SN Bus Econ (2023) 3:107
https://doi.org/10.1007/s43546-023-00489-2

ORIGINAL ARTICLE

Real options in health insurance decisions: the Portuguese ADSE system

Raquel J. Fonseca[1,2] · **Luísa Cunha**[2]

Received: 7 November 2022 / Accepted: 20 May 2023 / Published online: 31 May 2023

Abstract

The choice between two different health insurance providers is, more often than not, taken from a static point of view, measuring costs and benefits at a specific point in time, not considering all the relevant changes that may occur in life and in health conditions. Inspired by the new regulations set in place by the exclusive Portuguese civil servant's insurance scheme designated by ADSE, this study proposes a novel approach based on real options for an individual that needs to choose between a private health insurance and the apparently cheaper option provided by ADSE. Starting from the net present value approach, we subsequently show that, depending on some life changing events that may occur, it would be more beneficial for the individual to either abandon the health system or enter it at a later date. By incorporating the value of these options in the net present value calculation, decisions taken are not only more flexible, but also more realistic.

Keywords Real options · Health insurance · Investment analysis · Health economics

Introduction

Together with the National Health Service (NHS), considered to be of free access by the general population, there are in Portugal a significant number of private health insurance and health care services providers, as well as a few health insurances destined to specific professional careers. The ADSE system is one of the

✉ Raquel J. Fonseca
rjfonseca@ciencias.ulisboa.pt

Luísa Cunha
luisalcunha@gmail.com

1 CMAFCIO, Universidade de Lisboa, Lisbon, Portugal

2 Departamento de Estatística e Investigação Operacional, Faculdade de Ciências da Universidade de Lisboa, Lisbon, Portugal

latter, exclusive to civil servants and their families. Created in the early 60s, ADSE (Assistance in Disease to the State civil servants) began fully funded by the national budget, with considerably lower out-of-pocket costs (compared to other private insurances), but it soon started collecting a contribution from its beneficiaries. This contribution started at 1% from monthly salary and is currently (since 2014) at 3.5%.

Amidst the economic crisis and the increase in the beneficiaries' contribution, a new policy was introduced enabling current beneficiaries to leave the system and new civil servants to opt out. What was once a mandatory, but very cheap access to private health care services, was now an optional service with an increasing premium, especially for high-earning careers within the State. In some cases, it was shown that the monthly contribution largely exceeded the monthly premium of the most complete private health insurance coverage.

In light of this new policy, taking into account the beneficiary's monthly income, family situation, and expected health conditions and subsequent costs, what is the best decision to take? Foremost, what could be the best approach to tackle this issue? In a previous work, Fonseca and Cunha (2020) presented a net present value approach, by constructing different life and health scenarios and estimating the stream of health care costs, considering comparatively the ADSE system and a private health insurance. Based on their estimates, we extend their work further to include real option analysis. As this work will show, real options introduce a higher degree of flexibility in the decision-making process and enable the individual to change his/her decision at any point in time in the future.

Our contribution may be summarized as follows:

1. we expand the work presented in (Fonseca and Cunha 2020) regarding a net present value approach (NPV) to a health insurance decision by including real options;
2. we define both a deferral and an abandonment option as well as its main parameters in accordance to the terms of our problem;
3. we calculate the value of these options with respect to different life scenarios and assess the decision to be taken by the individual from a strictly financial point of view;
4. we study the main differences between this more flexible and complete approach in relation to the simple NPV case.

The remainder of the manuscript is organized into four different sections. The next section describes the theory behind real options and provides a brief literature review on the main applications of real options. The methodology used to value these options in relation to the problem here described together with the most relevant assumptions is presented in the section "Problem description", while the main results are presented in the section "Numerical results". The paper concludes in the section "Conclusion".

Real options and capital budgeting

Financial options

An option may be defined (from the buyer's point of view) as the right to buy or sell a specified quantity of an underlying asset for a given price, called the strike price, at or before a specific point in time in the future, the maturity date of the option. To obtain this right, the investor must pay the option premium, and since this is not an obligation but a right, the buyer may choose whether or not to exercise the option. The right to buy is called a call option, while to the right to sell is a put option (Damodaran 2002).

The payoff of an option depends on the value of the underlying asset at maturity date. Consider a call option: the buyer of the call option will only exercise his/her right to buy the underlying asset if the value of the asset in the market is greater than the strike price; otherwise, the option will expire worthless. The buyer of the put option, on the other hand, will only exercise his/her right to sell the underlying asset, if its price is lower than the exercise price. If not, again the option will expire worthless. In both situations, the investor has the guarantee that the maximum loss will not exceed the premium paid. The value of an option depends therefore on many variables related, in a first instance, to the underlying asset, and in a second level to the financial markets. These variables are: the current value of the underlying asset (S_0) and its volatility (σ^2), the strike price (K), the time left to expiration (T), and any potential events occurring up to the maturity date with a negative/positive impact in the value of the underlying asset, such as dividends.

Several models have been developed to value an option, though generally they all stem from the seminal work of Fischer Black and Myron Scholes, in what came to be known as the Black–Scholes model (Black and Scholes 1973). The model is relatively simple, with the value of an option written as a function of five variables, that is

$$\text{Value of a call} = S_0 N(d_1) - K \exp^{-rT} N(d_2) \tag{1}$$

$$\text{Value of a put} = K \exp^{-rT} N(-d_2) - S_0 N(-d_1), \tag{2}$$

where

$$d_1 = \frac{\ln(S_0/K) + (r + \sigma^2/2)T}{\sigma\sqrt{T}} \text{ and } d_2 = d_1 - \sigma\sqrt{T},$$

and

- r is the risk-less rate;
- $N(\cdot)$ is a probability estimated by the cumulative standardized normal distribution.

The goal of real options is to try and apply the same concepts behind financial options to real investment projects, based on the premise that a financial evaluation exclusively supported by the net present value is incomplete and lacks flexibility.

Applying financial options to real investments

Traditionally, an investment project is evaluated according to its net present value being positive, and whether or not the internal rate of return is higher than the hurdle rate. While this is the most common approach, it fails to consider the vast amount of options and decisions' management may take along the entire life of the project, such as expanding the project or simply abandoning it, when conditions in the market become more or less favorable, respectively. In fact, it may even be rational for a company to invest in a project with a negative net present value if the value of the options attached to such project is positive.

Myers (1977) was the first to recognize that growth opportunities within a firm could be seen as call options on real assets, where the exercise price is equivalent to the future investment needed to buy that asset. In essence, assets whose value is dependent on the firm's investment decisions could be seen as call options. From this first study, several others works have been developed, turning real options into one of the most dynamic and prominent fields of research. Dixit (1989) develops a model in which entry and leave decisions have to be taken in a context of uncertainty. These decisions are seen as call options, and the exercise price of these options is calculated. His work helped in the consolidation of the field and in extending the application of real options to many other areas of research. In 1993, Trigeorgis (1993a) provided a comprehensive overview of the real option applications in the literature, as well as guidelines to the use and valuation of real options in the context of investment projects. This later work was more fully detailed in a previous manuscript where the firm manager is confronted with an investment project with not only one option, but several different options (expand, abandon, and deferral), and he/she needs to value them all collectively (Trigeorgis 1993b).

While this new approach gained extensive popularity among academics, practitioners were still reluctant to adopt these techniques into their strategic management decisions. According to Lander and Pinches (1998), there are three main reasons for this delay in the acceptance and incorporation of real options in investment decision-making. First, it does not appear to be among practitioners a clear understanding of the models proposed, nor of the required mathematical skills to handle such complex models. Also, theoretical assumptions often fail when trying to replicate the models in a real-life application, and in the cases where additional assumptions are needed to guarantee mathematical tractability, these tend to limit the scope of the models, thus invalidating their practical application. Recently, Bellalah (2016) extends the issues related to real options to include sunk costs, which are very common in investment projects especially where the need for prior research and development (R &D) is greater. In this work, sunk or shadow costs are related to the existence of imperfect information and heterogeneous expectations, as well as short sales constraints. For a direct use of real options in the context of a portfolio of R &D projects, the reader is referred to van Bekkum et al. (2009).

Nevertheless, the most recent studies in real options theory have shown its wide range of applicability, as well as its dynamism and flexibility. Clearly, the area from where most of the works have stemmed is energy markets. Cartea and González-Pedraz (2012) use real options to price the interconnectivity between two country-wide electricity markets, as they found that the value of an interconnector is equivalent to a strip, that is, a combination of call and put options on the same underlying asset. Fleten et al. (2017) study the U.S. energy market and the impact of regulatory uncertainty in the decisions to shutdown, startup, and abandon taken by managers. While previous works focused mainly in cash-flow uncertainty due to changes in the price of the underlying asset, the innovation in their work derives from the consideration of possible alterations in regulations and the valuation of the abandon option. Ceseña et al. (2013) documented the most recent applications of real options in the area of electricity generation.

Inventory management and labor shifts are typical operations' research problems. Fernandes et al. (2013) have developed a novel approach to these issues by considering real options, particularly by considering the need to augment the workforce level due to demand increases as an option to expand. For an extensive review of the real options approach applied to operations research, please refer to (Trigeorgis and Tsekrekos 2017), where the authors provide a survey of all the manuscripts published between 2004 and 2015 in five international renowned journals. Also, in more finance-related areas, has the application of real options been tested. Leasing is such an example, where Grenadier (1995) tried to construct a term structure of equilibrium lease rates similar to the term structure of interest rates. Still in the scope of leasing agreements, but focusing on fleet replacement, Ansaripoor and Oliveira (2018) develop a stochastic minimization risk model incorporating real options, in this manner allowing enough flexibility to account for technological and fuel prices' changes.

Other applications include metal mining (Savolainen 2016); indeed, the textbook example of real options is the extraction of a goldmine, aircraft acquisitions (Hu and Zhang 2015), new product releases in the market (McIntyre and Chintakananda 2013), renewal investments in obsolete capital (Reindorp and Fu 2011), and even the real-estate market (Čirjevskis and Tatevosjans 2015). A general overview of the link between real options and strategic management is provided in (Rózsa 2015) and (Trigeorgis and Reuer 2017). The common thread among all of these applications is the high level of uncertainty associated with cash-flows, regulations, prices, and demand, to name a few. Healthcare and health costs are no exception in this category.

Problem description

The civil servant has to decide, given his/her expected stream of future health costs, whether to stay or leave the public health system (ADSE) and in this later case contract a private health insurance. Although there is in Portugal an NHS system, (almost!) freely available to all, we admit that the individual is willing to pay an additional fee to access the private market to skip waiting lists, access a wider range of providers, or have a more comfortable stay in hospitals, for instance.

Previous works on this issue have considered either a static approach, which is very limited as only the present time is considered, or a net present value approach, with the construction and further comparison of health costs through the entire life time of the individual in different scenarios. Fonseca and Cunha (2020) calculated the net present value from the point of view of the individual deciding to stay or leave the ADSE system, that is, his/her investment question was whether or not the total costs with a private insurance were greater than the total costs with ADSE. If so, then the best decision from a financial perspective would be to stay in ADSE: a positive net present value indicates an acceptance of the project. Although the latter provides a deeper understanding of the total health costs an individual and his/her family have to endure, it still fails to recognize the flexibility inherent to the investment project, namely, the decision to defer entry in a health system and/or to abandon the system later on.

The option to defer entry

Capital budgeting techniques imply the calculation of the present value of all the cash-flows in the project, not taking into consideration how these may change over time and the subsequent impact of those changes. A project with a negative net present value today may still be viable in the future if current conditions change or new situations come to place. The investor, therefore, may be willing to wait and only begin the project at a later date to capture these positive cash-flows, meaning that the project has in fact a defer or delay option embedded.

Although, according to current legislation, it is not possible to defer the decision to enter the ADSE system for more than 6 months, it will be shown that for certain scenarios, it would be advantageous to wait for a longer period of time. We assume that for scenarios with a negative present value, there is an embedded option to wait to take on the investment, which may be regarded as a call option. Our goal is to value that call option using the Black–Scholes model (Black and Scholes 1973) already described in the previous section for financial options. To that end, we start by presenting a correspondence between the parameters needed for the Black–Scholes model and the parameters of the health insurance choice model, extending the work previously done in (Fonseca and Cunha 2020).

Table 1 reflects that correspondence, which we now explain. Since this is a call option, the exercise price is the price set to acquire the asset in the future, that is, how much the individual must pay to enter the ADSE system. This price is a constant percentage of the individual's annual income, currently fixed at 3.5%. The underlying asset is the value of healthcare, so its price includes all the estimated future costs associated with a private health insurance, such as annual co-payments and annual premiums, net from the annual co-payments in the ADSE system, and discounted to the present time. All of the cash-flows included in K and in S_0 are computed until the individual's retirement age (P). Because the individual is postponing his/her entrance in the public health

Table 1 Parameters in financial and in real call options

	Financial option	Option to delay the project
K	Exercise price	$\sum_{i=1}^{P} 3.5\% \times \text{Annual Income}_i$
S_0	Underlying asset price	$\sum_{i=1}^{P}(\text{Net total costs private insurance})_i - \text{Cost of delay}$
σ	Volatility	40%
T	Time to maturity	Number of years until option exercise
r	Risk-free rate	Average of spot rate term structure

system, every passing year he/she incurs in additional costs using a private health insurance instead of ADSE. This difference in costs is designated as the cost of delay (parameter Z) (Damodaran 2002).

Given that there are, to our knowledge, no studies on the expected lifetime health-care costs in Portugal, the value of 40% assumed for the volatility was based on a similar study conducted by (Forget et al. 2008), regarding variations of lifetime healthcare costs by gender across a population in Canada. As for the risk-free rate, it is based on the spot rate yield curve published by the Eurostat from all euro area central government bonds in 2022. The complete table may be found in the appendix, Table A1.

As long as the value of the call option is greater than the net present value of the investment, it is more advantageous to stay with a private health insurance and delay entrance in the ADSE system.

The option to abandon

Consider now that, even though the project has a positive NPV, there is a significant risk associated and the probability that cash-flows are not as high as estimated is also very high. Having the possibility to divest, that is, having the option to abandon may add considerable value to the project. The key point is on the comparison between the liquidation value of the project if it were abandoned today and its remaining value. Valuing this option is equivalent to calculating the price of a put option, where the strike price is the liquidation value, and the price of the underlying asset is the remaining value of the project. The option is exercised when the liquidation value exceeds the estimated remaining value of the project.

In this case, the project that we might want to abandon is the ADSE system, and we will want to do so if the total costs with the ADSE system are greater than the total costs with a private health insurance, including both premiums and co-payments. As before, co-payments are calculated on an annual basis

$$\sum_{i=1}^{P}(3.5\% \times \text{Annual Income}_i + \text{Co-payments ADSE}_i) \geq \sum_{i=1}^{P}(\text{Annual premium}_i + \text{Co-payments private insurance}_i).$$

Table 2 Parameters in financial and in real put options

	Financial option	Option to abandon the project
K	Exercise price	$\sum_{i=1}^{P}(3.5\% \times \text{Annual Income}_i - \text{Annual premium}_i)$
S_0	Underlying asset price	$\sum_{i=1}^{P}(\text{Co-payments private insurance}_i - \text{Co-payments ADSE}_i)$
σ	Volatility	40%
T	Time to maturity	Number of years until option exercise
r	Risk-free rate	Average of spot rate term structure

Table 3 Out-of-pocket annual expenses per type of membership in ADSE (in €)

Age	M	M+S	M+S+1D	M+S+2D	M+1D	M+2D
20–29	49.75	99.25	128.25	157.25	78.75	107.75
30–49	70.25	140.5	169.5	198.75	99.25	128.25
50–60	90.50	181.25	210.25	239.25	119.50	148.50

Let us separate the deterministic from the random component, and rewrite the above condition as

$$\underbrace{\sum_{i=1}^{P}(3.5\% \times \text{Annual Income}_i - \text{Annual premium}_i)}_{\textbf{Deterministic parameters}} \geq$$

$$\underbrace{\sum_{i=1}^{P}(\text{Co-payments private insurance}_i - \text{Co-payments ADSE}_i)}_{\textbf{Random parameters}}.$$

Again, to apply the theory of real options to the problem here described, Table 2 provides the respective correspondence between the parameters in the Black–Scholes model and the parameters relevant to our problem.

Scenario selection

In the previous work, Fonseca and Cunha (2020) constructed a total of 48 scenarios differing in terms of age of the individual, marital status, and number of children included in the insurance contract. For all of these scenarios, both the annual premiums and co-payments either with ADSE or with a private health insurance were computed. To keep this manuscript self-contained, we repeat here the tables with the respective expenses (Tables 3, 4 and 5), where **M** accounts for the active member, **S** for the spouse, and **D** for any dependents.

Naturally, a number of assumptions regarding the use of health care services were made, always in line with the previous studies on this field. For a more detailed

Table 4 Out-of-pocket annual expenses per type of membership with a private health insurance (in €)

Age	M	M+S	M+S+1D	M+S+2D	M+1D	M+2D
20–29	140.75	281.50	346.50	411.50	205.75	270.75
30–39	204.75	409.50	501.00	592.50	296.25	387.75
40–49	228.75	457.50	547.50	637.50	318.75	408.75
50–60	276.00	552.00	651.25	750.5	375.25	474.50

Table 5 Annual premium per type of membership with a private health insurance with average coverage (in €)

Age	M	M+S	M+S+1D	M+S+2D	M+1D	M+2D
20–29	405.09	736.02	991.27	1 210.13	671.80	909.05
30–39	529.92	1 012.00	1 261.16	1 461.00	809.87	1 063.84
40–49	643.04	1 039.90	1 265.27	1 446.89	802.54	1 041.48
50–60	692.52	1 357.38	1 685.18	1 914.21	1 068.11	1 364.24

Table 6 Cash-flow stream in ADSE and in a private insurance for a given scenario

Year	Cash-flows (€)		Interest rate (%))	Present value		Net accum. gain (€)
	ADSE	Private insurance		ADSE	Private insurance	
0	785	546	0.00	785	546	-239
1	785	546	0.66	780	542	-476
2	785	546	0.97	770	535	-711
3	785	546	1.15	758	527	-941
4	785	546	1.30	745	518	-1 168
5	952	1 452	1.44	886	1 351	-703
6	952	1 452	1.57	867	1 322	-248
7	952	1 452	1.68	847	1 292	197
8	952	1 452	1.78	827	1 260	631
9	952	1 452	1.87	806	1 229	1 054
⋮	⋮	⋮	⋮	⋮	⋮	⋮
35	1651	1 940	2.36	729	857	7 356
Total	41 828	53 561		27 740	35 097	7 356

explanation of the scenarios simulated and the respective net present value calculations, we refer the reader to their cited work. In this study, we would like to focus on the application of real option techniques, and we will use some of the scenarios as examples of those applications.

Table 6 presents such an example for the scenario corresponding to a 25-year-old individual with a monthly income of 1 500€, before taxes. For the first 5 years, this individual is single, and for the remaining years, he/she is married. No dependents are included. Total costs with ADSE include the values of column **M** for the first 5 years and subsequently from column **M+S** from Table 3, plus 3.5% times the monthly income of 1 500€ times 14, as salaries are paid 14 times per year in Portugal. For the first years, these costs amount to 785€, increasing every decade as out-of-pocket expenses increase as well and also when another beneficiary is added (the spouse). As for the costs with private health insurance, these are computed from the values in Tables 4 and 5, column **M** and then column **M+S**. Again, these increase due to the changes in the individual's age and when the spouse is added. All of these costs are then discounted to present time based on the rates from Table A1, year 2022, included in the appendix. From the computation of the net present value, the rational decision is to stay in ADSE, as total private insurance costs are substantially higher than costs in ADSE.

Let us now take a closer look at the last column from Table 6: up until year 6, total accumulated costs with private insurance are always lower than total costs with ADSE. In fact, it is only in year 7 that costs that year surpass those of ADSE. In light of this, it would make financial sense for the individual to contract first a private health insurance and only afterward adhere to ADSE. This is actually one example of the adequacy of the application of real options. Even though the net present value of the investment in a private health insurance (comparatively to staying in ADSE) is negative, it would be rational to invest in this project given that there is an abandonment option embedded. The best decision would be to stay in a private health insurance until year 6, and only then move to ADSE. From a different perspective, one could also assume this is a delay option, there is, the individual may postpone his/her decision to enter ADSE to a later date, in this case, the wait would be about 6–7 years to enter the system.

The next section demonstrates the application of both delay and abandonment options in the most relevant scenarios, along with the estimation of the value of the options and the respective impact in the decision-making process.

Numerical results

Starting from similar tables as Table 6 and following the same approach as in the previous section, 5 of the 48 scenarios were considered appropriate to test the application of real options. In four of these scenarios there is a call option embedded in the decision, and in the last one, there is an abandonment option. We will treat these cases and present the corresponding results separately, in the sections "The option to defer entry" and "The option to abandon", respectively. Again, all of the assumptions regarding health care services costs, ADSE, and private insurance costs were derived from the previous work of Fonseca and Cunha (2020) and already presented in the previous section. We have included in the appendix all the tables with the cash-flow streams for all of the scenarios considered (Tables A2, A3, A4, A5, and A6).

The option to defer entry

The investment project described forces the individual to choose immediately between the ADSE system and a private health insurance. In some cases, however, it may make sense not choose today, but only later on in the future, given the current monthly income and/or expected life changes with impact in future health costs. How may we account for this other alternative that is to wait to implement the project? The answer is to consider the value of this call option embedded in the project. We selected four scenarios in which the best decision would be to wait to enter the ADSE system:

A Individual with 25 years old, monthly income of 1 500€, average insurance coverage, two dependents included at 35 years old
B Individual with 25 years old, monthly income of 1 500€, married at 30 years old, with spouse included in an average insurance coverage
C Individual with 25 years old, monthly income of 1 500€, married at 30 years old, one child at 35 years old, with spouse and child included in an average insurance coverage
D Individual with 25 years old, monthly income of 1 500€, married at 30 years old, two children (one at 35 and a second at 40 years old), with spouse and children included in an average insurance coverage.

A 2% annual increase in the monthly salary is also considered. This is relevant to calculate the fixed payment to ADSE. We exemplify the procedure with scenario A and include all the relevant parameters regarding the option to defer entry in Table 7. The volatility considered was, as indicated before, 40% and the interest rate is 1.99% in all the scenarios.

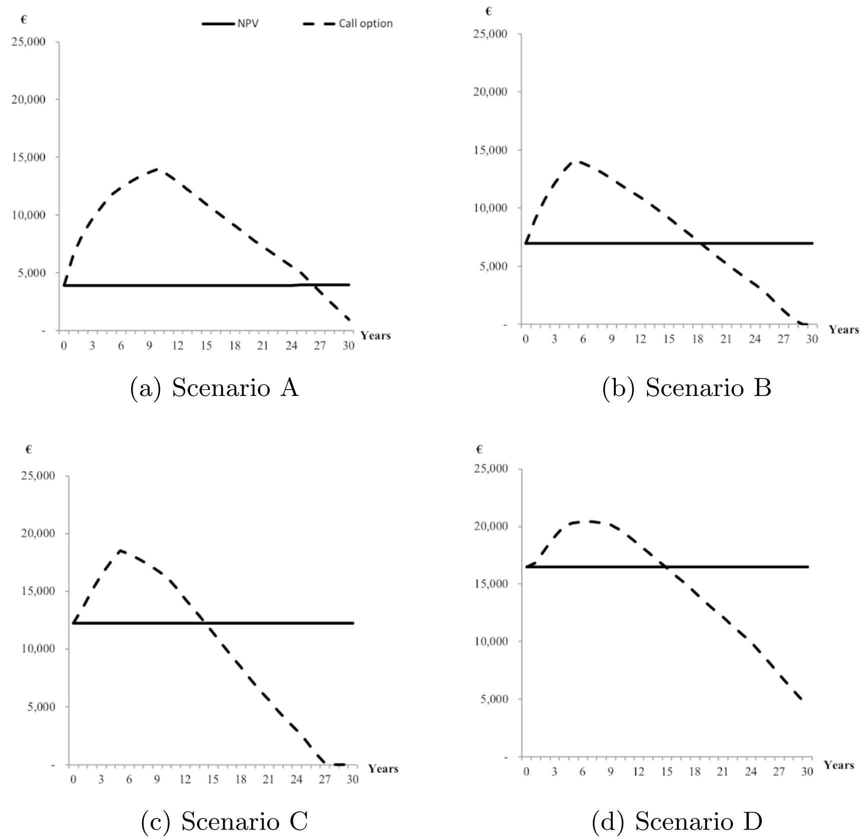
Let us start by consider the option to defer entry by 1 year. According to the Black–Scholes model, the value of this call option is 6 663€. Given that the NPV of this particular scenario is only 3 927€, lower than the value of the option, then it would be worth it to wait at least 1 year before contracting the ADSE insurance. This procedure is repeated every year, changing only the maturity of the option, up to the point where the NPV is equal to the value of the call option, corresponding

Table 7 Value of the parameters in the option to defer entry for 1–5 years (in €)

T	S_0	K	d_1	d_2	Value
1	28 093	23 688	0.68	0.28	6 663
2	27 837	22 958	0.69	0.13	8 399
3	27 585	22 237	0.74	0.05	9 711
4	27 336	21 527	0.80	0.00	10 783
5	27 092	20 829	0.85	−0.04	11 690

to the point in time where it would be optimal to exercise the option. In the case of scenario A, the individual would be better off waiting for 26 years before deciding to enter the ADSE system. This long wait is justified by the fact that health care costs are not very high, while the monthly contribution paid to ADSE, which is salary dependent, is considerably higher than the private insurance premium.

This result is shown in Fig. 1a, which illustrates the value of the call option through time along with the NPV and the exact optimal moment to exercise the option. Figure 1b, c and d depicts a similar situation for scenarios B, C, and D, respectively. The number of years the individual should wait decreases, as each scenario considers a different number of dependents included in the health insurance coverage. For instance, in scenario D, a spouse and two children are included in the insurance coverage in addition to the individual. As health care costs rapidly increase, the value of the option augments in the first years, only to quickly reach the net present value after 12 years. The parameters for the call options considered in each scenario, as well as their value, are included in the appendix in Tables A7, A8, A9, and A10.



(a) Scenario A

(b) Scenario B

(c) Scenario C

(d) Scenario D

Fig. 1 NPV and call option value per scenario considered (panels (**a**) to (**d**) respectively)

The option to abandon

The option to abandon the ADSE health system may add value to negative NPV cases, where the decision would be not to enter the system at all, but where, at the same time, the individual knows that it is possible to leave the system at any time in the future, if he/she wishes to do so. Contrary to the previous approach for a call option, the goal is not to pin point when should the option be exercised, but to assume that there is an abandonment option included in the evaluation that may be exercised at any given future time. The procedure will be to price the put option using the Black–Scholes model, add it to the net present value previously calculated and only then assess whether or not the project is viable.

Let us consider a scenario (Scenario E) for a 35-year-old individual, with a monthly income of 2 000€ (growing at a 2% annual rate), and with one child included in an average health insurance coverage. According to Fonseca and Cunha (2020), the net present value of investing in the ADSE system for this individual is negative at -1 353€ (Table A6), and naturally the decision would be not to enter the ADSE system and stay with a private health insurance. But is this still the best decision once the value of the abandonment option embedded in this project is estimated?

The value of the option will be calculated based on the Black–Scholes model. Table 8 repeats the parameters described in Table 2, assigning the corresponding value to each one of them. for this particular example, we considered an option maturity of 6 years. Table A11 in the appendix calculates the value of the abandonment options for different maturities, up until the individual is 60 years old.

The value of the put option estimated with the parameters from Table 8 is 2 349€, clearly above the original NPV. Therefore, the total NPV of the project is in fact 997€, which, given that it is positive, forces the individual to change his/her initial decision from staying in a private health insurance to actually entering the ADSE system.

Sensitivity analysis

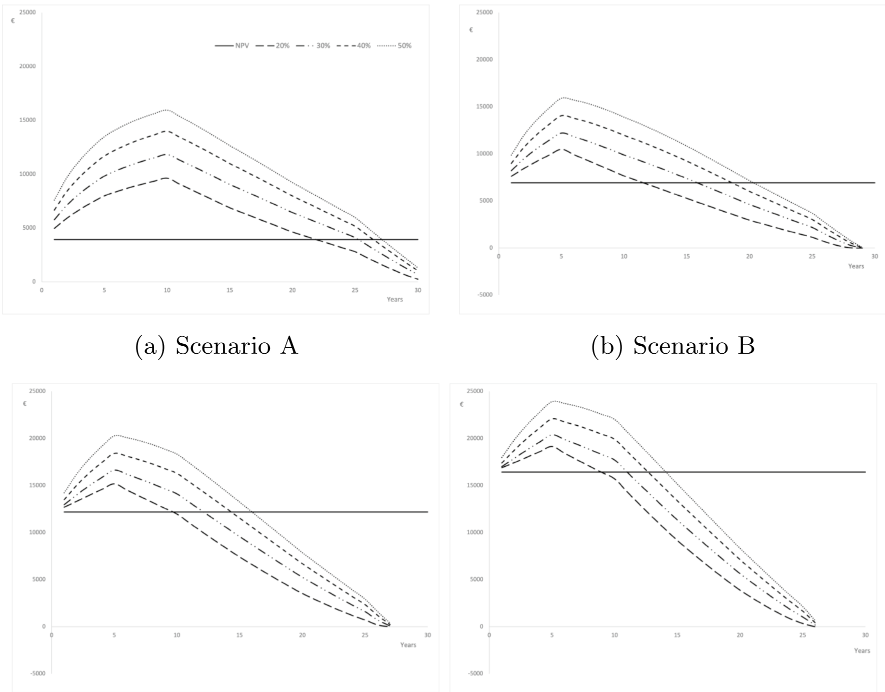
To make this analysis more robust, a sensitivity analysis on the volatility was performed. We have opted not to change the value of the interest rate, as this would also impact the NPV and the cash-flows throughout the years.

Table 8 Value of the parameters in the abandonment option

	Option to abandon the project	Value
K	$\sum_{i=1}^{P}(3.5\% \times \text{Annual Income}_i - \text{Annual premium}_i)$	4 852€
S_0	$\sum_{i=1}^{P}(\text{Co-payments private insurance}_i - \text{Co-payments ADSE}_i)$	3 424€
σ	Volatility	40%
T	Number of years until option exercise	6
r	Average of interest rate term structure	1.84%

The call options or the options to defer entry in the ADSE system were re-calculated with a 20%, 30%, 40%, and 50% volatility in each of the four scenarios considered. The results are illustrated in Fig. 2. As expected, in all of the scenarios, increasing the volatility increases the value of the call option, and consequently postpones the date at which this option would be exercised by the individual.

The same conclusions may be drawn when analyzing the put option or the option to abandon the system. A change in the volatility of the cash-flows leads to a change in the value of the option in the same direction, that is, decreasing (increasing) the volatility leads to a reduction (increase) in the option premium. Table 9 indicates the total value of the investment project that results from adding the negative NPV of − 1 353€ with the value of the put option for a maturity of up to 10 years. The scenario considered is the same as in the previous section.



(a) Scenario A (b) Scenario B

(c) Scenario C (d) Scenario D

Fig. 2 Impact of increasing volatility on the call option value per scenario considered (panels (**a**) to (**d**), respectively)

Table 9 Total value of the investment: NPV plus abandonment option premium for different volatility values

T	Volatility			
	20%	30%	40%	50%
1	66	174	319	482
2	160	351	575	809
3	240	485	756	1 033
4	306	588	891	1 195
5	360	668	993	1 313
6	334	660	997	1 324
7	300	638	980	1 308
8	261	604	947	1 271
9	217	562	901	1 217
10	169	511	843	1 150

Conclusion

The decision to stay or leave the ADSE system was addressed in the previous works using the net present value, an approach that, though enabling a more dynamic and systematic view of future health costs, still poses some limitations. Particularly, the NPV approach assumes that decisions must be made today, at the present moment, and may not be changed in the future, when in most cases not only can the investor postpone his/her decision, but also abandon the investment altogether. Real options may be seen as complementary to capital budgeting analysis, as they try to address such limitations.

Results suggest that, even in cases where the NPV previously estimated was positive, and therefore the best decision would be to contract the ADSE system, the individual would have to gain if he/she waited a certain number of years. This deferral period would naturally depend on the age, income, and family status of the individual. The higher the number of dependents included in the insurance coverage, the shorter the waiting period. On the other hand, scenarios with originally a negative NPV may now stand for viable projects in light of the value of an abandonment option there embedded.

Legally speaking, it is only possible to defer entry in ADSE for 6 months, so, in reality, our individual would not have at his/her disposal such deferral options. Nevertheless, this same approach could be taken by anyone trying to choose between two private health care insurances. In countries with a national health service, as Portugal, the technique here described would help the individual decide when to contract a private health insurance, given his/her future expected health care costs and the respective insurance premiums to be paid. Finding the best time in the future to contract a health insurance is one example of the type of analyses possible.

We have tried to perform a pure financial analysis on a very controversial and relevant subject. We find that this approach provides a more adequate response to our original problem, as it is able to incorporate the high degree of uncertainty associated with health care costs and health conditions overall the life time of an individual.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s43546-023-00489-2.

Author contributions All authors have contributed to the study conception and design. Material preparation, data collection, and analysis were performed by LC. The manuscript was written by RJF.

Funding Open access funding provided by FCT|FCCN (b-on). The authors did not receive support from any organization for the submitted work.

Data availability statement The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. Partial datasets analyzed during this study are included in Fonseca and Cunha (2020).

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

References

Ansaripoor AH, Oliveira FS (2018) Flexible lease contracts in the fleet replacement problem with alternative fuel vehicles: a real-options approach. Eur J Oper Res 266:316–327

Bellalah M (2016) Issues in real options with shadow costs of incomplete information and short sales. J Econ Asymmetries 13:45–56

Black F, Scholes M (1973) The pricing of options and corporate liabilities. J Political Econ 81:637–654

Cartea Á, González-Pedraz C (2012) How much should we pay for interconnecting electricity markets? A real options approach. Energy Econ 34:14–30

Ceseña EM, Mutale J, Rivas-Dávalos F (2013) Real options theory applied to electricity generation projects: a review. Renew Sustain Energy Rev 19:573–581

Čirjevskis A, Tatevosjans E (2015) Empirical Testing of Real Option in the Real Estate Market. Procedia Econ Finance 24:50–59. https://doi.org/10.1016/S2212-5671(15)00611-5. www.sciencedirect.com/science/article/pii/S2212567115006115

Damodaran A (2002) Investment valuation, 2nd edn. John Wiley and Sons, Hoboken

Dixit A (1989) Entry and exit decisions under uncertainty. J Political Econ 97:620–638
Fernandes R, Gouveia B, Pinho C (2013) A real options approach to labour shifts planning under different service level targets. Eur J Oper Res 231:182–189
Fleten SE, Haugom E, Ullrich CJ (2017) The real options to shutdown, startup, and abandon: U.S. electricity industry evidence. Energy Econ 63:1–12
Fonseca RJ, Cunha L (2020) A net present value approach to health insurance choice. Dec Econ Finance 43(2):709–724. https://doi.org/10.1007/s10203-020-00290-y
Forget EL, Roos LL, Deber RB et al (2008) Variations in lifetime healthcare costs across a population. Healthcare Policy 4(1):e148-67
Grenadier SR (1995) Valuing lease contracts a real-options approach. J Financ Econ 38(3):297–331. https://doi.org/10.1016/0304-405X(94)00820-Q
Hu Q, Zhang A (2015) Real option analysis of aircraft acquisition: a case study. J Air Transp Manag 46:19–29. https://doi.org/10.1016/j.jairtraman.2015.03.010
Lander DM, Pinches GE (1998) Challenges to the practical implementation of modeling and valuing real options. Q Rev Econ Finance 38(3):537–567. https://doi.org/10.1016/S1062-9769(99)80089-1. www.sciencedirect.com/science/article/pii/S1062976999800891
McIntyre DP, Chintakananda A (2013) A real options approach to releasing "network'' products. J High Technol Manag Res 24:42–52
Myers SC (1977) Determinants of corporate borrowing. J Financ Econ 5(2):147–175
Reindorp MJ, Fu MC (2011) Capital renewal as a real option. Eur J Oper Res 214:109–117
Rózsa A (2015) Real Option as a Potential Link between Financial and Strategic Decision-making. Procedia Econ Finance 32:316–323. https://doi.org/10.1016/S2212-5671(15)01398-2. www.sciencedirect.com/science/article/pii/S2212567115013982
Savolainen J (2016) Real options in metal mining project valuation: review of literature. Resour Policy 50:49–65
Trigeorgis L (1993a) Real options and interactions with financial flexibility. J Financ Manag Assoc 22(3):202–224
Trigeorgis L (1993b) The nature of option interactions and the valuation of investments with multiple options. J Financ Quantitat Anal 28(1):1–20
Trigeorgis L, Reuer JJ (2017) Real options theory in strategic management. Strateg Manag J 38:42–63
Trigeorgis L, Tsekrekos AE (2017) Real options in operations research: a review. Eur J Oper Res. https://doi.org/10.1016/J.EJOR.2017.11.055. www.sciencedirect.com/science/article/pii/S0377221717310664
van Bekkum S, Pennings E, Smit H (2009) A real options perspective on R &D portfolio diversification. Res Policy 38(7):1150–1158. https://doi.org/10.1016/J.RESPOL.2009.03.009