

Evolution of studies of real options theory in health: a bibliometric study

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Abstract

The Real Options Theory, commonly used to evaluate investment in situations of uncertainty, had its origin after the analogy made by Myers (1977). After Myers (1977), the number of papers about real options grew and its application in several sectors has been observed, but in the health sector, the studies on Real Option Theory - ROT started in 1996. With the focus in to identify the evolution of the studies in the health sector, the present article presents a bibliometric study that aims to analyze the studies published in the main scientific bases, observing the aspects related to authors, year of publication, the objective of the study, object analyzed and study cited. To analyze the data it was used the descriptive statistics. The main conclusion it is that the application of ROT in the health sector is not only in the evaluation of investment or scenarios, but also has been observed its applicability in medical decision making.

Keyword: Real Options Theory; Health.

Introduction

The studies on real options started from the need to evaluate investments in situations of uncertainty since the existing models did not adequately consider such a variable. Given this need, Myers (1977) made the analogy between the pricing of financial options contracts and the expansion opportunities of a company, based on Black & Scholes (1973) and Merton (1973) studies. When Myers (1977) transported the concepts used in the financial market for investment valuation, he began the studies in a new topic in corporate finance, this study provided a basis for several models and confirmatory studies developed later. However, it is important to note it was in the 1960s that the basis for the theory of real options was developed. Samuelson's (1965) paper entitled "Rational Theory of Warrant Price" presented the introduction of stochastic calculus in finance and managed to deduce the optimal exercise condition from a high-contact of the American option.

It is important to note that in addition to the work of Samuelson (1965), there are three other papers, which discuss the idea that the value of the option is created by the irreversibility of decisions. Those paper are "Environmental Preservation, Uncertainty,

and Irreversibility" by Arrow and Fisher (1974), "Investments Decisions under Uncertainty: The Irreversibility Effect" and "Option Values in the Economics of Irreplaceable Assets, those last two by Henry (1974a, 1974b). Since, subsequently, the points related to irreversibility was incorporated into Real Option Theory - ROT as one of the requirements for applying this technique in the investment analysis.

Despite the cited articles and the Black & Scholes (1973) and Merton (1973) papers, these last two about the valuation of financial options, are pointed out as the basis for the construction of the real options theory, it is important to note that Fisher (1907) had already discussed the options available to an entrepreneur. In Fisher (1907) paper were presents three different types of options, namely:

(1) options among employment of capital which differ in kind, as, for instance, the options previously cited of using land for mining, farming, or forestry; (2) options among employments of capital which differ in the degree of certainty, as, for instance, the choice of sailing a ship over several routes differing in the constancy of wind and current; and (3) options among employments of capital which differ in size and time-shape (Fisher, 1907, p 178).

After Myers (1977) the number of studies on the subject has grown significantly, being observed studies in several segments of the economy. The application of real options in the health sector occurred in 1996, when Magiera and McLean (1996) applied the technique to evaluate the investment of purchase of lithotripter. After the Magiera and McLean (1996) other studies with focus on the evaluation of investment in the health sector have emerged, however, it is observed the application of ROT not only for investment assessment but in medical decision making, as is the case of "watchfully waiting", discussed by Driffield and Smith (2007). The authors showed how it is possible to apply ROT concepts in the quest to reduce uncertainties, providing benefits to patients.

In this context, the objective of this article is to present the evolution of the studies was done in the health sector, which is still one of the sectors in which there is little application of ROT. This little number of study justifies the present paper, since it will map the discussions about the theory of real options in the health. Another point that justifies the development of this study is the gap observed in relation to bibliometric research, no similar article in the present was found.

Real Options Theory in Health

The studies related to the ROT began with Myers (1977) as was mentioned however, it was only in 1996 that journals reported the application of ROT in the health sector. Until then the studies have focused on natural resources such as the studies of Tourinho (1979), Brennan & Schwartz (1985), Titman (1985), Paddock & Siegel & Smith (1988), Capozza & Li (1994) and others sector.

As mentioned, the first published study was in the 1996s, when Magiera and McLean (1996), demonstrated how the Real Option Analyses - ROA can effectively support the decision to invest in either a stationary or mobile lithotripter. According to the authors, while the Net Present Value - NPV analysis favored a stationary device, ROA led to a different result. This happens because a mobile lithotripter includes the option to rent out the device to other medical institutions.

Between 2000 and 2010 the studies about ROT increased hardy. In 2000 Palmer and Smith (2000) conducted a research that develops an alternative approach to handling uncertainty in economic evaluation based on 'option-pricing' techniques. The authors used the cost-benefit framework, with the concept of net social benefit - NSB for to analyses evaluation of health care technologies.

In 2001 Maurer (2001) applies the ROT to financially evaluate agreements on care contracts. In 2002, it was the turn of Smyth and Swinand (2002) that through the ROT sought to evaluate the opportunities of capital investment, capturing the value of flexibility.

In 2005 the study related to ROT in health was done by Kallapur and Eldenburg (2005). The authors tests an implication of the real-options theory of investment and concluded that uncertainty leads firms to prefer technologies with low fixed and high variable costs.

In 2007, there are the Williams and Hammes (2007) and Driffield and Smith (2007) studies. The first study discusses the application of real options to support an investment decision for a hospital's new imaging department. In the other hand, Driffield and Smith (2007) performed a different application than the one commonly. The authors were the first to apply the ROT not to evaluate capital investment decisions, but applied the ROT in watchful waiting, demonstrating how the methods used to price financial options can be used to decide when to pursue a watchful waiting strategy for a particular patient.

The study of Driffield and Smith (2007) shows a new application of ROT, being this study relevant for the area. This happened because this study established a

methodological and conceptual justification for the use of real options analysis in medical decision making.

In 2008 the studies return the focus of investment analysis and, having the record of the Levaggi & Moretto (2008), Pertile (2008) and Pertile, Torri, Flor & Tardivo (2008) papers. The first study evaluated a relationship between quality and investment in health technology, then the study analyzing the optimal investment decision in a new healthcare technology of a hospital in an uncertain environment. In the second study Pertile (2008) using the ROT to analyzing the optimal timing of investment in new technologies by health care providers competing for patients and the role of alternative payment systems in the adoption decision. In the last study registered in 2008 the focus was the economic evaluation in a hospital's perspective of the investment in positron emission tomography.

In 2009, the studies was developed had several focuses. It was observed studies to evaluate investment, as Özogul, Karsak, and Tolga (2009) study, which valued an Enterprise resource planning - ERP system investment incorporating multiple options, and the Pertile (2009) study which incorporated option values into the economic evaluation of Positron Emission Tomography - PET. In addition, in the same year, it was observed the study with aims to apply the real options framework to understand the costs and benefits of risk sharing compared with other options, like the Towse and Garrison (2009) study. Finally, the application of ROT in 2009 was done by Wyant (2009). The author discusses the applications of real options analysis, with emphasis on healthcare settings, and addresses the importance of organizational characteristics on real options analysis.

In 2010 the study developed continues to follow the same ROT path with a focus on to evaluate an investment, and this time the objective was the investment in medicine stock. In this study Attema, Lugnér and Feenstra (2010) applied the ROT to value stockpiling of antiviral drugs as a precautionary measure against a possible influenza pandemic.

2011 have two studies, Pennings and Sereno (2011) and Sengupta and Kreier (2011). The first aimed evaluating pharmaceutical R&D investment projects in the presence of technical and economic uncertainties. The second article was focused on develops a dynamic framework for analyzing an individual's choice between a Preferred Provider Organization (PPO) and a Health Maintenance Organization (HMO), through the application of TOR.

In 2012 the authors Dortland, Voordijk and Dewulf (2012) developed a decision support tool that supports health organisations in defining what flexibility they need in order to develop a flexible real estate strategy and to adapt to future uncertainties.

In 2013 Favato, Baio, Capone, Marcellusi and Mennini (2013) discuss the potential advantages shown by using the payoff method in the valuation of the cost-effectiveness of competing HPV immunization programs. Another study also developed in the same year was done by Wernz, Gehrke e Ball (2013). The authors presented the application of real options analysis - ROA to a managerial decision-making problem.

In 2014 Dortland, Voordijk and Dewulf (2014) studied how real option thinking could support decision-making over the design of new healthcare facilities. For this purpose, we combined the scenario planning approach with real options theory.

In addition, in 2015 Baranov and Muzyko (2015) put forward a methodological approach to the evaluation of the effectiveness of venture capital investments in innovative projects in pharmaceutical industry using real options method.

Finally, the last published article about the ROT in the health it was Park (2016), which attempts to bridge a gap between economic model and epidemiological model to analyze the optimal vaccination strategy when the diffusion of pandemic disease follows a stochastic process.

2. Methodological procedures

The present article aims to present the evolution of the studies on the Real Options Theory in the health sector. A bibliometric study was developed and it was analyzed the papers published on Plubmed, Wiley Online Library, Sage, Web of Science, Science Direct, Springer Link e Emerald Insight.

To do this, a search was done with the words "real option" and "health". After evaluating the description of the articles found by the search of the words mentioned, the sample was created with twenty-five complete published articles. It is important to emphasise that was found two abstracts (*A real option approach to valuing pharmaceutical investments and firms* (Cassimon & Engelen, 2001) and *Deciding upon new and expensive technologies in health care: real options analysis in proton therapy* (Grutters, et. al, 2010), but those abstracts was not included in the sample.

After the composition of the sample the articles were evaluated in relation to the year of publication, authors, objective, object, country of the authors, cited works and journal where the article was published.

The year of publication was used to develop the timeline of published articles. The authors were evaluated according to the number of articles published by each one. The objective of the study was analyzed according to its purpose, demonstrating the applicability of ROT. On the other hand, the paper's object was used to evaluating which health segment the ROT has been most applied. The country of the authors was used to map where the research has been developed. The papers cited were used to analyze, through a network, the authors, in the health sector, who were cited the most. The papers of ROT that is not part of the health sector, but which was cited in the studies analyzed, it served as the basis for creating a ranking by order of papers more cited.

Data analyzes were performed by Excel and Gephi software. The Gephi was used to create the network.

3. Analysis and Result

In the first section of this paper a brief description of the published papers on real options and health was presented. For to illustrate the volume of studies published over time, Figure 1 presents the timeline composed by the year and author (s) of each publication evaluated.

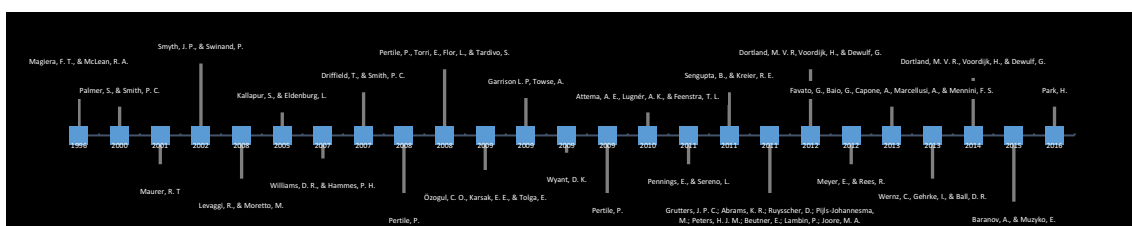


Figure 1. Timeline of the real options papers in the health sector
Source: Authors' elaboration

When evaluating the dates of the published articles, it is possible to observe that the annual production of articles is relatively small, having a larger volume in the years 2008 (3) 2009 (4) and 2011 (3), and in other years the value of published articles ranged from 1 to 2, as can be seen in Figure 2.

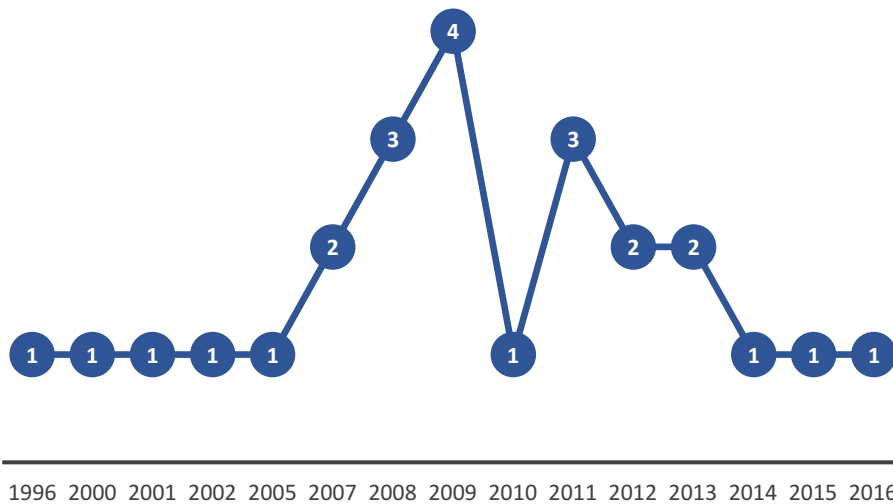


Figure 2. Annual scientific production

Source: Authors' elaboration

Regarding the author who published the most, it is possible, in Figure 1, to note that Pertile was the author who published the most. Pertile has two articles just with himself: “*Investment in health technologies in a competitive model with real options*” and “*An extension of the real option approach to the evaluation of healthcare technologies: the case of positron emission tomography*”, both focusing on health technology analysis. Pertile also published another paper with Torri, Flor, and Tardivo, entitled “*The timing of adoption of positron emission tomography: a real options approach*”.

Among the authors who published two articles are Smith, his first article was in partnership with Palmer, denominated “*Incorporating option values into the economic evaluation of health care Technologies*” and the second paper is “*A real options approach to watchful waiting: theory and an illustration*”, developed with Driffield. It is important to emphasize that the last article is of great relevance in the application of TOR in watchful waiting.

In addition, Dortland, Voordijk, and Dewulf be in the group of authors who published two articles. All those authors together published two papers, “*Towards a decision support tool for real estate management in the health sector using real options and scenario planning*” published in 2012 and the second is “*Making sense of future uncertainties using real options and scenario planning*” published in 2014. The other authors evaluated in this study presented one publication.

In relation to the countries that developed these studies, according to the information of the sample, the United States of America - USA is the country that produced the most articles about real options and health, seven, followed by Italy with five articles, and Netherlands with three articles. The others countries, United Kingdom - UK, Germany, Turkey, South Korean and Russia has one paper each one.

It is worth mentioning that the information was mentioned in the last paragraph represent only the studies that was developed by researchers residing in the same country. There are some articles published by researchers residing in different countries, like one article developed in partnership with researchers from the USA and the UK, other article developed between the UK and the Netherlands, and finally, more one article prepared by researchers from the USA and Germany. The Figure 3 illustrates these numbers.

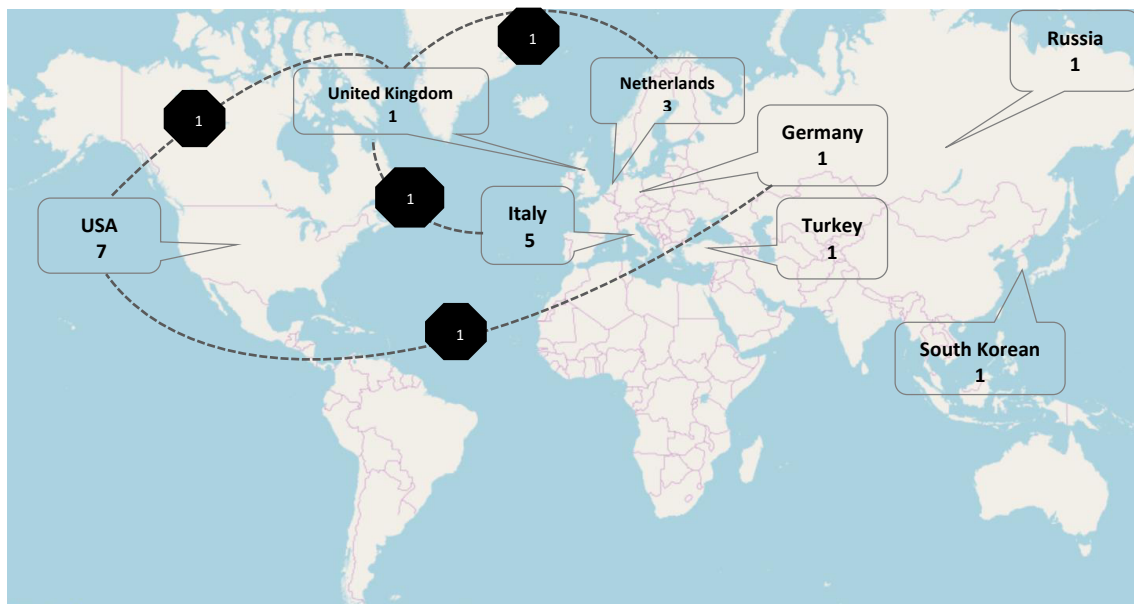


Figure 3. Scientific production in the world

Source: Authors' elaboration

Another aspect analyzed is the studies, which are more cited. As can be seen in Figure 4, there are two studies is more cited than others, Palmer & Smith (2000) and Driffield, & Smith (2007). In the Palmer & Smith (2000) study it was used the cost-benefit framework, with the concept of net social benefit - NSB for to analyses evaluation of health care technologies, something previously not done. On the other hand, Driffield & Smith (2007) paper is the first study that applies ROT in medical decision making.

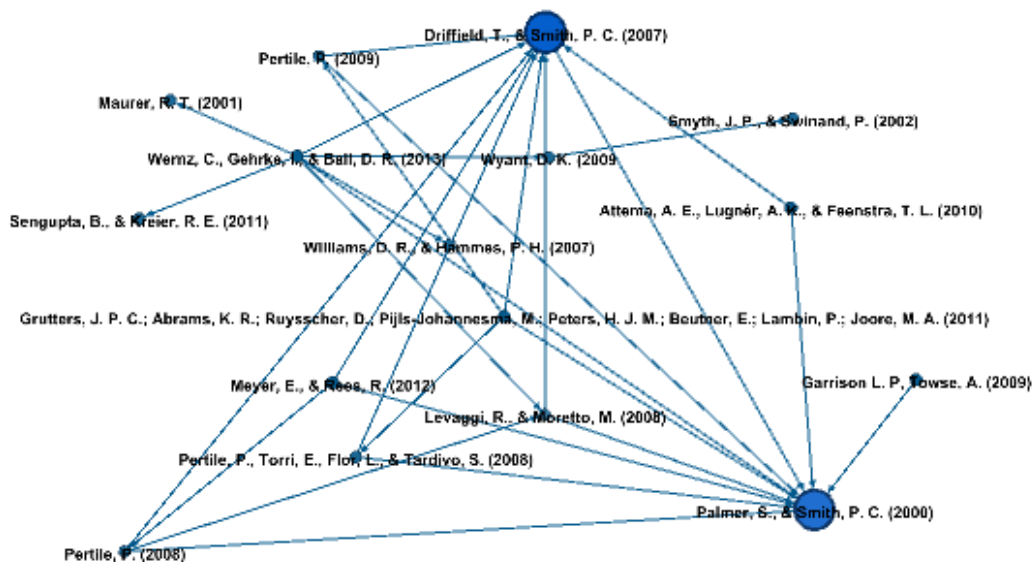


Figure 4. Network of citations
Source: Authors' elaboration

As mentioned the articles analyzed in Figure 4 were only those developed in the health sector. However, when evaluating all the studies of the sample, it was possible to observe that there are three most cited authors, they are Dixit & Pindyck (1994), Black & Scholes (1973) and Driffield & Smith (2007).

The first publication is a book where the authors present several points regarding ROT, discussing irreversibility, orthodox models of investment analysis and other points related to the topic. The second study is seen as one of the seminal articles, the authors develop an equation for European options of buying and selling in which there is no distribution of dividends or it is constant and proportional to the value of the object-asset. Finally, the third most cited study is considered of great relevance, since through them the authors show the benefit to the patients of applying the "watchfully waiting" delaying the treatment, such as surgeries, seeking to have more information about the clinical picture of the patient and reducing the uncertainties.

Table 1 presents the study cited in the analyzed sample about real options, also showing the number of citations of each one.

Table 1

Ranking of the papers cited

	Paper	Frequency
1	Dixit, A. K., & Pindyck, R. S. (1994)	11
2	Black, F., & Scholes, M. (1973)	8
3	Driffield, T. & Smith, P. C. (2007)	6
4	Trigeorgis, L. (1996)	5

5	Amram, M., & Kulatilaka, N. (1999)	4
6	Schwartz, E. S., & Trigeorgis, L. (2001)	4
7	McDonald, R. L., & Siegel, D. R. (1986)	3
10	Myers, S. C. (1977)	3
11	Adner, R., & Levinthal, A. L. (2004a)	2
12	Copeland, T., & Tufano, P. (2004)	2
13	Levaggi, R., & Moretto, M. (2008)	2
14	Merton, R. C. (1998)	2
18	Miller, K. D. & Waller, H. G. (2003)	2
19	Pindyck, R. (1991)	2
20	Arrow, K. J., & Lind, R. C. (1970)	1
21	Abel, A. B., Dixit, A.K. Eberly, J. C. & Pindyck, R. S. (1996)	1
22	Adner, R., & Levinthal, A. L. (2004b)	1
24	Agliardi, E., & Agliardi, R., (2005)	1
25	Angelou, G. N., & Economides, A. A. (2009)	1
26	Arrow, K. J., & Fisher, A. C. (1974)	1
30	BARONE-ADESI, G. I. O. V. A. N. N. I., & Whaley, R. E. (1986)	1
34	Carr, P., (1988)	1
35	Collan, M., Fuller, R., & Mezei, J. A. (2009)	1
40	Copeland, T., & Antikarov, V., (2001)	1
41	Dixit, A. K. (1989)	1
42	Geske, R., (1979)	1
43	Greden, L., & Glicksman, L. (2005)	1
44	Greer, A. L. (1985)	1
45	Herath, H. S., & Park, C. S. (2002)	1
46	Hull, J. C. (2003)	1
47	Hull, J.C., (2002)	1
48	Johnson, S.T., Taylor, T., & Ford, D. (2006)	1
49	Kellogg, D., & Charnes, J., (2000)	1
50	Kinnunen, J. (2013)	1
51	Lajeri-Chaherli, F., (2002)	1
52	Levaggi, R. (2005)	1
54	Martzoukos, S.H., & Trigeorgis, L., (2002)	1
55	Maurer, R. (2001)	1
56	McDonald, R. L., & Siegel, D. R. (1985)	1
57	Merton, R. C. (1997)	1
58	Mun, J. (2006)	1
61	Pertile, P. (2008)	1
62	Pertile, P. (2009)	1
63	Pertile, P., Torri, E., Flor, L., & Tardivo, S. (2009)	1
65	Sengupta, B., & Kreier, R. E. (2011)	1
66	Smyth, J. P., & Swinand, P. (2002)	1
68	Trigeorgis, L. (1993)	1
69	Vlek, P., & Kuijpers, M. (2005)	1
70	Williams, D. R., & Hammes, P. H. (2007)	1
73	Wu, M-C., & Yen, S. H., (2007)	1

Source: Authors' elaboration

Returning the analysis of the characteristics of the sample, it is important to highlight that the articles developed in the health sector presented five different focuses. The first one is the analysis of health investment, the second is the analysis of the cognitive and strategic aspects of RO, the third focus is watchful waiting, the fourth focus is the use of ROT to plan scenarios, and finally, the last one is a comparative between ROA and NPV. Figure 5 illustrates the grouping of the works according to their main focus.

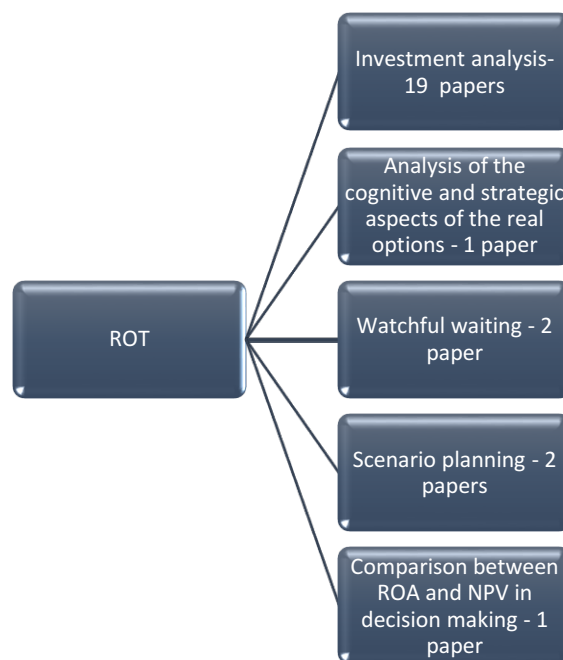


Figure 5. Focus of real options studies

Source: Authors' elaboration

Within the classification "investment analysis" it is possible to observe several applications. Having articles that applied the ROT to evaluate investment in equipment, others to evaluate technology in health, others to analyze health insurance, Risk-Sharing Agreements, medicines and therapies.

In another analysis was made regarding the data sources of the articles, it is possible to observe studies done with data hospitals, health plan, patients, the pharmaceutical industry and public health. The hospital is the most studied object, as the figure 6 illustrated.

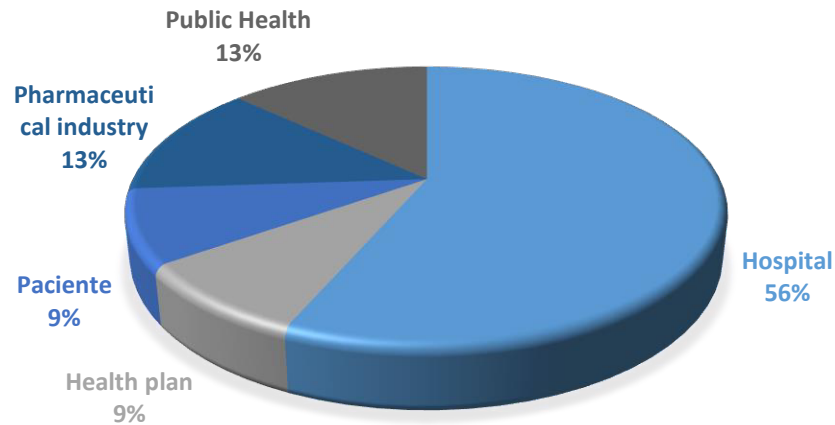


Figure 6. Study object
Source: Authors' elaboration

When evaluating the journals in which the articles analyzed were published, according to the Journal Citation Reports – JCR, these journals is classified in:

- ✓ Business – SSCI,
- ✓ Business, Finance – SSCI,
- ✓ Management – SSCI,
- ✓ Economics – SSCI,
- ✓ Health Policy & Services – SSCI,
- ✓ Computer Science, Software Engineering – SCIE,
- ✓ Computer Science, Theory & Methods – SCIE,
- ✓ Planning & Development – SSCI,
- ✓ Health Care Sciences & Services – SCIE,
- ✓ Pharmacology & Pharmacy – SCIE,
- ✓ Operations Research & Management Science - SCIE.

Twenty-five percent of the published articles were in Journals classified in the Economics - SSCI category, seventeen percent belong to Journal that is in the Health Policy & Services - SSCI category. It is important to note that eight percent of journals are classified neither in Business nor in Health, but in Computer Science. The Figure 7 illustrate this numbers.

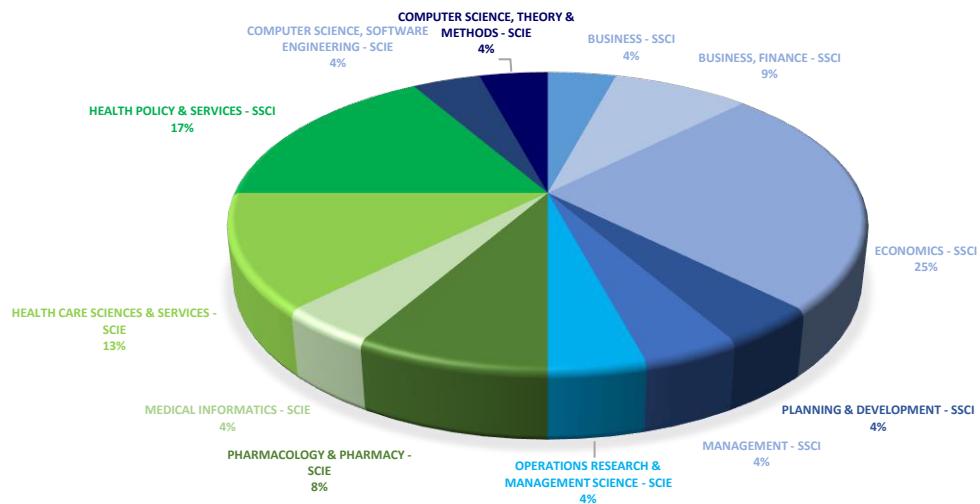


Figura 7. Classification of Journals where the articles were published
Source: Authors' elaboration

4. Conclusion

After the analysis developed some relevant aspects were presented, viz.

The scientific production on real options theory in the health sector is recent if compared to the first works on ROT. The first study is dated 1996, eleven years after the studies on real options began.

Among the several studies analyzed, no other study was found similar to the present, which presented a mapping of the studies developed up to the present moment.

When evaluating the most productive author it is possible to observe that Pertile was the one who produced the most articles about ROT in health, and his studies focused on the analysis of health technology. However, it is important to mention that it did not present a much larger scientific production than the other authors, which allows to evaluate that there is no concentration of a specific author.

In relation to the country that presented the major number of productions, the US was the country with the highest volume of study. An interesting point is the fact that in some articles the joint production of researchers from institutions that are in different countries was observed. This shows a partnership in the scientific development of the area.

As for the most cited studies, it is interesting to note that the first one, Palmer & Smith (2000), presents a discussion in which it is used the cost-benefit framework, with the concept of net social benefit - NSB for to analyses evaluation of health care

Technologies. The second was Driffield, & Smith (2007), which is the first study to apply ROT in medical decision making.

Regarding the focus of the articles, it was possible to observe that the studies were not only aimed at evaluating investment, as ROT is commonly used. It was possible to observe the application of ROT to evaluate watchful waiting. It is important to note the articles was evaluated can be classified in two groups, applied studies with the presentation of mathematical models and other more conceptual studies, like it was observed by Wernz, Gehrke, and Ball (2013).

Regarding the most evaluated object, it is possible to highlight that the hospitals were the most studied environment, it is believed that this happened due to the fact that this environment concentrates most of the health services.

When evaluating the classification of the journals that carried out the publication of the articles evaluated, a concentration was expected between the business and health journals, however it is interesting to note that there were also journals that are of the category of computer science. It is believed that the fact of having a considered volume of articles on evaluation of investment in technology in health may have led to articles published in journal of computer Science. However, it stands out that most of the articles were published in business journal.

It should be noted that the studies in the health sector are not only on the issue of investment evaluation, it is observing the application of ROT for other purposes. This, together with the small volume of studies in the health sector, in relation to other sectors, such as natural resources, makes it still a field with great potential for exploration, since it is an environment where there is the uncertainty, which contributes to the application of ROT.

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