# EVOLUTION OF STUDIES ON REAL OPTIONS THEORY IN HEALTH SECTOR

# EVOLUÇÃO DOS ESTUDOS DA TEORIA DAS OPÇÕES REAIS NO SETOR SAÚDE

# EVOLUCIÓN DE LOS ESTUDIOS DE TEORÍA DE OPCIONES REALES EN EL SECTOR SALUD

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## Abstract

**Objective:** The objective of this study was to identify the evolution of studies of real options theory in the health sector. For that, the present paper presents a study, which aims to analyze the studies published on the main scientific bases.

**Methodology/approach** – A bibliometric study was developed. Articles published in: Plubmed, Wiley Online Library, Sage, Web of Science, Science Direct, Springer Link and Emerald Insight were analyzed. Data were analyzed using descriptive statistics

**Originality / Relevance:** The originality and relevance is to present an analysis on the evolution of the studies of the theory of real options in the health sector already published.

**Main Results:** The main conclusion is that the application of ROT in the health sector is not only in the evaluation of investment, but also has been observed its applicability in medical decision making. In addition, we note that the first study on real options theory in the health sector was conducted eleven years after the start of studies on real options theory. Moreover, the option to defer is the most applied in the health sector.

**Theoretical Contributions:** This study contributes to scientific research in Applied Social Sciences by presenting an evaluation of the evolution of studies in the health sector.

**Keywords -** Real Options Theory; Health; Uncertainty; Irreversibility; Decision making

## Resumo

**Objetivo:** O objetivo deste estudo foi identificar a evolução dos estudos da teoria das opções reais no setor saúde. Para tanto, o presente artigo apresenta um estudo que visa analisar as pesquisas publicadas nas principais bases científicas.

**Metodologia:** Foi desenvolvido um estudo bibliométrico que analisou os artigos publicados em: Plubmed, Wiley Online Library, Sage, Web of Science, Science Direct, Springer Link e Emerald Insight. Os dados foram analisados por meio de estatística descritiva.

**Originalidade e Relevância:** A originalidade e relevância está em apresentar uma análise sobre a evolução dos estudos publicados sobre a teoria das opções reais no setor saúde.

**Principais resultados:** A principal conclusão é que a aplicação da TOR no setor saúde não é apenas na avaliação de investimentos, mas também na tomada de decisão médica. Além disso, observou-se que o primeiro estudo sobre a teoria das opções reais no setor saúde foi realizado onze anos após o início dos estudos sobre a teoria das opções reais. Sendo a opção de diferir a mais aplicada no setor saúde.

**Contribuições teóricas:** Este estudo contribui para a pesquisa científica em Ciências Sociais Aplicadas, apresentando uma avaliação da evolução dos estudos no setor saúde.

**Palavras-chaves:** Teoria das Opções Reais; Saúde; Incerteza; Irreversibilidade; Tomada de decisão.

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**Resumen**

**Objetivo:** El objetivo de este estudio fue identificar la evolución de los estudios sobre la teoría de las opciones reales en el sector salud. Para ello, este artículo presenta un estudio que tiene como objetivo analizar la investigación publicada en las principales bases científicas.

**Metodología / Enfoque:** Se desarrolló un estudio bibliométrico que analizó los artículos publicados en: Plubmed, Wiley Online Library, Sage, Web of Science, Science Direct, Springer Link y Emerald Insight. Los datos se analizaron mediante estadística descriptiva.

**Originalidad / Relevancia:** La originalidad y relevancia es presentar un análisis de la evolución de los estudios publicados sobre la teoría de las opciones reales en el sector salud.

**Resultados principals:** La principal conclusión es que la aplicación de los TOR en el sector salud no es solo en la evaluación de inversiones, sino también en la toma de decisiones médicas. Además, se observó que el primer estudio sobre la teoría de las opciones reales en el sector salud se realizó once años después del inicio de los estudios sobre la teoría de las opciones reales. La opción de diferenciar es la más aplicada en el sector salud.

**Contribuciones teóricas:** Este estudio contribuye a la investigación científica en Ciencias Sociales Aplicadas, presentando una evaluación de la evolución de los estudios en el sector salud.

**Palabras-claves**: Teoría de las opciones reales; Salud; Incertidumbre; Irreversibilidad; Toma de decisiones.

## 1. INTRODUCTION

The studies about Real Options started from the need to evaluate investments in situations under uncertainty. Until then, the models did not adequately consider such 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 stock market for investment valuation, the author began the studies in a new topic in Corporate Finance.

It is important to highlight that the study of Myers (1977) provided a basis for several models and confirmatory studies developed later. However, it is important to note that 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.

In addition to Samuelson (1965), there are three other papers, which discuss 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). Thus, Real Option Theory - ROT incorporated the points related to irreversibility.

Although the aforementioned articles are cited as the basis for constructing the Theory of Real Options, it is important to note that Fisher (1907) had already discussed the options available to an entrepreneur. Fisher (1907) 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).

It is possible to observe that the idea behind those options connects with the relation between return and risk; addressed in Corporate Finance by Markowitz (1952). When the options are considered in the investment analysis the investor seeks to a hedge the invest operation and maximize the result. For this reason, in investment situations under uncertainty, the Real Options have been used and the number of studies on the subject has grown significantly, observing studies in several segments of the economy.

In the health sector, the application of Real Options started in 1996 with Magiera and McLean (1996). The authors applied the technique to evaluate the investment of purchase of lithotripter. After Magiera and McLean (1996) other studies, which focus on the evaluation of investment in the health sector have emerged. As well as in medical decision-making. In this context, the objective of this article is to present the evolution of the studies in the health sector, which is still one of the sectors in which there is little paper published.

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 this type of research. No similar article in the present was found.

## 2. METHODOLOGICAL PROCEDURES

The present paper aims to present the application and evolution of the studies on the Real Options Theory in the health sector. Based on this aims a bibliometric study was developed that analyzed the papers published in: Plubmed, Wiley Online Library, Sage, Web of Science, Science Direct, Springer Link e Emerald Insight.

A search was done with the key words "real option" and "health", "real option" and "hospital", "real option" and "medical", "real option analysis" and "hospital", "real option analysis" and "health", "decision make" and "health", "decision make" and "hospital", "flexibility" and "hospital", "flexibility" and "health", "option value" and "health", and, finally, "option value" and "hospital".

All those articles found were read with the skimming strategy. Therefore, the articles that used the Real Option Theory were selected and included in the sample. Forty-seven papers were found. However, other refinement was done. For the design of this paper, we decided not to include in the final sample the articles that were not published in the journals.

In addition, the research that only had its summary published was not included, because it was not possible to access the complete articles. Moreover, the pharmaceutical industry was not considered in this paper. The reason for this was that we consider that there are many more articles on the subject than the ones found with the keywords selected in this research. Several articles on new technologies, new product, and patents are developed in the pharmaceutical industry and have used the ROT in their analysis. Another important factor is that this industry has very specific characteristics that deserve a separate study.

Then, after these criteria, the final sample was created with thirty-nine papers. The papers in the sample were evaluated in relation to year of publication, type of option, studies cited by other in the sample and objective. The year of publication was used to develop the timeline of published articles. The type of option shows what type of options have been used in the health sector. The papers cited by others were used to analyze, through a network, who are the most cited authors. In addition, the objective of the study was analyzed according to its purpose, demonstrating the applicability of ROT.

Data analysis were performed by Excel and Gephi software. The Gephi was used to create the network. Database searches were performed in December 2017 and updated in February 2019.

## 3. 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 and Schwartz (1985), Titman (1985), Paddock, Siegel and Smith (1988), Capozza and 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 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.

Still in the decade of 90, Mahul and Gohin (1999) examined how the irreversible strategy can affect the optimal dynamic decision-making process in contagious animal disease control under uncertainty. In this study, the authors present the discussion about to postpoing the decision to vaccinate.

Between 2000 and 2009, the studies about ROT increased greatly. 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 through the cost-benefit framework and the concept of net social benefit – NSB, analyzed health care technologies.

In 2001, Maurer (2001) applies the ROT to financially evaluate agreements on care contracts. This research was conducted based on the idea that managed care provider contracts with risk-based compensation arrangements have the value of contract dependent on the value of a more fundamental asset such as derivative securities. The next study was in 2002. Smyth and Swinand (2002) through the ROT evaluated the opportunities of capital investment, capturing the value of flexibility. According to authors, the value of managerial flexibility is higher in an investment opportunity under considerable risk.

In 2005, Kallapur and Eldenburg (2005) showed that uncertainty leads the hospital prefers technologies with low fixed and high variable costs. The authors conclude this, after testing an implication of the real-options theory in investment. Unlike 2005, in 2007 there are

record of three papers. The first study discusses the application of Real Options to support an investment decision for a hospital's new imaging department (Williams & Hammes, 2007).

In the other hand, the second study, which was done by 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[1]", demonstrating how the methods used to analyze investment can be used to decide when to pursue a watchful waiting strategy for a particular patient.

Finally, in the third paper, Smith (2007) evaluate whether the individual should take an option contract that could give a right to use a specific drug in the future. It is important to highlight that this papers focus its discussion on the option value and shows the value of a health benefit potentially at some point in the future.

In 2008, the studies continue to focus mainly on investment analysis and, as shown by Levaggi and Moretto (2008), Pertile (2008), Pertile, Torri, Flor and Tardivo (2008) and Eckermann and Willan (2008). The first study evaluated a relationship between quality and investment in health technology. The authors analyzed the optimal investment decision in a new healthcare technology of a hospital in an uncertain environment (Levaggi & Moretto, 2008).

In the second study of 2008, Pertile (2008) used the ROT to analyzing the optimal timing of investment in new technologies by health care providers competing for patients. In addition, it was analyzed the role of alternative payment systems. In the next study, Pertile, Torri, Flor and Tardivo (2008) focus to show the economic evaluation in a hospital's perspective of the investment in positron emission tomography.

Finally, the last paper in 2008, Eckermann and Willan (2008) applied the Expected Value of Sample Information - EVSI to decide to postpone decisions in health technology assessment, in which the costs of reversal are significant enough that the decision is irreversible.

In 2009, the studies were developed had several focuses. It was observed studies to evaluate investment, such as Özogul, Karsak, and Tolga (2009), which valued an Enterprise Resource Planning - ERP system investment incorporating multiple options. With the same

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[1] It is a patient management strategy in which immediate treatment is not given. Instead, the patient is observed and periodic tests monitor the progression of the disease. The Watchful Waiting is supported by the idea that postponing a decision may allow more relevant information to be obtained by avoiding expensive, irreversible or risky treatments. (Driffield & Smith, 2007).

approach, Levaggi, R., Moretto, M., & Rebba (2009) used a Real Options framework for evaluating an investment in a new technology. Other study is Pertile (2009), which incorporated option values into the economic evaluation of Positron Emission Tomography – PET.

In the other hand, Wyant (2009) presented the application of Real Options analysis, with emphasis on healthcare settings, and addresses the importance of organizational characteristics on Real Options analysis. In the next years, the studies still follow the same ROT path like the last years. Some studies focus on evaluating an investment address the real option, other focus on the option value and others on the medical intervention.

As an example of the first focus mentioned, Attema, Lugnér and Feenstra (2010) applied the ROT to value stockpiling of antiviral drugs as a precautionary measure against a possible influenza pandemic. Adding the option to defer in their analysis. In 2011 Sengupta and Kreier (2011) 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 the other hand, Grutters et al. (2011) examined whether should adopt proton therapy in the treatment of inoperable stage I non-small cell lung cancer compared to stereotactic body radiotherapy. Still in 2011, Lovejoy and Desmond (2011) defined the value of being able to delay the use of an inpatient bed for a patient on observation status.

In the next year, Dortland, Voordijk and Dewulf (2012) developed a decision support tool that supports health organizations in defining the flexibility needed to develop a flexible real estate strategy and adapt to future uncertainties. In the same year, Meyer and Rees (2012) brings again the discussion about watchful waiting and shows a model based on the idea of the benefit of the medical intervention.

Still in 2012 Forster and Pertile (2012) also applied the ROT for decide if adopt a new health technology in preference to an existing one in the patient treatment. With other approach, Sanchez et al. (2012) quantified the additional value patients receive when innovative treatments allow them to survive until the advent of even more effective future treatments.

It was in 2013 the year with the most research about ROT in health. Favato, Baio, Capone, Marcellusi and Mennini (2013) discuss the potential advantages demonstrated by using the payoff method to evaluate the cost-effectiveness of competing HPV immunization programs. Wernz, Gehrke and Ball (2013) presented the application of Real Options analysis

to a managerial decision-making problem. In the other hand, Cruz and Marques (2013) applied the ROT in another approach in which the double entry matrix was proposed as a new model for contract flexibility for the hospital. Also in 2013, Pertile, Forster and La Torre (2013) presented a bayes sequential economic evaluation model for health technologies. In this model, the investigator has the flexibility over the timing of a decision to stop carrying out research.

Finally, the last paper in 2013 identified which types of Real Options could be recognized in project coalitions at the hospital (Dortland, Dewulf & Voordijk, 2013). In 2014, the discussion about ROT was how thought of real option could support decision-making over the design of new healthcare facilities (Dortland, Voordijk and Dewulf, 2014). In addition, how could ROT presents the optimal timing for implementation of a globally coordinated adaptive strategy to address the pandemic threat (Pikea et al., 2014).

In 2015, Girling et al. (2015) applied a model to obtain critical business information as the product proceeds along a development pathway, indicating some future directions for the development of the approach. In the other hand, Mello-Sampayo (2015) examined when patients should switch to second-line antiretroviral therapy (ART) under health uncertainty and in the absence of viral load monitoring.

Different from other approaches, Park (2016) attempted to bridge a gap between the economic model and epidemiological model. The main idea was to analyze the optimal vaccination strategy in which the diffusion of pandemic disease follows a stochastic process. In the same year, Smith and Yip (2016) presented the importance of option pricing theory in offering the possibility of developing treatable methods to address the complexity and interconnectedness of the health system.

In 2017, Thornton et al. (2017) developed a model of the option value of the option that therapy provides, allowing patients to live to see subsequent innovations and applied the model to the case of nivolumab in renal cell carcinoma. With other approach Garrison Jr et al. (2017) presented the importance of consider the real option in the cost-effectiveness analysis. Finally, Lakdawalla et al. (2018) wrote the last paper in the sample. The authors showed that real option is considered as one of elements of Value in Health Care.

After all those information presented, it is possible to see that during over twenty year ROT has been applied in the health sector in different ways, with different objectives, specially to analyze investment and in the medical decision-making.

## 4. DISCUSSION

Previously it was presented a brief description of the published papers on Real Options and health. 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.
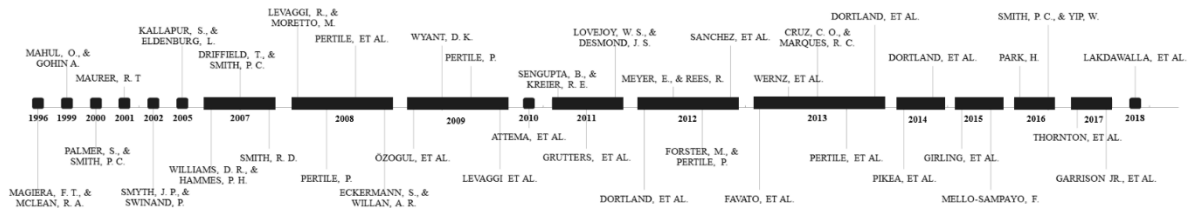


**Figure 1.** Timeline of the Real Options papers in the health sector

Source: Authors' elaboration (2019)

When evaluating the dates of the published articles, it is possible to observe that the annual production of articles is relatively small, being 2013 the year with more paper published (5). Followed by 2008 (4), 2009 (4) and 2012 (4).

Although there are few numbers of research studies using ROT in the health sector, Garrison Jr. et al. (2017) and Lakdawalla et al. (2018) present the relevance of Real Option, in the health sector. According to Garrison Jr. et al. (2017), the real option is one of the elements related to the value of knowing and informational externalities. Contributing to the discussion by Garrison Jr. et al. (2017), Lakdawalla et al. (2018) show that the actual option is one of the value elements.

It is possible to say that the real option in the health sector has been used as a hedge; focused on optimizing the result. No matter whether it is to apply in investment analysis, decision-making in public health, or in medical decision-making. The main idea was to include the actual options in the assessment.

According to the sample of this study, the option to defer was the most used. This type of option is common used in the investment analyses for decide to take now or in the future a new technologies for treatments, in other cases to postponing the decision to vaccinate, also in the watchful waiting.

The investment analyses in the health sector following the same logical that is to apply in others sector, in which the investor try to maximize the zero time expected present value of the payoff. Also in the others cases in the health, as watchful waiting, the logical is the same,

because the irreversibility and risk are presents. For example, the decision to start treatment is irreversible; the resource applied could not be used for any other purpose. However, the option to defer de treatment is reversible. The same logical that Trigeorge (1995) presents when the author discuss about the value of waiting to invest.

It is possible to observe in Driffield and Smith (2007) and Meyer and Rees (2012) that when the option to delay the treatment is adopted, this decision is leading to a rule that says start treatment only if benefits exceed costs by a certain positive amount and benefits for patient. So, in most of those cases the decision involves comparing the value of start today (zero time) with the present value at all possible time in the future. Whether the decision is postponing more information could be access, then the risk could be decrease. It is important to say that in the medical decision-making the time decisions are made by risk-averse.

It is noteworthy that is not possible to diversified portfolios, as it is done in traditional investments. Doing in the same time different treatments in the same patient could not be possible. For this reason, the option to switch the treatment could be exercised, as the Mello-Sampayo (2015) discuss about decide whether or not, and when, to switch a therapy should be done.

The option to expand and option to abandon were the others that were observed, especially to evaluate investment in technology. In the option to expand, Levaggi and Moretto (2008), and Özogul, Karsak and Tolga (2009) present that it could be used to maximize the return and minimize the risk of the investment. In the same way Dortland, Voordijk and Dewulf (2013), Pertile, Forster and La Torre (2013), Wyant (2009) present the use of option to abandon.

In addition, others options were observed, as the example of option to knowing, option to care and option to choice. The first one was present by Grutters et al. (2011) in which the authors examined the adoption of proton therapy compared to body stereotactic radiotherapy in the treatment of inoperable stage I non-small cell lung cancer. According to the authors, the options are: (a) to adopt without further research; (b) to adopt and undertake a trial ("adopt and trial"); and (c) postpone adoption and undertake a trial ("delay and trial").

In this research, Grutters et al. (2011) show the relevance of the information for choosing the best treatment in a certain time. It is possible to observe that the value of information is very important, especially because the technical uncertainty involved in some

treatment could lead the decision-maker choice the option of treatment that could not be the best. More information decreases the risk and helps to go the expected return.

The option to contract also was observe in the health sector. Smith (2007) evaluated whether the individual should take a contract in the present moment that give the right to use a specific drug in the future. This kind of option help the decision-maker do a hedge operation when there is uncertainty about the healthily conditions and the availability of the treatment. Again, the idea behind of this kind operation is decrease the uncertainty of the future and maximize the result, which in this case could be save the life of patient, give more years of life, or give better conditions to survive.

The last kind of option that was observe is the option to choice. This term was not found in the traditional literature of real option, however face discuss present by the author this terms seems more appropriated. Favato et al. (2013) applied the payoff method to determine the real option values of four different HPV vaccination strategies. Accordint to authors, the payoff method presented distinctive advantages in the valuation of the cost-effectiveness of competing health care interventions.

It is import to say that other kind option was observed, for example option to shrink, option to accelerate and option to lengthen. Dortland et al. (2013) analyzed those options when they evaluated considered and exercised flexibilities in separated and integrated project coalitions in the design and construction phase and the operations and maintenance phase of a healthcare construction project.

As observed many types of options, which are applied in the health sector, is the same that Trigeorge (1995) and Amram and Kulatilaka (1999) discuss, as well as an idea behind of its use. No matter whether the idea is applying in the patient treatment, analyses of public health strategy or investment analyses. The central idea is to reduce the uncertainty in the future for any decision taking in the zero time. Another aspect analyzed it is the studies more cited. As can be seen in Figure 2, there are two studies more cited than others; Palmer and Smith (2000) and Driffield, and Smith (2007).

Palmer and Smith (2000) used the cost-benefit framework, with the concept of net social benefit - NSB to analyze the evaluation of health care technologies, something previously not done. On the other hand, Driffield and Smith (2007) was the first study that applies ROT in medical decision making.
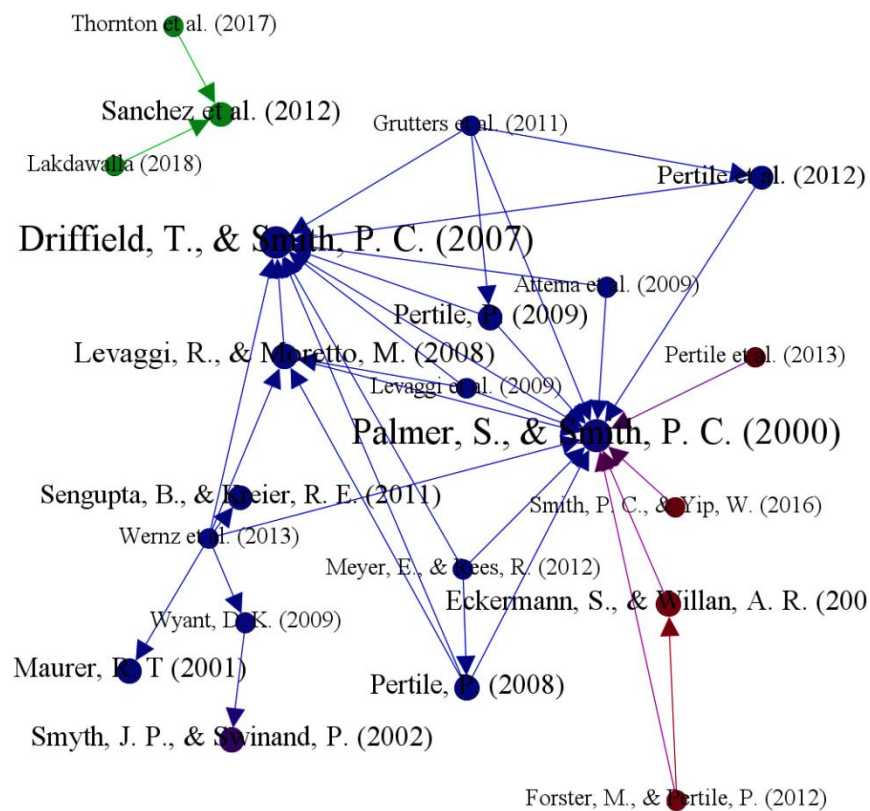
**Figure 2.** Network of citations

Source: Authors' elaboration (2019)

When the network is analyzed, it is possible to see that there is a cluster of study that has not related to the others. The studies in this cluster present the value of option, and use it to take decision about treatment, or how to use the infrastructure.

It is important to highlight that Arrow and Fisher (1974) mentioned some points about the value option. According to authors, Burton Weisbrod suggests that there may be some benefit to the individual in addition to the conventional price-compensating consumer surplus in situations that there is uncertainty in demand for a publicly provided good or service. This benefit is called "option value". In addition, Henry (1974a, 1974b) showed that the value of the option is created by the irreversibility of decisions.

If the value of option is also created by irreversibility, the ROT fits in situations that there is irreversibility, as it is possible to see when the focus of the papers is analyzed. The sample was cluster and four different purposes was identified: investment analysis, medical decision-making, value of option and relevance of Real Options, as represented in Figure 3.
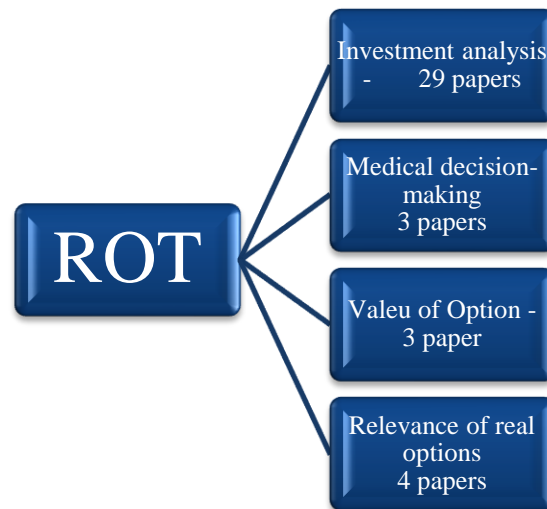
**Figure 3.** Focus of Real Options studies

Source: Authors' elaboration (2019)

In the first group are the studies, which analyzed the investment in the machine, technology, stock of drugs, health insurance plan, public health, new treatment, infrastructure, and health system. Those studies represent the traditional application of real option, in which the investor analyze if should invest his money in some project and this project should return among higher than the Company's Cost of Capital.

The second cluster is composed by the studies about watchful waiting and to switch the patient therapy. In this kind of approach, the ROT is applied for to help the physician to decide whether some treatment should start in zero time or the treatment should start in other time in the future. This kind of approach is interesting because in this situation the patient's life condition should be part of the return and risk equation following by the investor.

The studies that have the focus to measure the value of option of treatment or being able to delay the use of in inpatient bed for a patient on observation status are party of the third group. In the health sector is very common to use the cost-effectiveness analyses to decide which treatment should be adopt. However, it is possible to see papers like Lovejoy and Desmond (2011), Sanchez et al. (2013) and Thornton et al. (2017) that applied the ROT with the same focus as the cost-effectiveness.

The last cluster presents shows the importance of considering the real option when talking about the value in health care. As it was mentioned, Garrison Jr et al. (2017), and Lakdawalla et al. (2018) brings this focus in theirs papers. Also Wernz et al. (2013) emphasize the relevance of real option when the authors showed that ROA is more accurate

analysis method than NPV, in which uncertainty is a fator and decisions imply various future options.

## 5. CONCLUSION

After the analysis developed, some relevant aspects were presented.

The scientific production on Real Options Theory in the health sector is recent if compared to the first studies 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 similar to the present one was found, which presented a mapping of the studies developed up to the present moment.

About the type of option, the option to defer is the most applied in the health sector. When evaluating 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) that is the first study to apply ROT in medical decision making.

After knowing the main idea of research about ROT in the health sector and face all the information presented, it is possible to observe different approaches, in special in the medical decision-making. This approach is possible because the scenario in which the physician taking the decision there are uncertainty and irreversibility; important points that, according to Dixit and Pindyck (1994), are relevant for the existing of real option.

In addition, the use of real option to evaluating the value of option in the health sector is other approach that was observed, and, according to Figure 2, started other area of study. As it was mentioned, for the use the ROT it is necessary there are the uncertainty and irreversibility in the analyzed environment. Situations that those variables are observed and involve to take some decision, the ROT have being fit very well and help the decision-maker to plan and analyze the best option that should adopt. In addition, it does not matter whether it will be used to analyze investment in infrastructure, new projects or treatment.

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