18,577	2.83	716[a]	0.44	790[a]	0.18	159[a]	0.02	1,049	0.11
Sepember 1993	28,096	4.28	1,502	0.92	1,534	0.35	320	0.04	1,586	0.17
December 1993			1,849[a]	1.14	2,087[a]	0.47	394[a]	0.05		
June 1994	36,825	5.60	2,718	1.67	3,470	0.79	586	0.07	3,359	0.36
December 1994							781[a]	0.10		
March 1995	44,110	6.71	4,198	2.58	5,875	1.33	942	0.12	4,278	0.45
December 1995	52,595	8.00	5,284	3.25	10,236	2.32	1,492	0.19	5,536	0.59
December 1996	53,099	8.08	7,986	4.92	12,979	2.94	2,496	0.31	8,079	0.86
December 1997	56,696	8.63	10,380	6.39	20,656	4.67	4,268	0.54	11,920	1.26
December 1998	58,963	8.97	10,570	6.51	24,055	5.44	6,412	0.80	14,194	1.50
December 1999	61,800	9.40	10,620	6.54	30,150	6.82	8,699	1.09	16,028	1.70
December 2000	63,725	9.70	11,036	6.79	32,500	7.35	12,576	1.58	17,170	1.82
December 2001							15,568[a]	1.95		

Notes: Data refer to ISO survey, with the exception of the marked ones ([a]). These last have been harmonized with those from each national accreditation and certification body

Sources: ISO (2001), UK Standards and Technical Regulations Directorate (2001) (UK), The United Kingdom Accreditation Service (UKAS) (2002) (UK), The Dutch Council for Accreditation (RVA) (2002) (The Netherlands), TGA Accreditation Body e DQS GmbH (2002) (Germany), Asociation Espanola de Normalizacion y Certificacion (AENOR) (2002) (Spain) and Association Francaise de Normalisation (AFNOR) (2002) (France)

Table IV.
Italian entrepreneurial classification

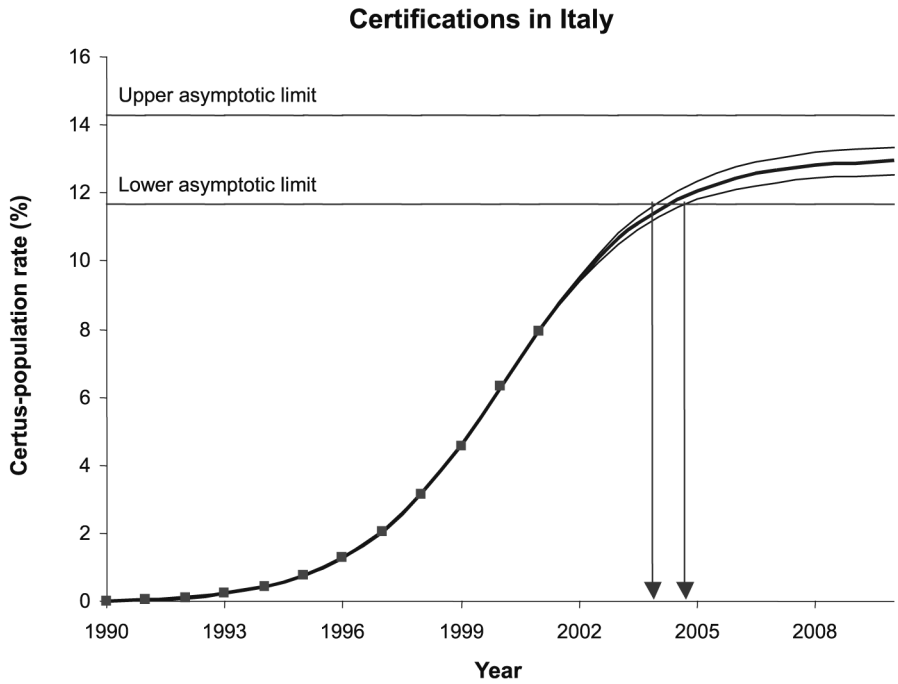
Year	Total	Corporations	Percentage	Partnerships	Percentage	Sole traders	Percentage	Others	Percentage
1995	3,578,931	386,531	10.8	751,188	21.0	2,361,689	66.0	79,523	2.2
1996	3,806,838	401,044	10.5	785,462	20.6	2,539,871	66.7	80,461	2.1
1997	4,704,107	416,197	8.8	806,234	17.1	3,399,814	72.2	81,862	1.7
1998	4,727,504	435,727	9.2	832,364	17.6	3,375,206	71.4	84,207	1.8
1999	4,774,264	459,728	9.6	849,426	17.8	3,377,230	70.7	87,880	1.8
2000	4,840,366	490,427	10.1	867,007	17.9	3,389,839	70.0	93,093	1.9

Sources: Italian Institute for Statistics (ISTAT) (2002), Italian Institute for Foreign Trade (2002) and Italian Ministry of Productive Activities (2001)

Number of corporation companies	Year	Number of certifications	Percentage rate
298,811[a]	1991	161	0.05
319,241[a]	1992	348	0.11
339,671[a]	1993	810	0.24
360,101[a]	1994	1,589	0.44
386,531	1995	3,033	0.78
401,044	1996	5,097	1.27
416,197	1997	8,513	2.05
435,727	1998	13,690	3.14
459,728	1999	21,069	4.58
490,427	2000	30,895	6.30
503,111[a]	2001	40,000	7.95

Note: [a] Data related to years 1991, 1992, 1993, 1994, 2001 have been extrapolated
Sources: SINCERT (2001) and Italian Ministry of Productive Activities (2001)

Table V.
Quality certification growth in Italy with reference to the total number of corporation companies



Notes: The curve shows the percentage rate related to the total number of corporation companies over time. The figure highlights the empirical data (squares), the fit curve (thick line), and the forecast confidence interval (95 percent) (thin lines). A tolerance interval of 10 percent around the asymptotic value (13 percent) defines two asymptotic limits: 11.7 percent and 14.3 percent (±0.1 of 13 percent). The saturation phase starts at the beginning of 2004, when the predicted curve cross the lower asymptotic limit

Figure 2.
Forecast of the Italian ISO 9000 standard certus-population growth elaborated by a modified logistic model until 2010

the estimated curve, obtained for the Italian certus-population growth. The curve has been derived by applying to the empirical data a first-order nonlinear regression fit (Seber and Wild, 1989). Table VI reports the estimated values of the model parameters, while Table VII illustrates the details of the expected Italian certus-population growth until 2010.

The estimated average asymptotic value $N(\infty)$ of the fraction of certified companies is approximately 13 percent of the total number of corporation companies. Starting from the first half of 2004, the whole amount will be contained within a ± 10 percent tolerance interval around the asymptotic value

Table VI.
Parameter values and confidence limits (risk coefficient: $\alpha = 5$ percent) for the modified logistic model (equation (1)) applied to the Italian data

Logistic model parameters	Estimated values	Lower confidence limit	Upper confidence limit
N_0 (%)	0.063	0.058	0.067
K (%)	13.07	12.66	13.48
r_0 (year^{-1})	0.53	0.52	0.54

Note: Years are numbered since 1990

Year	Progressive year (reference year 1990)	Empirical percentage rate (%)	Estimated percentage rate (%)	Lower confidence limit (%)	Upper confidence limit (%)
1990	0	0	0.00	0.00	0.00
1991	1	0.05	0.04	0.04	0.05
1992	2	0.11	0.12	0.11	0.12
1993	3	0.24	0.24	0.23	0.24
1994	4	0.44	0.44	0.42	0.45
1995	5	0.78	0.78	0.74	0.78
1996	6	1.27	1.30	1.25	1.29
1997	7	2.05	2.10	2.03	2.07
1998	8	3.14	3.23	3.14	3.18
1999	9	4.58	4.69	4.57	4.62
2000	10	6.3	6.37	6.24	6.29
2001	11	7.95	8.07	7.93	8.00
2002	12		9.57	9.39	9.56
2003	13		10.74	10.51	10.82
2004	14		11.57	11.29	11.74
2005	15		12.12	11.80	12.37
2006	16		12.47	12.12	12.77
2007	17		12.69	12.32	13.02
2008	18		12.82	12.43	13.18
2009	19		12.89	12.50	13.28
2010	20		12.94	12.54	13.33

Notes: The estimated average asymptotic value is equal to 13 percent of the total number of corporation companies. Starting from the first half of 2004, the certus-population will be contained inside of a tolerance interval of ± 10 percent of the asymptotic value (13 percent)

Table VII.
Results obtained by implementing the modified logistic model (equation (1)) with the Italian data

(13 percent). This point will mark the conclusion of the evolutionary process (see Figure 2).

According to the EA classification scheme (SINCERT, 2001), a deeper analysis of the Italian certification growth has been performed for each merchandise sector. The study has clearly evidenced a different involvement of the various sectors. Referring to the percentage rate of certified companies over the total number of corporation companies, the first three places are respectively held by sectors 19 (electrical and optical equipment), 14 (rubber and plastic products) and 37 (education). On the other hand, if we consider the average annual certification growth rate in the last three years, the first three positions are respectively held by sectors 29c (repair of personal goods and household goods), 31 (transport, storage and communication) and 29b (repair of cycles, motor-cycles and motor vehicles).

The situation in other European countries

Italian results have been compared with those of other European countries characterized by a similar economic and entrepreneurial structure. Among these, particular attention has been directed to UK, The Netherlands, Germany, Spain and France. Table II shows the entrepreneurial macro-structure of each country, while Table III illustrates the certus-population growth rate over time.

Table VIII shows the pooled results of the analyzed European countries, obtained by the modified logistic model (eqiuation (1)). The Tables provide the parameters r_0, N_0 and K and the forecasts for the asymptotic saturation values of each country (for the next five years).

Figures 3-7 report the empirical points, the fitted certus-population growth rate, and their respective confidence intervals (95 percent).

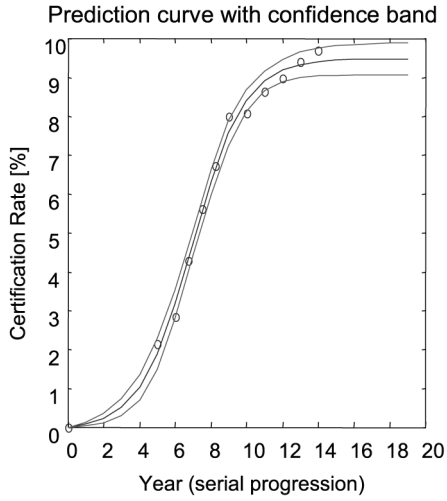
Data related to the Italian, British, Dutch and German situations show many analogies, but also some meaningful differences. First of all, certus-population growth is not synchronized in the different countries. The starting times and the diffusion dynamics depend on the local political and economic conditions. The common element is the shape of the evolution growth that is very well fitted by a logistic model.

A second relevant aspect is that the asymptotic value (saturation level) is a very small fraction of the total number of corporation companies present in each country. Certification penetration is a very "limited" phenomenon. The set of factors that pushes or inhibits the certification process finds a synthesis in a saturation value close to the 10 percent of the corporation companies there operating. This number, in analogy with the bio-population behavior, can be considered a kind of native property of the certification process, for well-defined context conditions typical of some European countries.

Table VIII.
Regression results obtained by the modified logistic model (equation (1)), for Italy, UK The Netherlands, Germany, Spain and Italy

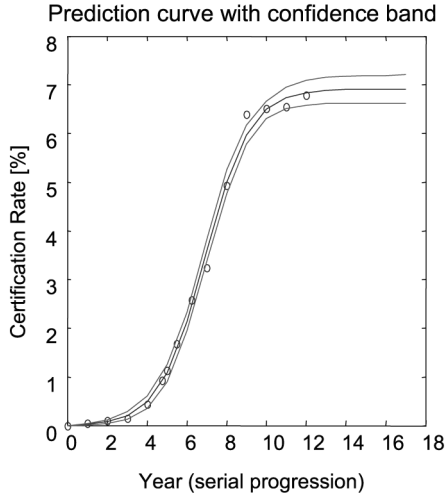
Parameter	Italy Value	Italy 95 percent confidence interval	UK Value	UK 95 percent confidence interval	The Netherlands Value	The Netherlands 95 percent confidence interval	Germany Value	Germany 95 percent confidence interval	Spain Value	Spain 95 percent confidence interval	France Value	France 95 percent confidence interval
N_0 (%)	0.063	(0.058; 0.067)	0.080	(0.008; 0.152)	0.016	(0.004; 0.027)	0.023	(0.005; 0.041)	0.004	(0.002; 0.006)	0.012	(0.005; 0.019)
K (%)	13.07	(12.66; 13.48)	9.55	(9.08; 10.01)	6.93	(6.63; 7.23)	8.12	(7.36; 8.89)	3.01	(2.63; 3.40)	2.03	(1.87; 2.19)
r_0 ($year^{-1}$)	0.53	(0.52; 0.54)	0.68	(0.56; 0.81)	0.88	(0.76; 1.00)	0.68	(0.57; 0.78)	0.55	(0.51; 0.60)	0.62	(0.53; 0.70)
Forecasts for next five years (% CC)	12.45	year 2006 (12.12; 12.77)	9.47	year 2005 (9.05; 9.88)	6.91	year 2005 (6.62; 7.20)	8.07	year 2005 (7.35; 8.79)	2.91	year 2006 (2.59; 3.23)	2.01	year 2005 (1.87; 2.16)

Notes: The Table shows the model parameter values and their respective 95 percent confidence intervals. The forecasts for next five years of the asymptotic saturation values, as a percentage of corporation companies, are also reported



Note: The curve shows the percentage rate related to the total number of corporations companies over time

Figure 3.
UK certifications growth (since 1986)

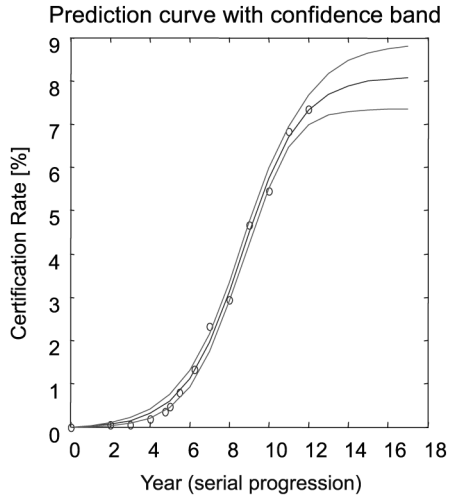


Note: The curve shows the percentage rate related to the total number of corporations companies over time

Figure 4.
The Netherlands certifications growth (since 1988)

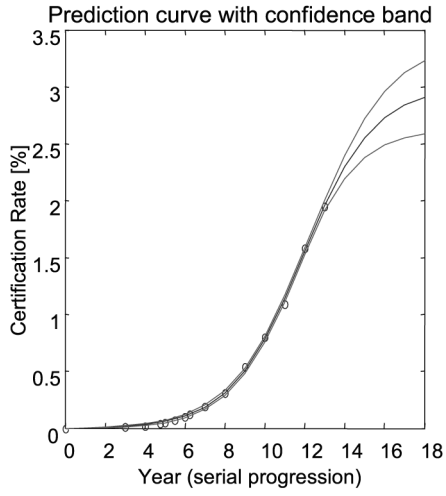
Conclusions

The paper presents an analysis of ISO 9000 standard quality certification growth in some European countries. In detail, the research suggests a model to describe the certification diffusion process related to each specific economic-entrepreneurial macro-structure. The model allows providing a



Note: The curve shows the percentage rate related to the total number of corporations companies over time

Figure 5.
Germany certifications growth (since 1988)



Note: The curve shows the percentage rate related to the total number of corporations companies over time

Figure 6.
Spain certifications growth (since 1988)

forecast of new certifications growth, together with the time required to reach the saturation level.

The central idea of the proposal is based on the close analogy between certification diffusion and bio-population growth. The certus-population

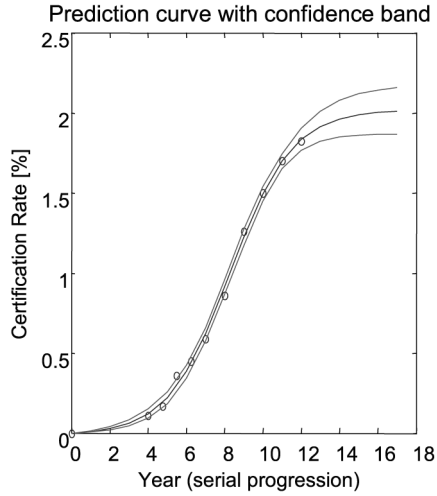


Figure 7.
France certifications growth (since 1988)

Note: The curve shows the percentage rate related to the total number of corporations companies over time

growth of Italy and of some other European countries has been deeply analyzed.

Being the phenomenon close to the saturation in many countries, some questions come out about the future of quality certification. Will the certification market go on? Will certified enterprises continue to be interested on it? Can be foreseen new certification approaches? If yes, towards what new aspects of quality?

Hazarding a hypothesis, we think that the new focus on the certification will shift from the inside of enterprises (internal quality systems), to the actual beneficiaries of their performances. In line with this new view, enterprises will be evaluated on the basis of how and what they are able to perform with reference to their own stakeholders. So, no more general principles and quality rules to be observed. Then, the new "tool" could become, why not, the certification of stakeholder satisfaction?

References

Anderson, S.W., Daly, J.D. and Johnson, M.F. (1999), "Why firms seek ISO 9000 certification: regulatory compliance or competitive advantage?", *Production and Operations Management*, Vol. 8 No. 1, pp. 28-43.

Asociation Espanola de Normalizacion y Certificacion (AENOR) (2002), private communication (updated to January 31, 2002).

Association Francaise de Normalisation (AFNOR) (2002), private communication (updated to January 31, 2002).

Beattie, K.R. and Sohal, A.S. (1999), "Implementing ISO 9000: a study of its benefits among Australian organizations", *Total Quality Management*, Vol. 10 No. 1, pp. 95-106.

Centraal Bureau voor de Statistiek (CBS) (2000), "Bedrijven naar grootte, naar rechtsvorm en naar regio vanaf 1993-2000", available at: www.cbs.nl (and private communication (updated to January 31, 2002)).

Cherruault, Y. (1983), *Biomathematiques*, PUF, Paris.

Comite Francaise d'Accreditation (2002), available at: www.cofrac.fr (updated to January 31, 2002).

Deutsche BundesBank (2001), "Monthly report December", available at: www.bundesbank.de (and private communication (updated to January 31, 2002)).

Docking, D.S. and Dowen, R.J. (1999), "Market interpretation of ISO 9000 registration", *The Journal of Financial Research*, Vol. XXII No. 2, pp. 147-60.

(The) Dutch Council for Accreditation (RVA) (2002), available at: www.rva.nl (and private communication (updated to January 31, 2002)).

Ebrahimpour, M., Withers, B.E. and Hikmet, N. (1997), "Experiences of US- and foreign-owned firms: a new perspective on ISO 9000 implementation", *International Journal of Production Research*, Vol. 35 No. 2, pp. 569-76.

Edelstein-Kesher, L. (1988), *Mathematical Models in Biology*, Birkhaeuser, New York, NY.

Eurostat (2002), available at: www.eurostat.eu (and private communication (updated to January 31, 2002)).

Garvin, D.A. (1987), "Competing on the eight dimensions of quality", *Harvard Business Review*, Vol. 65 No. 6, pp. 101-9.

Instituto Nacional de Estadistica (2001), available at: www.ine.es (and private communication (updated to January 31, 2002)).

Italian Institute for Foreign Trade (2002), "Le nuove guide Paese", available at: www.ice.it (and private communication (updated to January 31, 2002)).

ISO (2001), *The ISO Survey of ISO 9000 and ISO 14000 Certificates: Tenth Cycle, 2000*, ISO, Geneva.

ISO 9000 (1994), *Quality Management and Quality Assurance Standards – Guidelines for Selection and Use*, ISO, Geneva.

ISO 9000 (2000), *Quality Management Systems – Requirements*, ISO, Geneva.

Italian Institute for Statistics (ISTAT) (2002), available at: www.istat.it (and private communication (updated to January 31, 2002)).

Italian Ministry of Productive Activities (2001), available at: www.minindustria.it (and private communication (updated to January 31, 2002)).

Mann, R. and Kehoe, D. (1994), "An evaluation of the effects of quality improvement activities on business performance", *International Journal of Quality & Reliability Management*, Vol. 11 No. 4, pp. 29-44.

Ministere de l'economie de France (2001), available at: www.minefi.gouv.fr (and private communication (updated to January 31, 2002)).

Ministry of Economic Affairs, Division Accreditation Belgium (BELCERT) (2002), Private communication (updated to January 31, 2002)).

Murray, J.D. (1993), *Mathematical Biology*, Springer-Verlag, Berlin, Heidelberg and New York, NY.

Mouvement des Enterprises de France (2001), "Situation des enterprises", available at: www.medef.fr (updated to January 31, 2002).

Pearl, R. (1978), *The Biology of Population Growth*, History of Ecology Series, Ayer Co. Pub., New York, NY.

Rayner, P. and Porter, I.J. (1991), "BS 5759/ISO 9000 – the experience of small and medium sized firms", *International Journal of Quality & Reliability Management*, Vol. 8 No. 6, pp. 16-28.

Seber, G.A.F. and Wild, C.J. (1989), *Nonlinear Regression*, Wiley Series in Probability and Mathematical Statistics, New York, NY.

SINCERT (2001), "Database query", available at: www.sincert.it (and private communication (updated to January 31, 2002)).

Statistisches Bundesamt (1999), "Steuerpflichtige und deren Lieferungen und Leistungen 1999 nach Wirtschaftsabschnitten und Rechtsformen", available at: www.destatis.de (and private communication (updated to January 31, 2002)).

Stoneman, P. (1995), *Handbook of the Economics of Innovation and Technological Change*, Blackwell Handbooks in Economics, Oxford.

Sweden Board for Accreditation and Conformity Assessment (2002), available at: www.swedac.se (and private communication (updated to January 31, 2002)).

TGA Accreditation Body e DQS GmbH (2002), available at: www.tga-gmbh.de (and private communication (updated to January 31, 2002)).

(The) United Kingdom Accreditation Service (UKAS) (2002), available at: www.ukas.com (and private communication (updated to January 31, 2002)).

UK National Statistics (2001), "Size analysis of UK businesses", available at: www.statistics.gov.uk (and private communication (updated to January 31, 2002)).

UK Standards and Technical Regulations Directorate (2001), private communication (updated to January 31, 2002).

Weston, F.C. (1995), "What do managers really think of the ISO 9000 registration process?", *Quality Progress*, Vol. 28 No. 10, pp. 67-73.

Withers, B.E., Ebrahimpour, M. and Hikmet, N. (2000), "Does ISO 9000 certification affect the dimensions of quality used for competitive advantage?", *European Management Journal*, Vol. 18 No. 4, pp. 431-43.

Withers, B.E., Ebrahimpour, M. and Hikmet, N. (1997), "An exploration of the impact of TQM and JIT on ISO 9000 registered companies", *International Journal of Production Economics*, Vol. 53 No. 2, pp. 209-16.

Zhu, S. and Scheuermann, L. (1999), "A comparison of quality programmes: total quality management and ISO 9000", *Total Quality Management*, Vol. 10 No. 2, pp. 291-7.

Further reading

Enterprise Register Statistics Sweden (2000), available at: www.scb.se (and private communication (updated to January 31, 2002)).

Entidad Nacional de Acreditation (2002), available at: www.enac.es (updated to January 31, 2002)).

European Co-Operation for Accreditation (2002), available at: www.european-accreditation.org (and private communication (updated to January 31, 2002)).

National Bank of Belgium, Central Balance Sheet Office (2000), "Annual account 2001", available at: www.nbb.be/BA/E/homee.htm (updated to January 31, 2002).

OECD Statistics Directorate (2002), "Structural-ANalysis (STAN) database query", available at: www.oecd.org/statistics (and private communication (updated to January 31, 2002)).

Appendix

A logistic model is based on the hypothesis that the population growth rate r declines with the population density. At low densities ($N \ll 0$) the population growth rate is maximal and equal to r_0. Parameter r_0 can be interpreted as the population growth rate in the absence of intra-specific competition. The population growth rate reaches the zero value when $N = K$. The population growth rate can be described as:

$$r = r_0\left(1 - \frac{N}{K}\right), \tag{A1}$$

where K is the upper limit of population growth and is called carrying capacity. It is usually interpreted as the amount of resources expressed in the number of bio-organisms that can be supported by these resources.

The dynamics of the population is described by the following differential equation:

$$\frac{dN}{dt} = rN = r_0 N\left(1 - \frac{N}{K}\right), \tag{A2}$$

which has the solution:

$$N(t) = \frac{N_0 \cdot K}{N_0 + (K - N_0)e^{-r_0 t}}, \tag{A3}$$

where N_0 represents the number of bio-organisms at time $t = 0$.

Parameter r_0/K can be interpreted as the indicator of the competitive level of the evolutionary environment, while r_0 represents the maximum possible rate of population growth which is the net effect of reproduction and mortality. In absence of competition the population growth is described by an exponential model with parameter r_0.

For the certification process, the parameter r_0 stands for the maximum rate of population growth of the certified companies, while K is the carrying capacity of certified enterprises. It takes into account the interaction effect among enterprises. This close analogy between the two growth mechanisms has a meaning under the following hypotheses:

- first of all, the model considers only the total number of certified enterprises, paying no attention to their specific dimension and to their commodity sector;
- for certus-populations K parameter (saturation level) is affected by market competition and by the economic policies pursued by the Central Governments;
- parameter r_0 is influenced by national incentives, by the presence of local governments' encouragement and by the number of certification bodies;
- we suppose there are not events or external interferences that can change the natural evolution of the certus-population (for example, international/national changes, competitive pressure, regulatory/legislation changes);
- while the number of elements of a bio-population is $N(0) \neq 0$ when $t = 0$, for a certus-population the initial value is $N(0) = 0$ (at the certification launch, the certification number is zero).

Taking into account this last consideration, the model (equation (A3)) can be modified so as to impose the passage through the origin:

$$\frac{d(N+N_0)}{dt} = (N+N_0)\cdot r_0 \cdot \left[1-\frac{(N+N_0)}{K}\right] \text{with } N_0 > 0, \tag{A4}$$

with the following initial condition $N(0) = 0$.

Solving equation (A4) we obtain:

$$N(t) = \frac{N_0 \cdot K}{N_0 + (K-N_0)e^{-r_0 t}} - N_0, \tag{A5}$$

where:

- N_0 represents the translation value to assure the condition$N(0) = 0$;
- $N(\infty) = (K - N_0)$ is the certus-population saturation level, that is the asymptotic plateau level of $N(t)$;
- $r(0) = N_0 \cdot r_0 \cdot [1 - (N_0/K)]$ identifies the certus-population growth rate at the launch. This represents the slope of the curve just at the right side of the origin in the plane (N, t). Larger is the emphasis on the certification process by quality national bodies, greater will be its value.