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Valuation of Biotechnological Research: A Real Options Application for a Mexican Company

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Abstract

This paper deals with the valuation of a project of Mexican Bioclon Institute, a firm producing antivenoms; this valuation comprises a R&D research portfolio of three antivenoms targeted to the US market. A compound option methodology is used. Bioclon Institute is a world leader in the production, research and development of fabotherapics; these products are manufactured using its own technology, recognized internationally; it is a large company of antivenoms globally and it is the only Mexican biotech company authorized by the US to conduct clinical trials. Real Options valuation constitutes an important analytical tool of limited use by managers and entrepreneurs in developing countries because they are not fully aware about this methodology and its benefits for strategic sequential project analysis.

Keywords: Real Options; Valuation Biotech; Compound Options; Antivenoms; Mexico.

1. Valuation of Biotechnological Corporations with Real Options

Current research advocates real options theory as an important approach to determine the value of Research and Development (R&D) projects, as well as the value of companies in the pharmaceutical/biotech sector (Bogdan and Villiger, 2010; Berk and DeMarzo, 2011; Ljumovic and Cvijanovic, 2012; Chan *et al.*, 2012, Nigro, Morreale and Enea, 2014; Lund and Jensen, 2016; Morreale *et al*, 2017, just to mention a few). However, there are few applications for companies from this industry whose operations are located in emerging countries (Erbas and Memis, 2012), albeit investment is expected to grow significantly in emerging markets and will largely drive global growth in these two sectors (Deloitte, 2017). This paper deals with the valuation of a project of Mexican Bioclon Institute, a firm producing antivenoms; this valuation comprises its R&D research portfolio of three antivenoms targeted to the US market. A compound rainbow option methodology is used. In practice, the use of the Real Options Analysis (ROA) in the valuation of companies is severely limited by three factors. The first relates to the problem of modeling. In many situations it is not easy to find out if an option is embedded in an investment project. Second, real options valuation is an extension to real assets valuation from the valuation theory of financial options. This reasoning assumes a number of simplifications that could not be met in many real-life situations. Third, real options valuation requires the use of complex analytical methods, which restricts its use by managers and entrepreneurs who currently are not fully aware about this financial methodology (Collongham, 2004; Driouchi and Bennet, 2012; Trigerogis and Reuer, 2016).

Real options valuation is relatively new and promising area for emerging economies (Xu and Meyer (2013). However, most of the research and literature comes from the United States and Europe;[1] proposed models need to be adapted to the economic, financial, tax, accounting and business environment of an emerging economy (Siu, 2008). In this regard it should be noted that biotechnology's potential future income is closely linked to the company intellectual property. Thus, it is expected that the value of a biotech company and its projects should essentially reflect the value of its intellectual assets (Devkota, 2015).

1. It is important to note that Mexico is the eleventh global market for pharma with a net worth of 13.2 billion dollars. Global companies perceive this market as having enormous potential and companies hold high expectations for their local subsidiaries (DuTilly Consultors, 2017).

Table 1. Studies Valuing Pharmaceutical/Biotech Firms Applying Real Options Theory

Authors	Year(s)	Projects and/or Corporations valued	Real Options Type Employed	Models Employed
Kellog and Charnes	2000	Agouron Pharmaceuticals, Inc.	Abandonment Option and Put Option	Decision Trees and Binomial Trees
Borissiouk and Peli	2003	Serono International S.A.	Compound Rainbow Option (learning options and abandonment options)	Margrabe Model, Carr Model (1988) and Binomial trees
Demirer, Charnes and Kellog	2003 y 2007	Agouron Pharmaceuticals, Inc.	Abandonment Option and Growth Option	Influence Diagrams, Decision Trees and Binomial Trees
Rubio	2003	Zeltia	Abandonment Option, Put Option and Growth Option	Decision Trees. Binomial Trees, Margrabe Model and Carr Model (1988).
León and Piñeiro	2004	PharmaMar (part of Group Zeltia)	Abandonment Option,	Schwartz Model (2004) and Pindyck (1993)
Rubio and Lamothe	2008	Eight world´s largest Pharmaceuticals	Abandonment Option	Schwartz Model (2004) and OLS Longstaff and Schwartz (2001). with Monte Carlo.
Pennings and Sereno	2011	Name of the corporation not revealed	Abandonment Option and Compoud Option	Technical and economic uncertainty Modeled applying Poisson jumps and standard diffusion, respectively
Fujiwara	2013	Name of the corporation not revealed.	Growth Option	Options model-Montecarlo simulation
Baranov and Musyko	2015	Name of the corporation not revealed.	Venture Growth Option and Compound Option	Black&Scholes (1973); Barone-Adesi and Whaley (1987) Baranov and Musyko (2013)
Romoska	2017	Name of the corporation not revealed	Compound option. Compared with Risk adj. NPV	Black&Scholes applied to different products
Montajabiha *et al.*	2017	Name of the corporation not revealed	Compound option	Black & Scholes (1973) integer programming Optimization algorithm
Morreale et al.	2017	Pharmaceutical and two biotech. Names not revealed.	Sequential competitive offers for licensing	Real Options Game

Source: Authors' editing.

That is, in the case of emerging biotech companies and start-ups that have no line established or recognized products or other assets that generate income, their value depends almost entirely on its knowledge capital and its management (Kiskis, 2017). Certainly, anyone who tries to set a value to a project or a company in this industry must understand the regulatory hurdles for approval and the complexity inherent in the whole R&D process. Thus, valuation in a pharmaceutical/biotech company becomes a difficult task due to the nature of the business models applied in this industry; innovations presented by the company, the absence of many tangible assets, and the limited availability of financial records and exaggerated forecasts made in the industry (Larrabee and Voss, 2013). These issues make necessary balancing between quantitative and qualitative metrics in the task of valuation; however, this poses additional difficulties. Indeed, valuation of a pharmaceutical/biotech company is a combination of art and science, and depends on the investor or financial analyst to achieve the right combination (Keegan, 2009; Favato *et al*. 2015). Biotechnology company and a pharmaceutical company. The first difference refers to the fact that the value of a pharmaceutical company is made up primarily of products already on the market. Additionally, Villiger and Bogdan (2005), Jeppsson and

Holmberg (2009), and Herbst and Tölle (2016) note that the issue of valuation has several limitations, ambiguities and misunderstandings in biotechnology. Bogdan and Villiger (2010) correctly identify two differences between a pure Meanwhile, biotechnology companies have their projects still in the process of R&D and potential sales are not yet observable.[2] With their development projects, sales projections of biotech companies show a high uncertainty, and beyond that should be taken into account technological risk rates. The second difference consists in that valuation of a pharmaceutical company is driven by the benefits of incoming years depends of the development of a drug, a process defined by steps in which each phase determines the success of the previous phase.

Thus, each phase is similar to buying a call option and the entire development process can be conceived as a series of call options (Villiger and Bogdan, 2005; Sereno, 2010). Finally, it is very difficult to know the exact number of studies under research since in the pharmaceutical/biotech industry these data are of the highest confidentiality and awareness of these details is equivalent to virtually knowing company's business strategies. Data protection (trade secrecy) in this industry is important in all phases of a research and development project to attain competitive advantages (Nealy *et al*, 2015). Table 1 shows various studies implementing the Theory of Real Options in the valuation of pharmaceutical/biotech companies.

2. Application to Bioclon Institute

2.1. The Corporation

Bioclon Institute is a world leader in the production, research and development of fabotherapics (effective and safe antivenoms against the sting and bite of poisonous animals); these products are manufactured using its own technology, recognized internationally. In fact, Bioclon Institute is the largest company of antivenoms globally and it is the only Mexican biotech company authorized by the US to conduct clinical trials. In this respect, concerning antivenom development and its future, scientific experts affirm that biotech is firmly advancing in new alternatives cost-effective antivenoms research (Lausten et *al*, 2017).

Bioclon Institute is a medium sized company 100% Mexican, resulting from mergers in 1990 among several companies of the biological and pharmaceutical industry. The company bases its competitiveness in technological innovation based on a qualified staff and a wide network of relationships with research centers, opinion leaders and national and international companies. It is also the only Mexican company that obtained from the Food and Drug Administration (FDA) of the United States, the designation of "orphan drug" (absence of any drug or medication to treat a specific condition) for three of its products in which is the world leader in the development and production of fabotherapics; the Institute is the creator of a "Third Generation" of anti-venoms, with unique global biotech traits; this has required knowing the world's poisonous fauna and implementing research to develop antivenoms.

2.2 Patents

Bioclon Institute´s intellectual property is safeguarded by a protection strategy that includes obtaining patents and registering trademarks. Currently, the company has five patents (two in the United States, one in Mexico, one in Australia and one regional patent in the European Union); additionally, it has three patents under process abroad. In terms of brands it has a portfolio of 43 trademarks (in Mexico and abroad) and twelve are under registration processes.

[2] However, differentiation between biotech and pharmaceutical companies is nowadays fuzzy.

2.3 Research and Development

Currently, the process of research and new product development is carried out in collaboration with researchers in Mexico and abroad. Its antivenoms are not only differentiated by their quality and price but also to be free of all viral load and production processes which have generated substantial improvements, being more flexible and cheaper than those of competitors by not requiring refrigeration. Bioclon Institute divides R&D of a new antivenom into five main phases and a post evaluation phase:

1. Invention, creation or preparation of the molecule and Preclinical Research

2. Clinical trials Phase I

3. Clinical trials of Phase II

4. Clinical trials Phase III

5. Regulatory Review

A post-evaluation phase, mainly marketing updating

Table 2. Classification of Antivenoms of Bioclon Institute

Antiscorpion	Antiarachnids	Antisnakes	Anticoral
Alacramyn®/Anascorp® Alacramyn® North Africa and Middle East	Aracmyn® Plus/Analatro® Reclusmyn®	Antivipmyn®/Anavip® Antivipmyn® TRI Antivipmyn® Africa Antivipmyn® North Africa and Middle East Antivipmyn® Europe	Coralmyn®

Source: Authors´ research gathering.

2.4 Market

Bioclon Institute products are sold directly to hospitals and clinics, as well as to zoos and individuals. Recently, the company succeeded in establishing a significant milestone in Mexican biotechnology; FDA approved antivenon Anascorp® in August 2011. The company has presence in South America, Africa and Europe, with a favorable trend in terms of expansion in these markets. It is estimated that each year there are 6.5 million accidents caused by poisonous animals worldwide; it has been estimated that around 20 million units of antivenoms could take care of these cases.

2.5 Antivenoms Portfolio of Bioclon Institute

A part of antivenom Anascorp® which was approved in August 2011 by the FDA for marketing, Antivipmyn® and Aracmyn Plus®, were acknowleged by this agency as orphan drugs, and were authorized as new drugs under investigation (Investigational New Drug, IND). Table 2 shows a classification of antivenoms that the company has developed or else is currently developing, according to the category indicated. In total Bioclon Institute produces six antivenoms, three are still under clinical trials.

2.6 Valuation of Bioclon Institute Applying Real Options

Corporate valuation requires making relatively long financial projections; in the case of biotech firms this means cash flow projections up to 10 or 20 years, depending on the stage at which the drug is, which carries a high level of uncertainty. However, using real options theory to value a biotech company like Bioclon Institute enhances the chances of success of development projects, in this case of anti-venoms. Moreover, with Real Options Theory there is the possibility of taking into account the rational behavior of the firm (administrative flexibility), i.e., an optimal decision is obtained when a project is abandoned if the expected value thereof is lower than the marginal investment, or, in other words, when costs are higher and/or cash flows lower than expected. Here, estimations of the input parameters for the ROA follow closely Keegan (2009). A binomial three model is used to test the viability of the products. Borissiouk and Peli (2003) and Sereno (2010) are among those who support this idea or extension of a Binomial Tree Model in their application to Serono International.

2.7 Valuation of the R&D Portfolio of Bioclon Institute Employing Binomial Trees

As previously mentioned Bioclon has a significant number of products under R&D stages. However, the company does not have its shares placed in a stock market, which brings about certain problems in valuation of the company because there is little information about the investments made and about R&D activities. To simplify valuation this paper limits it to the case of the portfolio of antivenoms of Bioclon targeted to the US market. Table 3 presents these antivenoms, highlightning several aspects. The first aspect is the omission of antivenoms Antivipmyn® TRI, Antivipmyn® Africa, Coralmyn® and Reclusmyn®. This omission concerns the fact that they are already sold in their respective markets, and there is not enough public information about the timing of the R&D phases. In the case of Reclusmyn®, the company revealed that to date is pending the development of Phase II.

A second aspect is that the Anavip® and Analatro®, antivenoms are recognized and designated by the US FDA as orphan drugs and Investigational New Drugs, IND; additionally Anascorp® is also approved by this agency. This situation contributes finding public information about various phases of each of these antivenoms; it is possible to identify the timing of each phase for the portfolio of these venoms. Phase II begins in 2005 and for two of them Phase III ends in 2012. These periods were established considering also information presented above, in regard to the length of the stages and phases of drug development for the US case; this gives the possibility of proposing that the review/approval of the FDA compliance for 2012-2013, so that launching of the antivenoms could be made in 2013.

A third aspect is this work assumes that the analysis of Bioclon's R&D portfolio started in 2006 for two reasons. The first is that public information was found only from Phase II on; secondly, because FDA evaluation some accounting adjustments were carried out leading to some financial reporting adjustments for 2004 and 2005. This matter was discussed personally by the authors with management of the company. A fourth aspect is the fact that these antivenoms are targeted to the US market which opens ups the possibility of using the comprehensive information provided by several authors, in addition to the information released by FDA and ClinicalTrials carried on by Bioclon Institute.

Table 3. Duration of Clinical Studies of the R&D Portfolio Targeted to the U.S.

Antivenom	Phase II	Phase III	Inspection/Approval FDA	Launching
Anavip® (orphan drug, FDA)	2005- 2007	2008-2012	Not available	Not available
Anascorp® (approved drug, FDA)	2005-2010		2011	Not available
Analatro® (orphan drug, FDA)	2005-2006	2009-2012	Not available	Not available
Standarization of Portafolio Phases				
	Phase II	**Phase III**	**Inspection/Approval FDA**	**Launching**
R&D Antivenoms Portfolio Targeted to the U.S. market (Anavip®, Anascorp® y Analatro®)	2005-NA	NA	NA	

Source: Based on information from www.bioclon.com.mx and www.clinicaltrials.gov.

On the other hand, in the United States patent protection lasts approximately 17 years and in the European Union is limited to 10 years, after final approval. In Mexico, patents last for 20 years. Thus, the effective life span of a patent for drugs is about 11 to 12 years. Therefore, since the R&D portfolio of antivenoms is directed to the United States market, it is assumed that after the launch of the three antivenoms, the company will earn revenue by its sales until 2022. This date is in line with the duration of US patents and date Bioclon Institute obtained the corresponding patent in that country.

2.8 Administration of the Antivenoms R&D Portfolio of Bioclon Institute

The value of a portfolio of projects is the sum of the values of each project. However, this is only one aspect concerning the valuation of a portfolio of projects. Other aspects are the risk profile, the distribution of cash flows, or else requirements associated with liquidity, or the structure of the portfolio. A standard project valuation is not very helpful for understanding these aspects. However, simulation methodologies are an appropriate tool to analyze

a portfolio of projects with respect to risk and its development through time. Also, a very important property of simulation methodologies is their ability to take into account correlations; a project from portfolios of pharmaceutical/biotech companies precisely can present these correlations. For example, two drugs that are based on the same mechanism of action are partially affected by the same risks (Bogdan and Villiger, 2010).

A diversified portfolio, like in the case of Bioclon Institute, consists of similar projects, where they all use the same mechanism of action. Bogdan and Villiger (2010) argue that, although the average value is the same, it is clear that a non diversified portfolio of projects shows much lower and upper values than diversified portfolios. While a portfolio of uncorrelated projects remains, in most cases, as a mixture of successes and failures, a portfolio of correlated projects is very much a black and white photograph. That is, if the mechanism of action is effective and safe, all projects will be approved, or else if the mechanism is not effective and safe, therefore no project will be approved (Bogdan and Villiger, 2010).

Thus, for the evaluation of the R&D portafolio of the antivenoms of Bioclon Institute it is assumed that the three projects Anavip®, Anascorp® and Analatro® antivenoms are strongly correlated, that is, the portfolio correlation coefficient close to one. Based on this assumption, it is possible to use the Binomial Tree Model because the three projects comprising its R&D portfolio move together "up" and "down"; the corresponding binomial trees can be adjusted to the standardized timing assumed in Table 3. Moreover, the company is the creator of the "third generation" of fabotherapics with unique biotechnological characteristics worldwide. Bioclon´s antivenoms seen as biotechnology products are obtained from the serum of immunized horses, with the venom of a specific poisonous animal; using the latest scientific advances the company has managed to purify these serums reducing significantly the severe allergic side effects, both immediate and lagged. Therefore, taking into account these characteristics of biotech antivenoms and that actually two antivenoms are designated as orphan drugs and one of them has already been approved by the FDA, it is reasonable to assume that these antivenom projects are strongly correlated.

2.9 Bioclon Institute's European Compound Rainbow Option

A compound option is an option class that provides access to other options.[3] This real option is equivalent to a set of European call options. Thus, the value of the investment in stages for the development of antivenoms that make up the portfolio of R&D of Bioclon Institute will increase if this investment is modeled as a European compound option, since the Institute would be able to adjust its R&D portfolio through additional financing taking into account the resolution of future uncertainty. In this way, sunk costs of the R&D portfolio will be reduced.

In particular, the value of the compound option is crucial if the R&D phases of a project characterized by a high level of technical uncertainty (technological or scientific) and if it requires considerable monetary investments. Similarly, it is important to recall that the option of deferring an investment carried out in stages has no value in the case of biotechnology projects. This argument is very important because it implies that the choice of the antivenoms R&D portfolio consists of a European compound option. Finally, a compound option is also a rainbow option, since its value is defined by two sources of uncertainty: economic and technical (Cassimon *et al*, 2012). Therefore, and based on the work of Borissiouk and Peli (2003), the valuation of the R&D portfolio from Bioclon Institute can be examined as a compound European rainbow option. Thus, the development and commercialization of R&D portfolio of antivenoms can be modeled as a sequence of learning investments in order to reduce uncertainty about their effectiveness, market potential and price of antivenoms; and abandonment option would aim at avoiding making continuous payments if the projects are not profitable. Thus, in order to realize its R&D portfolio of antivenoms, the company should take discreetly four investment decisions as shown in Table 4. These four options will be the core of the compound option model applied in this work.

Table 4. Decisions from Bioclon Institute to Finish the R&D Portfolio

Options	Start (beginnings of)	Expiration Date	Decisions
First Option	The firm acquires this option when invests for Phase I of clinical essays	2005-2006	Decision to begin Phase II of Clinical Essays
Second Option	2005-2006	NA	Decision to begin Phase III of Clinical Essays

[3] This section is based on the works by Bogdan and Villiger (2010), Borissiouk and Peli (2003), Keegan (2009), Ljumovic et al. (2013), Hauschild and Reimsbach (2014), and Daim (2017).

Third Option	2008	NA	Decision to request inspection/approval from FDA
Fourth Option	NA	2013 Assume	Decision to launch to the U.S. market antivenoms included in the R&D portfolio
	2013	2016	Additional marketing and sales studies.

Source: Assumptions made by the authors based on information from Bioclon Institute**.**

First Option. The starting point for the evaluation was set in 2005-2006.[4] Then the company had finalized the Stage of Preclinical (Trial) Studies and Phase I of its R&D portfolio. This means that in 2005-2006 the company had the right to decide whether investing in Phase II or abandon the project after Phase I. The company acquired this option at the time it had invested in Phase I. Thus, this was its first option with a defined maturity at the time the company exercised the decision to invest in Phase II. However, for the start of Phase II a payment which would be the exercise price $I_{Phase\ II}$ of the first option was required.

Also, by investing in Phase II the company automatically acquires a second option corresponding to the option to start Phase III. Thus, investment $I_{Phase\ III}$ is also considered as the exercise price of this second option. In addition, payouts of the first option do not depend directly on the expected cash flows at that time from the R&D portfolio after launching. These payouts include the value of the administrative flexibility of management to invest in the three subsequent phases of the R&D portfolio only if the technological and economic conditions are optimistic and favorable.

Second Option. The beginning of this second option is 2005-2006 and the maturity is defined when the company decides to invest in Phase III or in any case when abandoning the R&D portfolio. If the company decides to proceed, then it must pay exercise price $I_{Phase\ III}$ of the second option. This exercise price also represents the price of the third option, which corresponds to the option to request inspection/approval by FDA. In addition, the underlying asset is the expected value of the cash flows of the R&D portfolio of the three antivenoms, including the condition of optimization of the two subsequent phases of development of this portfolio at the time the second option is acquired.

Third Option. This option starts with the investment made in Phase III which takes place early 2008. If Phase III ends with positive results the firm can decide completing the documentation required for the inspection/approval by the FDA; if the results are not favorable the firm can stop the projects that make up the R&D portfolio. The exercise price of the third option is the investment required to cover the cost of the approval procedure $I_{Approval}$. Hence, by deciding to finance the approval stage and thus exercising the third option, the company acquires a fourth option, which corresponds to the option of launching to the U.S. market its antivenoms comprising its R&D portfolio. The underlying asset of the third option is determined not only by the present value of future cash flows generated by this portfolio but also includes the value of the right of the company´s directors to continue the launching phase of the antivenoms only if the value of the cash flows of the R&D portfolio exceeds the payouts of this phase, i.e., I $I_{Launching}$.

Fourth Option. The fourth option corresponds to a call option to launch and marketing the antivenoms that make up the R&D portfolio.[5] In any case, Bioclon Institute should take this decision only if the antivenoms are already approved by the FDA and if in addition economic uncertainties are solved, that is, the NPV of the R&D is positive. As shown in Table 3, the approval time is assumed to be about 1 year, which determines the maturity of the fourth option. The company must also face significant costs related to marketing the products. Thus, the exercise price $I_{Launching}$ includes all cost related to the marketing, force costs and field force. It is worth mentioning that when this last option ends it is possible to acquire all the cash flows generated by the sale of the products. Thus, the underlying asset of the fourth option is defined by the value that can be obtained from marketing of Anavip®, Anascorp® and Analatro® antivenoms. Summing up, by investing in each phase, the company gets in return an additional option related to the following phase, ultimately modeling ROA as a compound option.

[4] Partly, this paper deals with an ex-post ROA. Bioclon Institute´s managers became interested in knowing this technique for the evaluation of future and ongoing projects. Most information remained confidential; for this paper, information from the company, public information and interviews with the managers were employed.

[5] Borissiouk and Peli (2003) affirm that Phase IV has a limited impact on the value of R&D project, which is absent in preceding phases.

2.10 Parameters of the Real Options

Value of the Underlying Asset. For Bioclon´s R&D compound option of portfolio of antivenoms, the underlying asset consists of two parts. On one hand, there is the present value of the portfolio at the time of the acquisition of the compound option. On the other hand, the value of this portfolio implicitly takes into account the conditions of optimization of Phase III, Phase of Inspection/Approval by the FDA, and the final launching of the products phase. For example, the condition of optimization of the launching phase means that in 2013 the company will invest in this phase with the proviso that at that time it has a positive value the difference between the present values (in 2013) of cash flows generated by the antivenom portfolio and the present value (in 2013) of all marketing costs, force costs and field force.

In a discreet frame, the underlying asset value of the compound option is the sum of the present values (gross) of the expected future cash flows (sales revenue) of the projects that make up the portfolio of antivenoms defined in Table 3. Borissiouk and Peli (2003) argue that it is important to note that the value of the underlying asset incorporates optimality conditions on the subsequent phases of the R&D portfolio (that is, incorporating the values of the "simple" options Phases III and IV, Phase of Inspection/Approval by the FDA and Launching Phase, respectfully.

To obtain the whole Gross Present Value (GPV) of the R&D portfolio of antivenoms, which is the value of the underlying asset, it was difficult to cleave information needed to reach an accurate value. This is because there is no public information indicating the financial statements of the company to identify its projected revenues and direct costs, taxes, depreciation, working capital, i.e, all those metrics that are necessary for the calculation of GPV and net present value (NPV). It should be noted that in this case the underlying asset is GPV and not the NPV, because values of the investments made in the various stages or phases must not be taken into account since these investment will subtracted as strike prices in the calculation the compound option (Borissiouk and Peli, 2003).

Tax incentives received by the Bioclon Institute give and idea of its potential benefits during the 2004-2009 period. These incentives from Mexico´s Federal Government are part of a support program benefiting income taxpayers who have invested in R&D in technology aimed at developing new products and materials or processes. The stimulus are based on the 2012 applicable Income Tax Law which consists of a tax credit of 30% of expenditure and verifiable investments in projects of products, materials and processes production, R&D in technology, among others. Thus to start up its investment, the company obtained financing from CONACYT Innovation Program ($25,304,413.00 pesos) and FONCICYT ($4,017,999.00 pesos), giving a total of $29,322,412.00 pesos.[6] Then, since the amount of $25,304,413.00 pesos is 30% of expenses and general investments, then the total amount (100%) is approximately $85 million pesos. Of these expenses and general investments are assumed to be $50 million pesos (about 60%), directed to the R&D portfolio of all antivenoms.

Hence, the firm invests about 25% of its sales in R&D, it can be assumed that by 2012 the company received from sales the amount of $200 million pesos. This last figure is the basis to estimate GPV for sales in the U.S. market. It can also be affirmed that part of GPV also includes management estimates fort Anavip® and Analatro® due to their status as orphan drugs and Anascorp® an antivenom approved by the FDA. With this designation, these antivenoms benefit from marketing exclusivity aimed at the recuperation of Bioclon Institute investment costs. Earlier, it was mentioned that the projected income of the company was estimated to last till 2022 in line with the life of patents; however, if the company obtains marketing exclusivity this projection should then be made until 2029.

GPV is obtained in this work applying simulation exercise scenario on Bogdan and Villiger (2010); For this exercise the value of peak sales is required; for this it will be taken into account that by the end of 2011, the company launched a new production plant in Toluca, State of Mexico; it estimated increasing its production six times from the 600,000 doses currently produced. Then simulation of peak sales in 2013 not only depends on uncertainty, i.e. volatility σ, but also on the launch time relationship $\tau = T - t$.. Equation 1 allows estimating simulated peak sales $V(T)$ in time T, given the current value $V(t)$, with the growth rate μ, ε_t is a random number from a normal distribution N(0,1) (Bogdan and Villiger, 2010).

$$V(T) = V(t)\exp\left[\left(\mu - \sigma^2/2\right)\tau + \sigma\sqrt{\tau}\,\varepsilon_t\right]. \quad (1)$$

Similarly, cash flows generated after 2029 until the end lifetime of the project must be estimated; that is, the terminal value $VTer$ of the project must be determined. To determine it, the formula of decreasing perpetuity will be used in this work; but instead of using a growth rate in the denominator a decreasing value rate is employed (Borissiouk and Peli, 2003; Reis and Augusto, 2013).

[6] CONACYT is Mexico´s National Council for Research and Technology; FONCICYT is CONACYT's Fund for the International Cooperation in Science and Technology.

Therefore, with the simulation exercise it is possible to find the GPV of the R&D portfolio of Anavip®, Anascorp® and Analatro® antivenoms. After performing a generic scenario for GPV a simulation of 10,000 scenarios is carried out; from this valued the average defines the GPV for 2005 and therefore the value of the underlying asset of the compound option is obtained, that is, $S_0 = \$2{,}825{,}109{,}469.00$ pesos.

Importantly, this GPV does not take into account the values of the investments made in the various stages or phases; the R&D portfolio of the three antivenoms can generate this amount on the condition that all clinical studies have 100% chance of success (Anascorp® fully meets this condition). However, as it is shown in Table 5, technological probabilities are estimated at 77% (Phase I), 50% (Phase II), 73% (Phase III) and 80% (Phase Inspection/Approval by FDA). These factors for investments and probabilities will be included in the Binomial Tree Model.

Exercise Prices (Investments by Stages). In the same vein, the exercise price of each option embedded in the compound option is the sum of the expenditure required in order to undertake the R&D and marketing stages of the projects that make up the portfolio of antivenoms. Throughout this section some figures have been referred to the amounts that Bioclon Institute must disburse to conduct clinical trials and therefore evidencing efficacy and safety of its antivenoms in the United States. However, again the tax incentives will be used in order to determine the strike prices of the compound option. First, adding up the incentives granted from 2005 to 2009 the total is $45,433,452.19. This amount represents 30% of expenditure and verifiable investments in projects of products, materials and production processes, R&D technology, etc.; then the total amount (100%) is approximately $151,444,841.00. Of these overheads $90 million pesos (about 60%) are assumed is the investment made by the company from 2005 to 2012 for the R&D portfolio of antivenoms.

Thus, for the exercise prices information presented by Bogdan and Villiger (2010) and Keegan (2009), is used about the costs of drug development. With this information the average percentages of the total amount for each of the stages of R&D are obtained. Both Bogdan and Villiger (2010) and Keegan (2009) indicate that their costs are approximate and vary significantly for a small and a large biotech companies; this work uses average percentages of total investment in R&D presented by these authors to use them for the case of the compound option of Bioclon Institute. Results are shown in Table 5.[7]

Finally, for the launching phase is necessary modeling stochastically costs related to this stage, we resort to building a Binomial Cost Tree (Borissiouk and Peli, 2003). This requires an initial value for 2005; for this purpose, the opinions of Bogdan and Villiger (2010), Cassimon *et al*. (2004), DiMasi and Grabowski (2007), and Keegan (2009), are taken into account; they argue that biotechnology launching costs are about the costs of the whole R&D process. Thus, in the case of Bioclon Institute a value of $30 million pesos is used in 2005, a third of $90,000,000.00 pesos.

Expiration Dates. Expiration dates for each of the four "simple" options that make up the European compound rainbow option is determined for the beginning of 2005, 2008, 2012 and 2013.

Dividends. Dividends are not included in the calculations for the value of the compound option because no cash flows are generated during the R&D process.

Volatility. First, biotechnology projects have two main sources of uncertainty that correspond to economic and technological uncertainties. Economic uncertainty arises from two input variables which are the future cash flows of the project (in this case a portfolio of projects) and uncertainty about the costs of the Launching Phase. Additionally, technological uncertainty is represented by the probability of success in each phase. Also, it is important to note that impacts are partly technological drivers of economic impacts. Thus, in the case of R&D portfolio of antivenoms, a reduction in the technological uncertainty will tend to reduce economic uncertainty.

[7] The amount of $90,000,000.00 equals 72.28% of the total quantity employed for the R&D process. This is used to determine the corresponding exercise prices.

Table 5. Exercise Prices of the Compound Option of the R&D Portfolio of Antivenoms[8]				
Stage/Phase I+D	**Start Year**	**Duration in in Years (Antivenoms Portfolio)**	**Average percentages from total investment amount for the R&D processes in Biotech presented by Bogdan and Villiger (2010) and Keegan (2009)**	**Exercise Prices considering the average percentages and investment for the period 2005 to 2012 ($90,000,000.00)**
Discovering	Not available	Not available	4.72%	Not available
Preclinical research	Not available	Not available	17.16%	Not available
Clinical Trials of Phase I	Not available	Not available	5.83%	Not available
Clinical trials of Phase II	2005	3	13.47%	$16,772,274.00
Clinical trials of Phase III	2008	4	52.44%	$65,296,071.00
Inspection/Aproval by FDA	2012	1	6.37%	$7,931,655.00

Source: Adapted from Bogdan and Villiger (2010) and Keegan (2009).

Expiration Dates. Expiration dates for each of the four "simple" options that make up the European compound rainbow option is determined for the beginning of 2005, 2008, 2012 and 2013.

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Volatility. First, biotechnology projects have two main sources of uncertainty that correspond to economic and technological uncertainties. Economic uncertainty arises from two input variables which are the future cash flows of the project (in this case a portfolio of projects) and uncertainty about the costs of the Launching Phase. Additionally, technological uncertainty is represented by the probability of success in each phase. Also, it is important to note that impacts are partly technological drivers of economic impacts. Thus, in the case of R&D portfolio of antivenoms, a reduction in the technological uncertainty will tend to reduce economic uncertainty.

Like other high-growth biotechnology companies, whether domestic or foreign, small, medium or large, Bioclon Institute is not free of risks; based on the portfolio of antivenom; one of the most important risks is that any of the two antivenoms (Anavip® and Analatro®) could not be approved by the FDA. Another important risk is that delays arising in the marketing of antivenoms precisely because commercial issues, which would entail a high opportunity cost. In general, there are many factors such as price, quantity, variable costs, capital expenditures, interest rates and probabilities of success, which may influence the company's potential antivenoms.

Following a suggestion by Borissiouk and Peli (2003), to obtain the volatility of a R&D portfolio is possible to use the volatility about stock performance of the company. Only few companies of emerging markets are listed on their

[8] Some public information was available from Phase II onwards. Financial adjustments in the company were made in 2004 and 2005.

stock markets and tend to be controlled by families or family groups. This is the case of Bioclon Institute it is not a company listed in the Mexican stock market; additionally it is a family business. Also, there are few companies engaged in the manufacture of antivenoms; however, the antivenom CroFab® owned by BTG plc is marketed in the United States and listed in the London Stock Exchange can be used as substitute or proxy of the volatility of the R&D portfolio from Bioclon Institute.

Hartmann and Hassan (2006) indicate that for project valuation, volatility in the valuation of companies derives from the historical volatility of the return on equity prices of biotechnology and pharmaceutical companies. Thus, the annual volatility (standard deviation) annual from historical stock returns of BTG plc from January 2003 to December 2010 (corresponding to the life of the compound option) is estimated a used in this work, which amounts to [9] $\sigma_{BTG} = 61.29\%$. However, *Keegan* (2009) also warns that significant errors can result in the task of valuation if there are only few comparable companies. In the case of Bioclon Institute, this situation is even more special because the company produces antivenoms with unique global biotech traits. Additionally, Mun (2005) and Mascareñas *et a*l. (2004) argue that the market value of a company whose shares are publicly traded depends on multiple interactions and diversified projects. Hence, individual projects are not leveraged but comparable companies are.

Therefore, Real Options Analysis concerning volatility value should be adjusted to discount the leverage effect by dividing the volatility of stock returns of the comparable company σ_{BTG} by $(1+D/E)$ where D/E corresponds to the debt to equity ratio (risk coefficient or leverage ratio) of comparable companies. Thus, if this ratio is 0.79, the adjusted volatility for Bioclon Institute is:

$$\sigma = \frac{\sigma_{BTG}}{(1+D/E)} = \frac{0.6129}{(1+0.79)} = 0.3424.$$

This is volatility used for the case of Bioclon Institute, $\sigma = 34.24\%$. It is important to recall that the volatility parameter used in determining the value of real options is the volatility of returns of a project, not volatility of its present value.

Risk free interest rate. The risk-free rate suggested by Copeland, Koller and Murrin (2000) is used. Of the three methods proposed by these authors for a risk-free rate (nominal) the most convenient for emerging markets because of its simplicity is the method where the rate of return of a bond in the United States and the inflation differential is required. In this work historical data for 10-year US government notes is used; concretely the geometric mean for the period 2003-2011, corresponding to the lifetime of the compound option of the R&D portfolio from Bioclon Institute; its value is 4.23%. On the other hand, the inflation differential between Mexico and the U.S. was 1.92% for the same period. Thus the relevant nominal risk-free rate to value Bioclon Institute equals 6.15% considering the 4.25% geometric mean for inflation in México for the same period, real risk free rate to value Bioclon Institute's R&D portfolio is 1.82%. Consequently the continuous rate $e^{0.0182}$ -1 = 0.0184; 1.84% annual.

Probabilities of Technological Success. The probability of technological success, following a suggestion made in an interview to managers of Bioclon Institute, corresponds to the average of values proposed by some authors, mainly Demirer, Charnes and Kellogg (2007), Bogdan and Villiger (2010), DiMasi and Grabowski (2007) which is shown in Table 6. It is important to point out these values have been indicated for the United States, which is the target country for Bioclon Institute R&D portfolio (Anavip®, Anascorp® and Analatro® antivenoms).

Previously it was mentioned that exercising one of the "simple" options Bioclon Institute receives in return the next option. However, the presence of technical risk in biotech R&D makes uncertain the subsequent acquisition of this option. In general, a company can invest in Phase II and thus exercise its first "simple" option for the second "simple" option, but unconvincing or unsatisfactory results in Phase II nullify the value of the R&D option in question; the right of the company to buy a call, Phase III disappears automatically. Thus, according to Table 5 the probability that this option is exercised becomes reduced to 50%, which is the chance of technological success of Phase II.

[9] Time decay used in this work = $\sqrt{252}$ to determine annual volatility.

Table 6. Success Probabilities in Biotech R&D. Average is used for Bioclon Institute				
Stage/Phase I+D	**Probabilities of Success**			
	Kellog and Charnes (2000) Kellog et al. (2003) Demirer et al. (2007)	Bogdan and Villiger (2010)	DiMasi and Grabowski (2007)	Average
Discovering	60%	Not available	Not available	60%
Preclinical research	90%	Not available	Not available	90%
Clinical Research Phase I	75%	71%	83.7%	77%
Clinical Research Phase II	50%	44%	56.3%	50%
Clinical Research Phase III	85%	69%	64.2%	73%
Inspection/Approval by FDA	75%	84%	Not available	80%
Post-Aproval	100%	100%	100%	100%

Source: Based on information gathered from authors included in the Table.

Construction of the Binomial Trees. It is necessary to know the parameters u, d and q (risk neutral probability), in order to have recombinant trees and correctly model a geometric Brownian motion; the following relationships are employed:

$$u = exp\left(\sigma\sqrt{\delta t}\right) = exp\left(\sigma\sqrt{T/N}\right) = 1.4083,$$

$$d = 1/u = exp\left(-\sigma\sqrt{\delta t}\right) = exp\left(-\sigma\sqrt{T/N}\right) = 0.7101,$$

$$q = \frac{exp(r\delta t) - d}{u - d} = \frac{exp\left[r(T/N)\right] - d}{u - d} = 44.18\%,$$

Where σ =34.24%, $\delta t = T/N$ with $T = Expiration\ in\ Years =$ 8 and $N = Number\ of\ Periods =$ 8 so that $\delta t = 1$, and r =1.84%.

The assumption that the standard deviation of the returns of the portfolio of R&D antivenoms remains constant over the life of the compound option allows using in the same period the values of u land d. One year nodes are applied in the model because biotechnology projects stop either after finishing one R&D stage, or else with respect to financial resources scarcity; biotech companies can re-assess the value of their R&D project and take more decisions at the end of each year. Thus, there is the possibility that each node Binomial tree can be adjusted from the date of allocation of the budget when the company decides to continue funding the project (Borrisiouk and Peli, 2003).

The information previously summarized can be used to determine the value of the underlying asset and developing the binomial tree. This value S_0 = \$2,825,109,469, as shown in Figure 1; at the lapse of one year, may reach S_0u =\$2,825,109,469 x 1.4083 = \$3,978,601,665 (if the economic uncertainty is favorably) or else conversely, decrease to S_0d = \$2,825,109,469 x 0.7101 = \$2,006,110,234 (if economic uncertainty is unfavorable). At the end of two years S_0 would have three values: S_0u^2 =\$2,825,109,469 x 1.4083^2 = \$5,603,064,725; S_0ud =\$2,825,109,469 x 1.4083 x 0.7101 = \$2,825,205,042 and S_0d^2 = \$2,825,109,469 x 0.7101^2 = \$1,424,538,877. In this manner the extreme right of the binomial tree has nine possible results for GPV of the R&D portfolio, which are needed to develop the binomial tree for the compound option.

R&D Phase	Phase II	Phase II	Phase II	Phase III	Phase III	Phase III	Phase III	FDA Approval	Launching	Steps	Risk Neutral	Average Value
Beginning of	2005	2006	2007	2008	2009	2010	2011	2012	2013	Up	State	Risk
Time-Years	0	1	2	3	4	5	6	7	8		Probability	Neutral
Underlying Asse	2,825,109,469											Probability
dt	1											
sigma	0.3424											
u	1.4083											
d	0.7101											
r	1.84%											
q	44.18%								43,711,601,163	8	0.001451	63,445,731
1-q	55.82%							31,038,557,952				
							22,039,734,397		22,040,480,001	7	0.014671	323,355,944
						15,649,885,960		15,650,415,395				
					11,112,608,081		11,112,984,020		11,113,359,972	6	0.064877	721,003,456
				7,890,796,052		7,891,062,998		7,891,329,953				
			5,603,064,725		5,603,254,277		5,603,443,835		5,603,633,399	5	0.16394	918,662,093
		3,978,601,665		3,978,736,261		3,978,870,862		3,979,005,467				
	2,825,109,469		2,825,205,042		2,825,300,619		2,825,396,199		2,825,491,782	4	0.258917	731,567,264
		2,006,110,234		2,006,178,101		2,006,245,970		2,006,313,841				
			1,424,538,877		1,424,587,089		1,424,635,263		1,424,683,458	3	0.261706	372,848,761
				1,011,565,057		1,011,599,278		1,011,633,500				
					718,312,347		718,336,647		718,360,949	2	0.165329	118,765,735
						510,073,597		510,090,853				
							362,203,262		362,215,515	1	0.059682	21,617,804
								257,200,536				
									182,638,101	0	0.009426	1,721,512
									Sum = Expected Value =			3,272,988,300

Figure 1. Binomial Tree for the Underlying Asset of the Compound Option

The next question has to do with the determination of the exercise prices of the compound option.

Previously, it was noted that when investing in certain stage of R&D, the company acquired in return the option to continue with the next R&D phase. Thus, the exercise prices within the binomial model are also defined by investments made in stages. It was also mentioned the need to build a binomial tree to represent the stochastic part of the (total) cost of the launching phase; this task requires a volatility parameter to set the parameters u and d. Thus, the volatility value will be the same as the underlying asset, i.e. σ=34.24%. This is the value used to construct the Binomial Tree corresponding to the marketing costs of the R&D portfolio shown in Figure 2.

R&D Phase	Phase II	Phase II	Phase II	Phase III	Phase III	Phase III	Phase III	FDA Approval	Launching
Beginning of	2005	2006	2007	2008	2009	2010	2011	2012	2013
Time (Years)	0	1	2	3	4	5	6	7	8
Launching Costs	30,000,000								
dt	1								
sigma	0.3424								
u	1.4083								
d	0.7101								
									464,176,008
								329,600,233	
							234,041,208		234,049,125
						166,187,039		166,192,662	
					118,005,425		118,009,417		118,013,409
				83,792,817		83,795,652		83,798,487	
			59,499,267		59,501,280		59,503,292		59,505,305
		42,249,000		42,250,429		42,251,859		42,253,288	
	30,000,000		30,001,015		30,002,030		30,003,045		30,004,060
		21,303,000		21,303,721		21,304,441		21,305,162	
			15,127,260		15,127,772		15,128,284		15,128,796
				10,741,868		10,742,231		10,742,594	
					7,627,800		7,628,058		7,628,316
						5,416,501		5,416,684	
							3,846,257		3,846,387
								2,731,227	
									1,939,444

Figure 2. Binomial Tree of Marketing Costs of the R&D Portfolio

Considering the values in Figure 3 and the amounts in Table 5 the exercise prices of the compound option can be summarized in full as shown in Figure 3.

R&D Phase	Phase II	Phase II	Phase II	Phase III	Phase III	Phase III	Phase III	FDA Approval	Launching
Beginning of	2005	2006	2007	2008	2009	2010	2011	2012	2013
Time (Years)	0	1	2	3	4	5	6	7	8
Exercise Prices	$16,772,274	$0	$0	$65,296,071	$0	$0	$0	$7,931,655	$464,176,008
									$234,049,125
									$118,013,409
									$59,505,305
									$30,004,060
									$15,128,796
									$7,628,316
									$3,846,387
									$1,939,444

Figure 3. Exercise Prices of the Compound Option of the R&D Portfolio

As previously mentioned, through the Binomial Tree Model can be analyzed separately the technical and economic uncertainties. That is, the economic uncertainty represented by the volatility of returns of GPV was concentrated in the Binomial Tree corresponding to the underlying asset; technological uncertainty embedded in the binomial tree by the probabilities of technological success.

First, it is necessary to obtain final payments (payoffs) from the information in Figure 1 and Figure 3, i.e.:

max{43,711,601,163 – 464,176,008, 0} = $43,247,425,155

max{22,040,480,001 – 234,049,125, 0} = $21,806,430,876

max{11,113,359,972 – 118,013,409, 0} = $10,995,346,563

max{5,603,633,399 – 59,505,305, 0} = $5,544,128,094

max{2,825,491,782 – 30,004,060, 0} = $2,795,487,722

max{1,424,683,458 – 15,128,796, 0} = $1,409,554,663

max{718,360,949 – 7,628,316, 0} = $710,732,632

max{362,215,515 – 3,846,387, 0} = $358,369,128

max{182,638,101 – 1,939,444, 0} = $180,698,657

The operation of subtracting the values of the underlying asset (GPV), given in 2013, of the launching costs of that year, is because the present value of future cash flows of the R& D portfolio can be acquired, assuming these costs. Then, if the net result of these differences were negative, then the company has the right not to exercise the option of the launching phase. By obtaining final payments it is possible to develop a Binomial Tree of the European rainbow compound option as indicated in Figure 5. This figure gathers the best decisions Bioclon Institute must make in each period and at each node. That is, the value at each node integrates contingent decisions given by:
→ The increase or decrease from economic uncertainty
→ Investments made by stages
→ The probability of success in R&D, that is, technological uncertainty

R&D Phase	Phase II	Phase II	Phase II	Phase III	Phase III	Phase III	Phaase III	FDA Approval	Launching
Beginning of	2005	2006	2007	2008	2009	2010	2011	2012	2013
Time (Years)	0	1	2	3	4	5	6	7	8
Exercise Prices	16,772,274	0	0	65,296,071	0	0	0	7,931,655	
R&D Portfolio Value	$412,446,629								
Prob. Success FDA	80%								
Prob. Success Phase III	73%								
Prob. Success Phase II	50%								
dt	1								
sigma	0.3424								
u	1.4083								
d	0.7101								
r	1.84%								
q	44.18%								43,247,425,155
1-q	55.82%								
exp(-r) (Discount Factor)	0.9818							24,559,468,959	
							12,729,081,251		21,806,430,876
						6,597,123,828		12,379,563,733	
					3,418,879,528		6,415,502,129		10,995,346,563
				2,361,597,844		3,324,414,628		6,238,152,614	
			1,210,639,993		1,722,436,781		3,232,037,998		5,544,128,094
		617,859,040		1,156,983,204		1,674,232,989		3,141,499,886	
	412,446,629		586,215,505		867,048,019		1,626,855,949		2,795,487,722
		294,182,132		549,586,445		842,170,231		1,580,090,313	
			271,365,097		435,739,661		817,483,108		1,409,554,663
				243,321,843		422,623,427		792,788,646	
					218,263,225		409,377,126		710,732,632
						211,077,460		395,811,500	
							203,599,907		358,369,128
								195,645,719	
									180,698,657

Figure 4. Binomial tree for the Compound Option

Calculations of the Binomial Tree shown in Figure 4 start at determining payoffs, which would become the intrinsic values of the fourth option, i.e. the option of launching. Then, these values are used as the underlying values for the third option, i.e. the option of completing the documentation required for the inspection/approval by the FDA. The general formula to arrive at the value of the option is given by (Baecker, 2013, Shockley, 2007):

$$F_j^{n-1} = max\left\{\exp(-r\delta t)\left[qF_{j+1}^n + (1-q)F_j^n\right] * Prob_{Phase} - I_{Phase},\ 0\right\}, \quad 2$$

here $0 \le j \le 1$, F_j^{n-1} is the value calculated for the node, r is the risk free rate, δt is time step with a value of 1, q and $(1-q)$ represent risk neutral probabilities, F_{j+1}^n y F_j^n are the values of the previous nodes (superior and inferior, respectively), $Prob_{Phase}$ represents the technological probability of the corresponding phase, and I_{Phase} represents exercise prices of the phase under consideration.

Therefore, for example, for the value of the top node at the end of 2012, first must be determined expected values in that year, which can be regarded as risk-free certainty equivalent values and thus can be discounted with the risk-free rate. Thus, using risk-neutral probability q = 44.18% and $1-q$ = 55.82%, the estimation is:[10]

EV_{2012} = \$30,709,248,267 = 0.9818[0.4418(43,247,425,155) + 0.5582(21,806,430,876)].

However, for this phase the probability of approval is 80%, therefore, adjusting the value of EV_{2012} by this technological probability, the expected adjusted value is given by

$EV_{2012}^{Tech} = EV_{2012} * Prob_{Aproval}$ = 30,709,248,267 * 0.80 = \$24,567,398,614.

Then, for the company to purchase this expected value needs to invest the amount of \$7,931,655, corresponding to the exercise price; then the net expected value is given by

$NEV_{2012}^{Tech} = EV_{2012}^{Tech} - I_{Aproval}$ =24,567,398,614 – 7,931,655 = \$24,559,466,959.

Finally, taking into account the condition of optimization, which in reality is defined by a long position in a European call option, the value is:

$max\left\{ENV_{2012}^{Tech},\ 0\right\} = max\left\{EV_{2012}^{Tech} - I_{Aproval},\ 0\right\}$ = \$24,559,466,959.

For clarity, it is also important to explain the value of the extreme top node at the end of 2011. First it must be considered that

EV_{2011} = 17,437,097,604 = 0.9818[0.4418(24,559,466,959) + 0.5582(12,379,563,733)].

For 2011, it must be taken into account the probability of success, as it passes from one year to another within a phase of R&D, so that

$EV_{2011}^{Tech} = EV_{2011} * Prob_{Phase\ III}$ = 17,437,097,604 * 0.73 = \$12,729,081,251.

Then, for the company to acquire the expected value does not require any amount, so

$ENV_{2011}^{Tech} = EV_{2011}^{Tech}$ = \$12,729,081,251.

Finally, taking into account the optimization condition:

$max\left\{ENV_{2011}^{Tech},\ 0\right\} = max\left\{EV_{2011}^{Tech},\ 0\right\}$ = \$12,729,081,251.

Using this methodology are obtained the values of all nodes of the binomial tree of the compound option, and in this way the value of the first node F_0^0 = \$412,446,629 pesos. The final ROA answer. In terms of Real Options Theory this value corresponds to the Strategic or Expanded NPV of the R&D portfolio of Anavip®, Anascorp® and Analatro® antivenoms, including the value of the option to abandon the R&D process at any of the mentioned phases when the project is not profitable: that is, when disbursement (exercise price) at any phase are greater than the cash flows generated by the portfolio of antivenoms. Therefore, Expanded NPV is:

$$Expanded\ NPV_{2005} = \$412,446,629 \text{ pesos.}$$

This value is defined in 2005; and to bring it to 2011, it should grow by at least the risk-free rate of 1.84%; then the Expanded NPV is:

[10] Numbers shown are rounded numbers.

$$Expanded\ NPV_{2010} = \$460{,}127{,}407 \text{ pesos.}$$

Nonetheless,due to positive result, the static or passive NPV remains unknown; consequently, the value created by the flexibility to abandon at any of the stages of R&D investing in the portfolio cannot be determined. It is important to stress that in the case of Bioclon Institute´s portfolio value of its three antivenoms for the amount of $460,127,407 pesos represents only a part of the total value of the firm, since it should be also added the value of other antivenoms under R&D processes, and cash currently hold by the company. However, due to the importance that at least until now antivenin Anascorp® has been approved and in the future is likely that Anavip® and Analatro® will be also approved by the FDA, no doubt the value obtained for the portfolio of these three antivenoms has an important weight in the total enterprise value.

3. Conclusion

Bioclon Institute is an important biotech Mexican corporation. Real Options Theory is an important tool to value it as well as its R&D projects. Although valuation of its R&D portfolio comprising three antivenoms, Anavip®, Anascorp® and Analatro® proved to be complex but fruitful because they are antivenoms with unique global biotech traits; also two of them have the status of orphan drugs and later on, Anascorp® was approved by the FDA for sale in the United States. These events were incorporated into the valuation methodology implemented in this work yielding important insights that managers of this corporation must take into account for their future strategic decision making. Due to the nature of the research and development process which comprises several phases, a compound rainbow European option was adequate. It should be stressed that this technique includes risk, technological and economic, and flexibility, both embedded in a project, as well as managers' administrative flexibility. Also, another contribution of this work is that it valued the three antivenoms as a portfolio, as whole and not separately for each of the projects. The importance of options theory to value research organizations must be conveyed to managers. Since this methodology is not sufficiently known by corporate managers, they must be convinced of the benefits of option theory valuation. This is an important task for scholars from emerging markets.

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