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The evolution of the use of Foresight methods: a scientometric analysis of global FTA research output

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Abstract An increasing number of quantitative and qualitative methods have been used for future-oriented technology analysis (FTA) to develop understanding of situations, enable creativity, engage experts, and provide interaction. FTA practitioners have used frequently one or a suitable mixture of these methods for their activities. Changing policy and strategy making contexts as well as enabling technologies increased the need and possibility for performing adaptive Foresight studies in order to improve decision making about the future and using making better use of limited resources. This study performs a scientometric analysis of the publications in the major FTA journals with the aim of understanding the dynamics of using Foresight methods across time. Among the other branches of FTA, including forecasting, futures, and technology assessment, a special emphasis is given on Foresight as a systematic and inclusive way of exploring long term futures, developing visions and formulating policies for action. The study aims at detecting the key Trends and Weak Signals regarding the use of existing methods and emerging ones with potential uses for Foresight activities. Further implications will be achieved with the generation of networks for quantitative and qualitative methods. This will demonstrate the most frequently combined Foresight methods by researchers and practitioners. Where possible the methods will also be cross-fertilised with the key thematic areas to illustrate the relationships between policy domains and industrial sectors covered by the scope of study with methodological choice. This output is considered to be taken as a methodological guide for any researchers, practitioners or policy makers, who might embark upon or involved in a Foresight activity. Further

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outputs of the study will include the identification of centres of excellence in the use of Foresight methods and collaboration networks between countries, institutions and policy domains. Overall, the paper demonstrates how scientometric tools can be used to understand the dynamics of evolution in a research field. Thus, it provides an overview of the use of methods in Foresight, and how it is distinguished from the other FTA activities; the evolutionary characteristics of methodological design and factors influencing the choice of methods; and finally a discussion on the future potentials for new cutting-edge approaches.

Keywords FTA · Foresight · Foresight methods · Scientometrics

Introduction

Rapid developments in science and technology; increasing social, economic and environmental complexity and uncertainty; and limited resources continuously demand for developing new future-oriented technology analysis (FTA) in a systematic way. In parallel, FTA is rapidly evolving by crossing multiple disciplines with new and more powerful capabilities each year. FTA explains a broad range of future-oriented activities involving, Foresight, forecasting, futures, forward-looking activities, and technology assessment among the others. The current paper is mainly concerned with Foresight, which looks into the longer term future of science, technology and society through the involvement of stakeholders in a systematic process with the aim of developing policies and strategies for action. Among all other areas covered by the term FTA, 'Foresight' differentiates itself as a distinct field of study by a few critical attributes, each of which recognises uncertainty and accepts complexity as necessary:

- Foresight does not claim to be predictive—instead, with Foresight the emphasis is on seeking to explore and present multiple, plausible and contingent pathways that can shape and elaborate an uncertain future. With a less deterministic approach, Foresight encourages all plausible options, alternatives or pathways to be treated as more or less equal given the complexity of future realities, and consequences and risks of adhering to simple predictions.
- Foresight relies upon structures, disciplined and complementary methods—these are typically tested, repeatable and provide diverse ways of seeing and elaborating the fundamental uncertainty and complexity present in any projection into the future. A number of approaches and methodologies have been developed by using quantitative and qualitative methods with the aim of scanning horizons, exploring futures, developing visions and policies and strategies to reach them.
- Foresight is inherently collaborative, and seeks diversity—i.e. to involve diverse groups of people with the aim of reflecting present and prospective future viewpoints. Participation provides the systematic involvement of stakeholders with a long perspective to facilitate mutual-learning, collective visioning and joint actions. In this way Foresight increases awareness of stakeholders about emerging trends, developments and issues; enables participatory policy and strategy formulation and thereby provides necessary ownership for the implementation of policies and strategies.

These attributes provide an outline for the main characteristics of the Foresight activity, which can be considered as guidelines when designing a Foresight methodology, and selecting and using methods. For instance, creative methods are used to go beyond

predictions and generate alternative futures; expert-based or data collection methods are used to provide evidence and future-oriented intelligence; and participatory methods are used to achieve inclusivity and impact in Foresight activities.

The present paper aims at understanding the patterns emerging in the use of Foresight methods across time. The key assumption is that changing scope, focus and uses of Foresight activities; the availability of new technologies and tools over time; and the preferences of policy makers across the world as well as in specific regions of the world affect the use of Foresight methods. Having a time based analysis will enable to detect the key Trends and Weak Signals regarding the use of existing methods and emerging ones with potential uses for Foresight activities. The scientometric study presented in the paper aims to demonstrate the most frequently used methods by researchers and practitioners. Generating networks of Foresight methods will make it possible to understand the patterns of integrating different methods with each other to design a Foresight methodology. The study will also indicate the use of Foresight methods for different thematic areas to illustrate the relationships between scientific and policy domains and the choice of methods. This output is considered to be taken as a guide for any researchers, practitioners or policy makers, who might embark upon or involved in a Foresight activity.

The paper first provides an overview of the use of methods in Foresight and will build hypotheses for research. Following the description of the methodology of the study, the paper will present the results generated through the scientometric analysis. The conclusions section will discuss the hypotheses and will indicate possible future avenues for research.

The use of methods in Foresight

Methods have been integral components of Foresight to acquire information and data, explore novel ideas, clarify situations and negotiate solutions (Saritas 2013). The use of formal methods have some other useful benefits including making the Foresight process more systematic; increasing the transparency of inputs, processes and outputs; constituting "hybrid forums" for interaction and communication between various system actors; and, aiding the visualisation of possible and/or desirable future (Miles and Keenan 2004). A wide pool of quantitative and qualitative methods exists to design and implement a Foresight activity. The selection of specific method(s) is dependent on a variety of factors. Ten typical selection criteria can be considered:

1. *Proof of concept—learning from other sites of application* successful applications elsewhere may be inspirational for Foresight practitioners. Learning has increased due to globalisation (e.g. social, economic and political systems cannot be isolated from the rest of the world anymore); possibilities for communications and collaboration (Information and Communication Technologies enable the exchange of ideas and knowledge); increasing number of academic and scientific work (ever growing number of publications); and the activities of international organisations such as UN and EU, which advocate and often enforce similar policies across diverse cultures and countries (Saritas and Keenan 2007).
2. *Availability of resources* information/knowledge, money, skills, facilities are among the key resources of Foresight and accessibility to them play a significant role in the design of exercises.

3. *Urgency—time constraints* Time is one of the most important resources for Foresight. A typical Foresight activity may take from a few months to a few years depending on the shape and size of the activity.
4. *Level of participation desired* desired breadth and depth of participation by experts and stakeholders is an important determinant for the selection of method. Some methods, such as Delphi, are good for engaging many people, though this engagement will usually be remote and fleeting. By contrast, expert panels achieve in depth deliberation, but typically amongst a much smaller cohort of people than can be achieved through a survey. This is an example of why combination of methods is usually favoured.
5. *Type of engagement* stakeholders might be engaged in Foresight in "normative", "substantive" and "instrumental" ways (Saritas et al. 2010). The normative rationale suggests that stakeholders should be empowered to participate in decision making. The substantive rationale implies that the content of the exercise may be improved through participation by accessing the knowledge, creativity and problem-solving capacity of stakeholders. Finally, the instrumental role asserts that participation increases stakeholders' trust and acceptance of, and commitment to the Foresight exercise. Each of these degrees of engagement requires a different set of methods.
6. Suitability for combination with other methods, both as feeders and as a complement to the results of other methods (triangulation). Formal methods are rarely used alone. They are often combined in a variety of ways. However, there are no simple recipes to follow, since (1) different topic areas and audiences require different approaches; and (2) formal methods are rather versatile, resisting simple classification according to their (assorted) roles in the Foresight process.
7. *Prior experience and familiarity* as Foresight has been applied widely for policy makers around the world, there is an increasing familiarity with the concept. Discussions on whether Foresight is a useful tool or not is getting to lesser extent, with more emphasis given on how to design a more customised Foresight approach. However, the use of Foresight has to be well justified and well explained. Prior experience undoubtedly helps and accelerates the process, with a considerable element of learning from the previous experience.
8. Objectives, desired outputs of Foresight exercises, which may be both process and product oriented. The former might involve a focus upon methods that nurture dialogue and interaction between disparate groups, whereas a more product orientation would require methods that generate 'hard' results, such as a list of critical technologies
9. Quantitative and qualitative data requirements, availability of expertise, and right of use. These may become determining factors particularly at the absence of data. If not available internally, expertise may be outsourced as the budget of the exercise permits.
10. Methodological competence is often a key factor, with individuals Foresight practitioners often tied to particular tools, having limited experience of other approaches. This is especially true of consultant practitioners, where there is often the temptation to offer the same methodological solutions to a variety of customers.

Overall, Foresight methods should meet the basic requirements of Foresight such as future-orientation, participation, evidence-based, multidisciplinary and action-oriented. Saritas and Smith (2011) state that if Foresight to become operationalized as future intelligence and eventually actionable information and insights for strategy and tactics, some additional requirements are essential: first, exactly who is the client and what are

their needs; i.e. these should be clearly specified along with whether the orientation and key needs of the client are suited to foresight methods. Second, the how—i.e. the client and foresight team must agree on the three critical boundary conditions;

1. How wide—what scoping boundaries for content and process conditions are covered;
2. How deep—to go in terms of exploring content knowledge, contingent pathways etc.;
3. How far—out in time to aspire to reach, probe and explore; e.g. 3, 5, 10 or 15 years, or in some cases beyond to 20 or 25 years.

Mapping systematically over 2000 Foresight exercises from 2004 to 2008, EFMN (2009) reached several conclusions about the use of methods in Foresight. First of all, literature reviews, expert panels and scenarios were listed among the most frequently used methods, with other methods including trend analysis, interviews, Delphi and other surveys, key technologies, scanning were mentioned as commonly used methods. The EFMN study also claims that Roadmapping, modelling and simulation, bibliometrics, morphological analysis, gaming and multi-criteria analysis were mentioned as less frequently used methods. Qualitative methods were considered to be the most popular methods with less emphasis on quantitative methods.

Regarding the number of methods used in Foresight exercises, EFMN concluded that the diversity of methods is high. Foresight studies tend to integrate multiple methods. An average of five methods was used in the Foresight exercises mapped. Among the most frequently integrated methods are Expert Panels, Brainstorming, Delphi and Scenarios.

Two caveats can be mentioned regarding EFMN work. First, the mapping study was conducted systematically until 2008. Since then there have been an increasing number of Foresight exercises, with the use of new methods and tools, particularly with the more advanced use of information, communication and computational technologies (Keller and von der Gracht 2014). Secondly, with the vast majority of the Foresight exercises (over 80 %) were from Europe, the results presented by the EFMN work can be considered to reflect dominantly the European perspective of Foresight as practiced in the middle of the 2000s.

Observing the past and recent trends in terms of changing scope and focus of Foresight exercises, wider variety of sites of application and expectations, with an ever increasing number of methodological approaches, the present study posits the following hypotheses:

H1 The variety of quantitative and qualitative methods used for Foresight has increased dramatically in recent years. Besides the well-known Foresight methods such as expert panels, scenarios and Delphi, more sophisticated methods have been introduced into Foresight and conventional methods have been advanced with the use of new technologies and applications.

H2 Recent Foresight exercises have adopted multi-method approaches with the integration of quantitative and qualitative Foresight methods. The number of methods integrated has been increasing continuously. For instance, the Japanese national Foresight exercises undertaken since 1971 have relied mainly on the Delphi survey. However, the 9th and more recently launched 10th Foresight exercises involved a wider variety of methods to include Horizon Scanning, Scenario Planning, Roadmapping as well as the Delphi method (Urashima 2014).

According to the "Systemic Foresight Methodology" (Saritas 2013), there is a strong relationship between the 'content' of Foresight (i.e. the main areas of focus in Foresight); the 'context' (i.e. the framework conditions); and the 'process' of Foresight (i.e. the

methodological design and implementation). In this respect two more hypotheses have been formulated as follows:

H3 There strong correlation between the scientific and technological domains, and methods used in Foresight remains.

H4 Differences in Foresight practices are observed in the world regarding the practice of the selection of Foresight methods in different countries and regions.

The aforementioned hypotheses were tested and discussed through the methodology described in the following section of the paper.

Methodological approach

This methodology of the present study is based on the use of scinetometric methods. Hess (1997) defines scientometrics as the "*quantitative study of science, communication in science, and science policy*" (p. 75). It provides measures for analyzing essential aspects of scientific activities by using quantitative and statistical methods. Scientometrics have been used to understand the past trends and predict the future directions of development in publication and patent data by exploring, organizing and explaining emerging trends and patterns. In the present study, the scientomeric analysis has provided an opportunity to investigate evolution of the use of Foresight methods within the ever changing context of changing social, technological, economic, environmental, and policy issues focused by Foresight studies.

For the purpose of the current study, a scientometric analysis was conducted in the Web of Science (WoS) database, which consists of large volumes of academic and scientific publications indexed by Science Citation Index (SCI) and Social Science Citation Index (SSCI) among the others. The scientometric analysis in the current study was performed with the use of the Vantage Point software (Watts et al. 1997). The results generated through the scientometric analysis were visualised based on their occurrence and co-occurrence across time with the use of the visualisation tools including the Vantage Point, Netdraw and Vosviewer software applications (van Eck and Waltman 2009).

Next section of the paper will present the results of the scientometric analysis and will discuss the key findings.

Results, discussion and implications

The use of "foresight" as a term for search in Web of Science generated 2659 publications for all years available. The scientometric analysis revealed a total number of 4424 keywords identified by the authors. These keywords were cleaned by using the Vantage Point software and were grouped with a fuzzy clustering technique. After six iterations of the process through expert consultations, 68 key methods were identified. These were visualised by using the Vantage Point, Netdraw and Vosviewer.

The first illustration in Fig. 1 shows the distribution of the 68 Foresight methods identified across time.

As the figure shows from 1991 to present, the number of Foresight methods used has increased and the collection of methods has widened dramatically. Whereas in the early 1990s, there were only a few Foresight methods used, as the present date is approached the

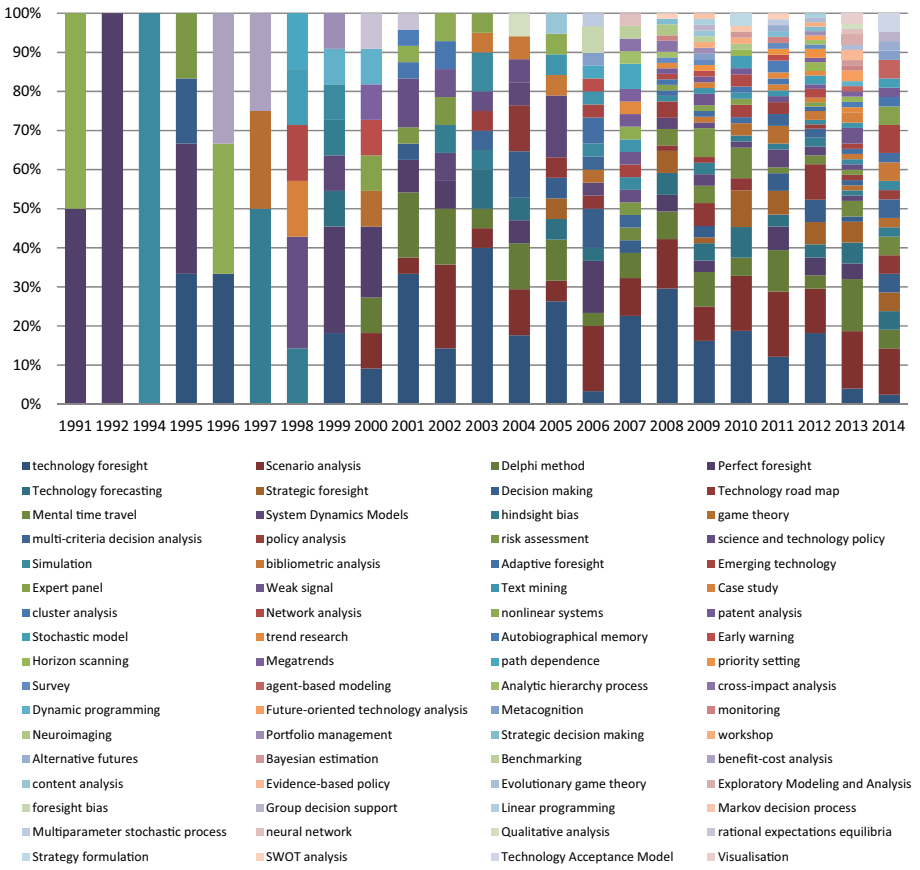

Fig. 1 The occurrence of Foresight methods in publications

number of methods presented increases from 1 to 2, and reaches over 30s. The variety of quantitative and qualitative methods used for Foresight at present is noteworthy. The figure also portrays that some of the key methods for Foresight such as scenario analysis, the Delphi method, forecasting and roadmapping still remain as the key methods, however, other new methods are increasingly used. These may be the other well-known methods, which have been used elsewhere and more recently transferred to Foresight activities such as system dynamics, bibliometric analysis and simulation. The increasing ranking of these methods among the others indicate the emphasis, which is currently being given on the quantitative methods. The presence of well-known methods on the agenda of Foresight researchers and practitioners proves the reliability of them. It should also be borne in mind that these conventional methods are currently being used in rather 'un-conventional' ways with new tools and technologies such as electronic surveys, advanced simulation-based scenarios, automated roadmaps among the others.

Regarding methodological integration, it can also be asserted that the increase in the variety of methods used consequently is due to the multi-method approach. Figure 2 illustrates the most frequently integrated Foresight methods. This data is presented in three

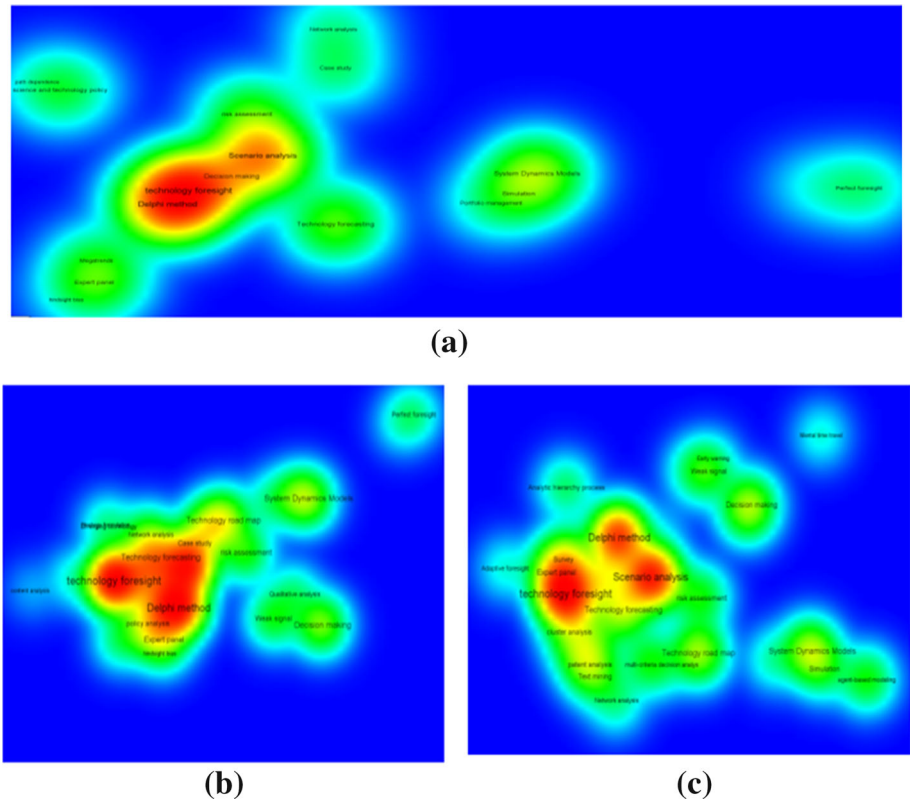

Fig. 2 Heat diagram for the integration of Foresight methods across time **a** 1991–2000, **b** 2001–2010, **c** 2011–present

snapshots in order to show how the integration of methods has evolved in the period of 1991–2000; 2001–2010; and 2011–present.

When the figure is examined, it can be seen that in 1991–2000 methodological integration is relatively limited and there are a number of idle islands distant from the core methods. The big island in Fig. 2a consists of several techniques populated around Technology Foresight including the Delphi method with relatively distant connection with scenario planning. System dynamics, network analysis are located in separate islands with technological forecasting in a separate but a closer island. Looking at Fig. 2b, it can be seen that Technology Foresight is closely associated with Delphi, forecasting, technology roadmaps, and to a greater extent with network analysis. It is also noteworthy that participatory approaches are given more emphasis with the expert panels becoming more significant. Getting closer to the present time, Fig. 2c shows that Technology Foresight exists as a strong methodological constituent along with Delphi and scenario methods. At this period of time Technology Roadmapping is given more emphasis. It is remarkably seen that quantitative methods like text mining, patent analysis and network analysis emerge as part of the central cluster and find applications in recent Foresight exercises. Similarly, another quantitative method, system dynamics, grows as a separate, but not a very distant, island containing other methods like simulation and agent-based modelling.

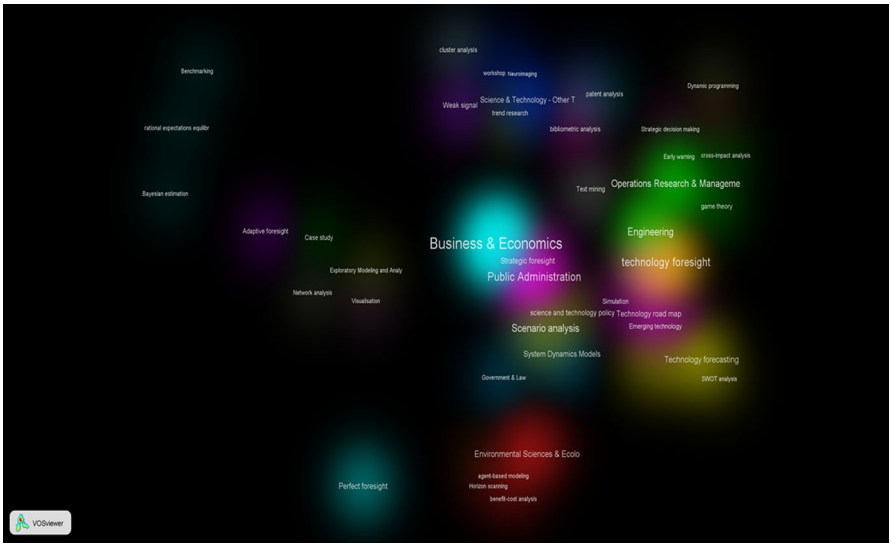

Fig. 3 Cluster density view

Moving from methods to the application areas, Fig. 3 illustrates a cluster density view between the top 10 categories as sites of application and closely connected Foresight methods to them.

Top 10 application areas were obtained through the analysis of the Web of Science categories where the publications in the database are most frequently associated to. They include:

1. Business and economics
2. Public administration
3. Engineering
4. Operations research and management science
5. Environmental sciences and ecology
6. Science and technology (S&T)—other topics
7. Energy and fuels
8. Materials science
9. Government and law
10. Metallurgy and metallurgical engineering

As most of the publications are categorised under these areas, they can be considered as the most frequently practiced sites for Foresight. Having a detailed look at a few of them, it can be seen that Business and Economics category is closely linked to Strategic Foresight. Public Administration, which appears to be the second largest site of application, widely uses scenario analysis, and methods related to science and technology policy along with technology roadmapping and emerging technologies. Engineering is another field where Technology Foresight has been applied widely. Regarding Operations Research and Management, Text mining, early warning, game theory and cross-impact analysis are among the most frequently used methods. Sensibly, Environmental Science and Ecology is engaged with horizon scanning, agent-based modelling and benefit-cost analysis methods. In other Science and Technology areas (i.e. the top cluster in Fig. 3), where Foresight studies have

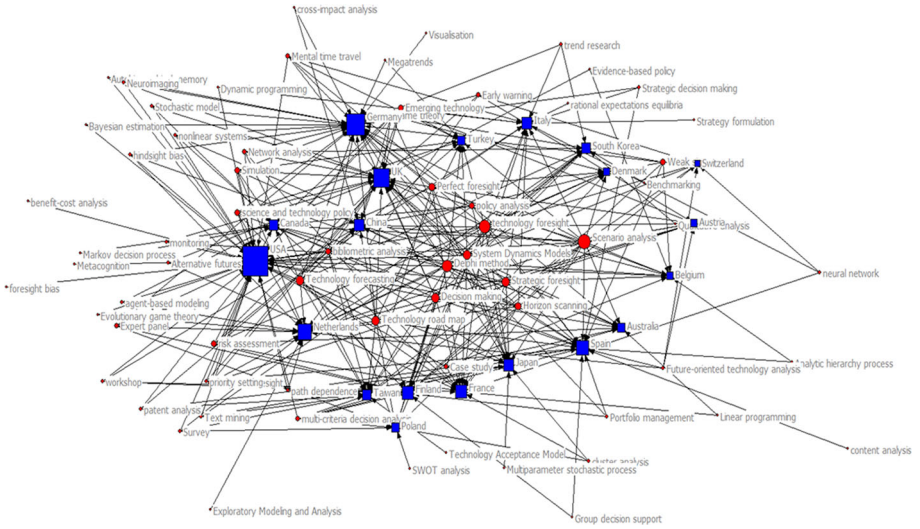

Fig. 4 The use of Foresight methods by top 20 countries practicing Foresight

been widely undertaken, trend analysis, weak signals, workshops, and bibliometric and patent analyses are among the most frequently used methods. The analysis of the relationships between application sites and methods, shows that there are clear methodological focus in most of the areas according to the nature and key characteristics of fields.

The final analysis presented in this paper, turns the attentions to the use of methods in different countries in the world. Figure 4 illustrates the network of top 20 Foresight practicing countries and the methods used by them.

Among the 20 countries, it can be seen that the US, the UK, Germany, and France are the ones, which are the most frequent users of Foresight methods. While the US has placed a great emphasis on Megatrends analysis and technology forecasting; Canada focused on simulation and stochastic methods. The UK has been engaged in the Delphi method, emerging technologies, early warning and policy analysis methods. Overall, it can be seen that the European countries including the Netherlands, Finland and Belgium are mapped around broader FTA methods, expert panels, methods for science and technology policy and technology roadmapping. Germany, in addition, also made use of megatrends and technological forecasting and cross-impact analysis. Going towards the East, it can be seen that Japan is engaged in the Delphi method and scenario analysis; South Korea is engaged in system dynamics, benchmarking, trend research and text-mining, whereas Taiwan is closely associated with patent analysis. Figure 4 noticeably indicates that although in earlier times most of the countries concentrated on one or a few methods, they currently use multiple Foresight methods and largely in an integrated way.

Conclusions

Methods are the means of organising and implementing systematic FTA activities. Therefore, there is a need for paying a continuous attention of their use. This study has aimed to understand the evolution of the use of methods by exploring the increasing variety

of them and the ways they are integrated and used for different application domains and contexts. As illustrated above with the mapping of Foresight methods, and various approaches of integrating them, a number of combinations can be developed.

The analysis of the evolution of Foresight methods through the use of scientometric methods helped to create considerable evidence to discuss the hypotheses formulated earlier. In summary, the study indicated that there is an increasing variety of quantitative and qualitative methods used in Foresight (H1). Whilst the traditional methods have remained as reliable tools to be used for Foresight, the way they are practiced have evolved. They are increasingly being accompanied by other emerging methods, which are largely quantitative in nature. Regarding the integration of methods (H2), the study has shown the ways Foresight methods are converging with each other. Previously, mainly qualitative methods were converged with each other, however, there is a greater tendency to integrate qualitative and quantitative methods by taking the advantage of participatory and creative aspects of qualitative methods, while exploiting the power of analysis, evidence generation and modelling of quantitative methods.

The analysis also revealed that the scope and focus of Foresight exercises remain as an important determinant of method selection and integration (H3). This can be considered as further evidence to the relationship between the content and process of Foresight exercises. The framework conditions such as policy making culture, priorities and visions inherent in different parts and regions of the world unavoidably bring different Foresight practices and variations in the use of methods (H4). The variety in the use of Foresight methods has been illustrated with the analysis of relationships between countries and the methods they use. Besides, these variations, there is also a strong evidence that countries widely learn from each other's practices, however, they tend to adapt the methodological approaches into their own context and conditions.

The analysis presented above focused on a wider timeframe by covering about 24 years of experience, which is wider than the other mapping activities currently presented. Regarding geographical focus, the analysis focused on the whole globe, without any biased region. However, it should also be remembered that the analysis is based on the publications. Therefore, there is no assumption that the study represents the exhaustive list of Foresight exercises, but the ones which have been published or referred to. Further research outputs from this study will include the identification of centres of excellences in the use of Foresight methods and collaboration networks between countries, institutions and policy domains.

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