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Internet of Things and Their Coming Perspectives: A Real Options Approach

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Abstract: Internet of things is developing at a dizzying rate, and companies are forced to implement it in order to maintain their operational efficiency. The high flexibility inherent to these technologies makes it necessary to apply an appropriate measure, which properly assesses risks and rewards. Real options methodology is available as a tool which fits the conditions, both economic and strategic, under which investment in internet of things technologies is developed. The contribution of this paper is twofold. On the one hand, it offers an adequate tool to assess the strategic value of investment in internet of things technologies. On the other hand, it tries to raise awareness among managers of internet of things technologies because of their potential to contribute to economic and social progress. The results of the research described in this paper highlight the importance of taking action as quickly as possible if companies want to obtain the best possible performance. In order to enhance the understanding of internet of things technologies investment, this paper provides a methodology to assess the implementation of internet of things technologies by using the real options approach; in particular, the option to expand has been proposed for use in the decision-making process.

Keywords: development; digitalization; investment; Industry 4.0; technological innovation; real options

1. Introduction Internet of Things

In recent years, companies have had to face extreme competition because of changes in technological and global issues. This has accelerated the pace of innovation concerning its acknowledgment, implementation, introduction, and diffusion within the market. Therefore, globalization of manufacturing has come about through a faster transfer of materials, complex payment systems, and compression of the life cycle of certain products [1]. Eventually, companies need technologies to be able to meet the increasingly sophisticated needs of customers and therefore remain competitive, and to create a higher value-added [2]. In doing so, companies can anticipate future trends by developing new concepts (ideas, products, or services) which allow them to differ from competitors by offering their customers a tailor-made experience. This ability may prove to be considered crucial for the development of a sustainable competitive advantage [3]. In order to estimate and anticipate future trends and to assess them accurately, real options may be implemented. Real options, a concept introduced by [4], provide an optimal tool for assessing managerial flexibility. A real option involves, for a given period, the possibility to take future decisions on real investments without committing oneself in advance [5]. They can be defined as the right, but not the obligation, to take future strategic decisions (e.g., to defer, expand, abandon, reduce, or otherwise alter a capital investment) [6]. This instrument allows managers to add value to the company and, therefore, helps them to take more informed decisions in the future since they have the freedom to revise their initial strategy. In other words, if through the life of the project events become different from those originally predicted, real options represent the possibility of taking decisions which can increase profitability or reduce losses [7,8].

It is worth analyzing the role of internet, since it has caused one of the greatest technological disruptions, and it is still evolving and offering novel approaches. Advanced manufacturing technologies rely on various information and communication technologies to achieve higher productivity, higher quality, and lower production costs [9,10]. In this way, the Internet of things (hereinafter, IoT) has become a new dominant feature for companies to revise the implementation of their operations as they will increase both manufacturing productivity and industrial growth, and will modify the profile of the workforce [11,12]. This has led IoT to question how to act in the competitive arena, and to cause companies to reshape their organizational and operational structures. In order to assess the value of redesigning the strategy, a real growth option is an ideal tool [13]. In this way, real options may improve the ability to evaluate a new technology such as IoT, given that real options analysis is particularly appropriate to projects which involve significant uncertainty, but where flexibility in future decisions may help mitigate it [14].

This engaging scenario makes IoT an attractive option for companies as it allows for the redesigning factory workflows, improvement of the tracking of materials, and optimization of distribution costs. Moreover, it allows production to operate in a flexible, efficient, and environmentally friendly way, maintaining quality and low cost [15]. Eventually, this is translated into optimized production systems, services, and decision-making processes [16,17]. Therefore, the adoption of IoT technologies is rapidly gaining recognition and relevance as a technological, societal, and competitive tool to innovate and maintain the level of transformation. In this manner, all efforts are focused on achieving a significant improvement in the well-being of society as a whole, bearing in mind its natural environment [18]. This enables companies to keep pace with continued investment in research and development in order to maintain their competitive advantage.

Although the reasons mentioned earlier constitute incentives for companies to implement any IoT technology, this inevitably involves a certain level of risk because when they fail to adapt to IoT technologies, painful consequences may result (e.g., established companies may lose their leadership positions to new entrants) [19]. For this reason, it becomes vital for companies to understand in advance the potential of adopting IoT technologies.

Ensuring satisfactory progress in the digitalization process and its associated capabilities depends on the prevailing situation of each company and the particular risk surrounding this kind of project. As IoT technologies advance and an increasing number of companies are adopting it, IoT cost-benefit analysis will become a subject of great interest [20]. Therefore, making a self-assessment of the distinct possibilities of success becomes essential for companies. This implies a way of identifying where companies are excelling at the present moment to redirect the efforts while improving their capabilities.

Considering all these circumstances, a reasonable and informed evaluation is needed to assess the implementation of IoT technologies. In effect, the application of an appropriate measure which accurately evaluates risks and rewards is necessary before deciding to invest. This is of particular relevance when dealing with IoT technologies because of their higher inherent flexibility compared to other kinds of technologies, given that they are increasing at a dizzying rate and they change direction quickly.

Real options play a uniquely important role in the assessment and justification of investments in technology projects. Specifically, [21] related real options theory with technology investment. As shown by [20], the real options approach may be applied in order to make informed decisions concerning IoT investments. To some extent, this financial assessment foresees the degree of success so that companies are better prepared to set their boundaries and to achieve their potential.

Investment in IoT technologies has therefore becomes a popular choice, as it can lead to operational and financial benefits. However, due to the uncertainty surrounding them, some problems arise as to the optimum moment for companies to realize this investment. Therefore, it is worth considering what the strategic value of the option of carrying out the investment in IoT technologies will be in the immediate future.

This study aims to shed some light on the assessment of investment in IoT technologies. The main contribution of this study is twofold. On the one hand, it offers an adequate tool to assess the strategic value of IoT technologies investments, since this has not been done in any previous study. In addition, the real options approach is proposed as a suitable tool for the strategic decision-making processes. On the other hand, it highlights the importance of acting quickly in considering the adoption of IoT technologies.

2. The Importance of the IoT

The revolution of IoT comes from its ability to interconnect different objects which have the capability of identification, sensorization, and processing. Initially, it allows the enrichment of different devices through integrated computing, which allows these to be interconnected at all times. However, IoT technology has been used with other technologies [22], comprising, among others, Radio Frequency Identification (RFID), sensors, wireless communications, cloud computing, and 3D virtual reality technology [23–25]. These technologies pose the challenge of establishing a global network which incorporates machines, warehousing systems and production facilities in the shape of Cyber-Physical Systems (CPS) [26]. Thus, companies will obtain their potential from the implementation of IoT when connected devices are able to communicate with each other. Also, it needs to be integrated, among other things, with inventory systems, customer support systems, business intelligence applications, and business analytics [20]. Eventually, the purpose of this set of technologies is to provide smart machines, storage systems, and production facilities capable of autonomously exchanging information, triggering actions, and controlling each other independently [27]. In this sense, these technologies have been identified as one of the major trends which will change society and business in the short- and long-term future, and even has been compared to the Industrial Revolution [28].

Deciding whether or not to implement IoT technologies is no longer a future trend, because, for most companies, it is a current issue as they are at the core of their strategic and research agendas [29]. The process of transforming themselves into digital-based companies requires them to decide on which specific technology has to be selected. Given that these technologies require novel approaches and new competencies [30], companies have to consider the development and the availability and/or suitability of different resources in their external and internal environment. Therefore, on the one hand, having close relationships with partners which they have previously developed within the supply chain, IoT acts as a guarantee of the adequacy of the technologies needed in the industry. Likewise, the development of their own capabilities to implement these technologies is going to ensure their optimum use and exploitation. On the other hand, the availability of technologies may constrain the development of digitalization itself. Similarly, if they go forward with the digitalization process, this requires companies to consider making further investments. This might be crucial at the beginning of the decision-making process, especially in those companies of smaller size, which usually have less access to resources. In this vein, companies face crucial investment decisions, involving significant challenges to the progress of the application of IoT [31].

Although some restructuring may be required, IoT allows companies to achieve a certain level of interconnectedness. In short, since it provides more accuracy and real-time visibility, IoT is transforming business processes into flows of materials and products. In a general sense, technological change, either radical or incremental, plays a significant role in the formation of new markets and in the development of new products and processes [19]. Therefore, IoT promotes increasing competitiveness by sharing specific knowledge and social value in the long term [32]. Here, the most important contribution is the facility to take full advantage of the information and data generated by the development of digitalization to improve operational efficiency, and then support interorganizational relationships.

IoT applications mainly focus on Industry 4.0, where the main objective is to improve the manufacturing process. Thus, the combination of IoT with manufacturing rises the Industry 4.0 [33]. In this sense, [27,34] have highlighted the increase in the number of possible IoT applications for industries. The treatment of IoT has been approached from different perspectives. For instance, Parry et al. consider that the data from IoT could affect the efficiency and responsiveness of the reverse supply chain by providing information on use in context, in addition to the real-time data on resource usage rates [35]. This would lead to sustainable gains by increasing the recycling of materials and reducing emissions. Comparably, Yu et al. consider the importance of developing skills in the use of IoT so that it can be translated into tangible business innovation, which contributes to economic development [36].

However, the study of IoT has been relevant from an investment perspective. Thus, Del Giudice et al. have considered the benefits of carrying out investment in IoT to transform traditional banks into banks of things [37]. Their results have showed that a high ROE is expressed by banks offering IoT retail and corporate services to customers. Thus, the investment in IoT is relevant in the banking sector because customers and investors require real-time information about the trend of the expected cash flow compared to the expected consumption and the security of their investment. Likewise, Murray et al. consider that IoT has an essential impact on the value of companies which show that the introduction of projects involving the use of IoT can increase the value of intellectual capital with time [38].

According to Adner, there are periods of disruption in which new unpredictable technologies can completely replace dominant designs and redefine the structures of an industry [39]. In this way, IoT generates uncertainty as it may impact on the promotion of knowledge flows, innovation processes, and company's competitiveness [32].

Information-sharing mechanisms support the organizational adoption of IoT infrastructures [40]. On the other hand, data security and privacy can potentially hinder the adoption of IoT [23].

Those companies which decide to implement IoT technologies are expecting different benefits which will eventually justify the basis for their decision. Therefore, companies will be tempted to invest in IoT due to benefits such as transparency and visibility of information and materials flows within business processes [41], improvement in product tracking and traceability [42], better inventory management and control [43], and improved productivity and cost savings [11].

From a practical point of view, the transformation of a company into a digital-based one requires it to choose a set of IoT technologies. In this sense, there may be multiple combinations of IoT technologies by means of which companies can obtain their digitalization. For the sake of simplicity, we have used the term "digital technologies" as an all-embracing concept, although each company should decide which combination best fits its needs.

3. Suitability of the Real Options Approach

In general, digital technologies represent investment opportunities for companies. However, only the most sophisticated ones implement them at their experimental stage. According to Lee and Lee, companies are expected to take advantage of the wave of IoT innovations in the coming years [20]. In this sense, companies must choose between an immediate investment and a delay in order to benefit from any further development of the specific technology in which the company is interested. Therefore, it will be the managers who use results based on the application of real options in order to determine the best time to undertake the investment (e.g., at the present time, in one year, or when the option achieves a specific value). Here, the flexibility inherent in the opportunity to make further investments allows managers to take advantage of upside outcomes and avoid downside ones [44]. Consequently, the real options approach allows for change and uncertainty as pervasive, where business strategies and investments are reevaluated continuously [45]. Real options analysis explicitly incorporates management flexibility, which has been considered a substantial part of the value of many projects [46].

The economic benefit of digitalization is not always easy to calculate; this is one of the main problems in securing funding and stakeholder buy-in [29]. Based on this, real options assessment is positioned as a tool which fits the conditions, both economic and strategic, which can indicate the possible value of investment in digital technologies. It considers that managers are flexible in reacting to uncertainties, which indicates the value of the option to delay and to revise investment strategy [47]. Given the inherent flexibility which this kind of project affords, the assessment with real options supposes an important novelty over traditional methods: the incorporation of uncertainty as an element which adds value to the project [48], provided that this flexibility is identified and used to respond to any additional information which may become available [49].

Real options consider the advisability of making an investment during a period of time. However, this does not imply an obligation to invest on the part of the company. According to Favato and Vecchiato, real options confer possibilities either to acquire or to divest assets in the future [44]. The authors suggest that said decision will be made within two possible scenarios: if the economic prospect of the project is eventually (a) favorable or (b) unfavorable. In the former situation, a company may decide to exercise the option (e.g., decide to implement a specific digital technology). In the latter, the company will abandon the option, which is translated into not making any subsequent investment.

The real options approach has been applied to a wide range of situations. Among the main relevant ones, we can find the valuation of pharmacological projects [50,51], the disruption risk in the supply chain [52,53], or the investment timing and capacity choice for energy projects [54–57] and its storage [58]. Likewise, real options assessment plays a significant role in long-term projects, for example, the assessment of future strategic actions by companies in a setting subject to the impact of climate change [59–61]. In the same way, the determination of the optimal time for the introduction in the market-place of a new product [62] or the identification of the right time to introduce new systems in a company [63] may be assessed with real options methodology. Recent studies such as [64–66] focus on the analysis, using real options, of the partnership between government and private investors to invest in public facilities projects or to provide public goods and services.

When trying to apply the real options approach to digital technologies investments, there is one central point to take into consideration. Previous investments in technologies, not necessarily digital, are essential for the development of digital technologies. That is to say, digital technologies need a technological base upon which to progress. Otherwise, an investment in digital technologies is doomed to fail. When dealing with decision-making processes, companies must therefore treat digital technologies investment as an expansion of the technology previously adopted.

4. Valuing Digital Technologies Projects

There is a great deal of theoretical work on how to model and value real options [8]; however, given the practical problems involved in its implementation, real options models are not widely used by companies. One of the significant problems facing the use of real options is that managers are not familiar with them, together with the lack of transparency of the methodologies employed to assess them [67]. Although there are several methods to assess real options, the majority of them are not easy to understand for managers, given that the comfortable and knowledgeable use of some models requires advanced mathematical skills [8].

The present value of the option to expand the investment in digital technologies by a percentage x (denoted by $O_E^{(n)}$), by incurring an additional expenditure $I_E^{(n)}$ at moment n, and by using a continuous stochastic process, is given by [68,69]:

$$O_E^{(n)} = \frac{1}{(1+r_f)^n} \int_{-\infty}^{+\infty} \max\left\{xV_n - I_E^{(n)},\ 0\right\} f(V_n)\mathrm{d}V_n$$

where:

- V_n is the random variable which describes the value of the project at the moment n,
- $f(V_n)$ is the probability density function of V_n, and
- r_f is the risk-free interest rate.

The abovementioned formula provides the consideration of different possibilities for the project, bearing in mind what managers believe them to be [20]. In order to apply this formula, both discrete and continuous distributions [70–74] have been used in the existing literature as a reference to find a suitable method to value real options.

Some sophisticated computer programs based on continuous methods are, for most corporate managers, a "black box," given that accent obtaining the value of the option without knowing how it has been calculated.

In this way, in the interest of offering companies a familiar formula to apply real options assessment, this work is based on the binomial method, initially introduced by [72], which uses the well-known nomenclature of the Net Present Value (NPV) [69]. It is a discrete model, frequently used for pricing financial options, which also is employed to assess the optimal investment strategy in uncertain environments.

Provided that the formula is readily employable, simple and reliable, it will be a valuable tool for immediate practical use. Peters and Smith and Nau analyze the strengths and weaknesses of the binomial option pricing model [75,76].

In this way, the binomial model is a discrete process based on an accurate reconstruction of each possible future scenario and its respective probability of occurrence. More specifically, it is assumed that the cash flow at instant k can be calculated starting from the cash flow at instant $k-1$ (say v) and fluctuates between an upper value $v^+ := uv$ (where $u > 1$) and lower value $v^- := dv$ ($d = 1/u$), with probabilities $p = \frac{(1+r_f)-d}{u-d}$ and $q = 1-p$, respectively [68]. Thus, the upper value would define the profitable scenario, whilst the lower value would define the non-profitable one. This binomial methodology is, together with the Black-Scholes model, one of the classical option pricing model developed by [72]. In this paper, the binomial model is used, given that it may estimate American-style options, where decisions can be taken at any time during the life-cycle of the project [77]. In comparison with the Black-Scholes model [72], [77] maintain the broader applicability of the binomial model for complicated real options in the decision-making process, given that it is very intuitive.

In this way, following the development of [69], the value of the corresponding option to expand at instant n (denoted by $O_E^{(n)}$) is given by Equation (1):

$$O_E^{(n)} = \begin{cases} xV_0 - \frac{I_E^{(n)}}{(1+r_f)^n}, & \text{if } I_E^{(n)} < d^n xV_0 \\ \vdots & \vdots \\ \left(\sum_{k=s}^{n} \binom{n}{k} \frac{p^k u^k q^{n-k} d^{n-k}}{(1+r_f)^n}\right) xV_0 - \sum_{k=s}^{n} \binom{n}{k} \frac{p^k q^{n-k}}{(1+r_f)^n} I_E^{(n)} & \text{if } d^{n-s+1} u^{s-1} xV_0 \leq I_E^{(n)} < d^{n-s} u^s xV_0 \\ \vdots & \vdots \\ 0, & \text{if } u^n xV_0 \leq I_E^{(n)} \end{cases} \quad (1)$$

The value of a project with the option to expand depends on its evolution. According to Cruz-Rambaud and Sánchez-Pérez, the exercise of the option to expand at any moment is only justified when the value of the project with the option is higher than the value of the project without it [69].

5. IoT in the World, a Real Application

In this section, we are going to analyze the option to expand in an aggregate way, that is to say, we will derive the value of the option to expand by applying real data of the investment in digital technologies to the global industrial sector.

The analysis has been based on [29], which contains information about 2000 companies from the nine major industrial sectors in 26 countries. This study explores the benefits of digitalizing the value chain of a company and proposes a blueprint for success. Thus, it helps leading digital companies to maintain their competitive positions in the complex industrial ecosystems expected in the near future.

The variables necessary to apply the model have been presented in a disaggregated way. Thus, their values have been calculated both directly and indirectly by using data from [29] according to the needs. Said values are shown in Table 1.

Table 1. Variables used for applying the real option model.

Variables	Source	Value
Time horizon (years)	Global Industry 4.0 (2016)	$n = 5$
Risk-free interest (%)	United States 5-year bond (consulted on 31 March 2019)	$r_f = 2.436$
Investment in digital technologies (billion p.a.)	Global Industry 4.0 (2016)	I_E = US$907
Digital revenue gains (billion p.a.)	Own elaboration	US$914
The average rate of investment in digital technology (% p.a.)	Own elaboration	$r = 16.0121$
The probability of occurrence of the profitable scenario	Own elaboration	$p = 0.86$
The probability of occurrence of the non-profitable scenario	Own elaboration	$q = 0.14$
The upper factor of cash-flow fluctuation	Own elaboration	$u = 1.033$
The lower factor of cash-flow fluctuation	Own elaboration	$d = 1/u = 0.97$

Source: Own elaboration.

Although some of the variables have been collected directly from the survey, others have needed a different treatment. We have therefore applied the following considerations:

- Following Fama and French, the risk-free interest rate has been calculated based on the United States 5-year bond [78] (consulted on 31 March 2019).
- In the survey, it is taken into account that the annual digital technologies investment revenue for the next five years across the industrial sector will amount to US$493 billion and reductions in cost are expected to be US$421 billion. This means that companies will add US$914 every year, amounting to US$4.570 over the five years studied. Furthermore, to calculate the present value of a project, it is necessary to take into account the annual investment in digital technologies (I_E= US$907 billion p.a., which amounts to US$4.535 in the total of the five years).
- The survey reinforces the belief that about 33% of industrial companies have already invested in digital technologies [29] (p. 11), which means that 67% of companies have not yet applied them. In addition, it is estimated that 72% of companies will have invested in digital technologies by 2024 [29] (p. 11). Therefore, by supposing that the number of companies which incorporate digital technologies increases every year at a constant rate, denoted by r, based on the companies which are operating without applying digital technologies yet, the following equation may be constructed to calculate the average percentage of investment in digital technology for the entire period:

$$D_0 + (1-D_0)r + (1-D_0)(1-r)r + (1-D_0)(1-r)^2 r + (1-D_0)(1-r)^3 r + (1-D_0)(1-r)^4 r = D_5 \quad (2)$$

where D_n represents the percentage of companies which have already invested in digital technologies at moment n ($n = 0,\ 1,\ 2,\ 3,\ 4$ and 5).

In this way, by applying the data in Equation (2), we obtain:

$$0.33 + 0.67r + 0.67(1-r)r + 0.67(1-r)^2 r + 0.67(1-r)^3 r + 0.67(1-r)^4 r = 0.72,$$

from where $r = 0.160121$.

Consequently, every year 16.0121% of the companies which have not yet applied digital technologies will decide to implement them. Table 2 shows the cash flows of the project of investing in digital technologies for those companies which are thinking of investing during the period under consideration (which represent 39% of the companies of the industrial sector).

- The survey found that "in the new industrial reality, most companies (86%) expect to secure simultaneous gains from both lower costs and added revenue in the next five years" [29] (p. 14). This means that the probability of occurrence of a profitable scenario is $p = 0.86$, which implies that the probability of occurrence of a non-profitable scenario is $q = 0.14$. In line with this, and by considering the identity $pu + qd = 1 + r_f$, we can calculate the values of the up and down factors which multiply the value of the project, being $u = 1.033$ and $d = \frac{1}{u} = 0.97$, respectively.

Table 2. Cash flow depending on the year of the investment (in millions of dollars).

	Percentage of Implementation of Digital Technologies (P_n)	**Income (1) US$4570 P_n**	**Expenditure (2) US$4535 P_n**	**Cash Flow (1)–(2)**
Year 1	$P_1 = \frac{0.67}{0.39} r = 0.107281$	US$1257.11	US$1247.49	US$9.63
Year 2	$P_2 = \frac{0.67}{0.39} (1-r) r = 0.090103$	US$1055.82	US$1047.74	US$8.09
Year 3	$P_3 = \frac{0.67}{0.39} (1-r)^2 r = 0.075676$	US$886.76	US$879.97	US$6.79
Year 4	$P_4 = \frac{0.67}{0.39} (1-r)^3 r = 0.063559$	US$744.77	US$739.07	US$5.70
Year 5	$P_5 = \frac{0.67}{0.39} (1-r)^4 r = 0.053381$	US$625.52	US$620.93	US$4.79

Source: Own elaboration.

Once all the information is gathered, we present the real option value of investing in digital technologies for the global industrial sector (Table 3). Several values have been calculated depending on the moment at which these companies invest.

No company invests in technology without prior predisposition. Although this could represent a filter, there is no guarantee of success. Many IoT projects have unclear scopes and goals and are using innovative technologies [20]. The higher level of risk and uncertainty in comparison to previous technology projects make them less attractive if this kind of project is being assessed by traditional methodologies which do not consider the value of the strategy.

With the application of the real options approach based on factual information, the value of adopting the said option is indicated at every stage. Considering the results itemized in Table 3, it can be seen that the value of the option to expand is decreasing with time. For instance, in year 1, the strategic value of carrying out digital technologies is expected to be US$47.06 billion; however, if companies wait until year 3, this strategic value drops to US$32.90 billion, which represents a strategic loss of US$14.16 billion on average. Likewise, this loss increases to US$23.11 on average if companies wait until the fifth year.

Even though there might be several reasons for decrease, it is worth highlighting the following facts: (a) early investors can exploit the advantage of novelty; (b) follower investors may reduce the uncertainty level as companies progressively obtain a better knowledge of the specific technology and can see whether the decision to invest has been successful or not in other companies. This reduction in the level of uncertainty may reduce their losses, but on the other hand, it may cause them to lose the opportunity of increasing their profits; (c) the increase in obsolescence of the company's existing technology so that the strategic value diminishes, which is more likely when the implementation is delayed; (d) the possible appearance of other innovative technologies which replace existing ones.

Table 3. Real option value depending on the moment of the investment.

Year	Real Option Value (See Equation (1))
0	
1	Given that $dxV_0 \leq I_E^{(1)} < uxV_0$, the option to expand in one period is: $\frac{p(uxV_0 - I_E^{(1)})}{1+r_f} =$ US\$ 47.06bn.
2	Given that $udxV_0 \leq I_E^{(2)} < u^2xV_0$, the option to expand in two periods is: $\frac{p^2u^2xV_0 - p^2I_E^{(2)}}{(1+r_f)^2} =$ US\$ 39.89bn.
3	Given that $u^2dxV_0 \leq I_E^{(3)} < u^3xV_0$, the option to expand in three periods is: $\frac{p^3u^3xV_0 - p^kI_E^{(3)}}{(1+r_f)^3} =$ US\$ 32.9bn.
4	Given that $d^2u^2V_0 \leq I_E^{(4)} < du^3V_0$, the option to expand in four periods is: $\left(\sum_{k=3}^{4}\binom{4}{k}\frac{p^ku^kq^{4-k}d^{4-k}}{(1+r_f)^4}\right)xV_0 - \sum_{k=3}^{4}\binom{4}{k}\frac{p^kq^{4-k}}{(1+r_f)^4}I_E^{(4)} =$ US\$ 27.67bn.
5	Given that $d^2u^3V_0 \leq I_E^{(5)} < du^4V_0$, the option to expand in five periods is: $\left(\sum_{k=4}^{5}\binom{5}{k}\frac{p^ku^kq^{5-k}d^{5-k}}{(1+r_f)^5}\right)xV_0 - \sum_{k=4}^{5}\binom{5}{k}\frac{p^kq^{5-k}}{(1+r_f)^5}I_E^{(5)} =$ US\$ 23.95bn.

Source: Own elaboration.

6. Discussion

Research, development, and innovation are the main contributors to the current context of business management. Managers are changing their attitude towards recent technologies and new methodologies necessary for their assessment. The wise implementation of digital technologies allows companies to improve their position in the global market. In a general sense, the results show that the investment in IoT is an excellent strategic option despite the challenges which it may pose to individual companies. When considered as a whole, the forecast shows that the use of digital technologies is going to be crucial in the industrial sector and will dominate business relations in the medium and long term. However, first adopters and those companies which have already started to employ a digital business model have the advantage of not having to struggle with a real implementation of digital technologies since they already have a digital base framework. They can therefore focus on creating a better customer experience. Those companies which have not yet adopted digitalization will be less equipped to cope with the development of digital capabilities, especially digital operational capabilities.

Companies which develop digitalization faster than the rest are obtaining a significant higher performance and are giving much more value to their industry. This situation generates a knock-on effect, which increases the pressure on other companies to go digital. However, companies should define the strategy which best fits their needs and, what is more important, rigorously execute it to achieve success.

Companies should act as fast as possible to consider opportunities and threats presented by digital transformation. To this end, the real options approach allows companies to identify the optimal moment for investment in the face of the expansion opportunity, and to maximize the value of adopting emerging digital technologies. Eventually, the real options approach provides a guide for the optimal timing for going digital. According to Haddud et al., companies individually face some benefits (e.g., more transparency and visibility of information, better control and management of inventories or improved integration of internal business processes), and challenges (e.g., lack of clear comprehension about the IoT benefits, difficulties in finding the necessary staff with the right skills and knowledge, and the risk associated with the implementation of new business) which condition their behavior [41]. In this sense, since the real options approach considers strategic characteristics, it provides companies with additional information to be presented to any cautious decision-maker. Ultimately, this can be understood as a tool which can offer the information necessary to take action at the right moment and in the best way possible.

Every industry has companies already involved in the digital transformation and which can be considered as a point of reference for those facing the challenge of going further. Therefore, companies can imitate some transformation patterns from the pioneers and use them as a base for the development of their own digital strategy. However, this advantage diminishes as time goes by because technological novelty is short-lived.

The adoption and implementation of IoT continues to expand, and it is expected to have a significant impact both on the economy and society. Companies are considering IoT essential and of high relevance as it is expected that the level of digitalization can shortly reach a higher level.

It might be said that the current competitive environment is characterized by an increasing interest in digital technologies, which is defining the future of competitiveness. This leads companies to reorganize their priorities since one of the most relevant objectives in the competitive arena is to be a leader in the digital landscape. Developing the capabilities needed to take full advantage of digital technologies takes a long time. Under these circumstances, it becomes almost essential to maintain the advantage of being a pioneer as this position weakens too quickly if not properly managed, and the consequences of losing it can be quite harmful. In addition, this development needs the support of top management commitment and the implementation of significant investment [29].

The decision to go digital has to be taken by using a holistic approach to consider all the conceivable possibilities, and the application of real options allows all different perspectives to be taken into account [67]. Defining where the company wants to go is an excellent starting point and has to be considered without the constraints of current limitations. Decisions surrounding this transformation are so crucial that once the company goes ahead, there is no going back since they can change the real structure of the business. At this point, financial decisions are fundamental, as most times they impose very real limitations.

In this sense, the real options approach has proven to be an appropriate tool to help managers in the decision-making process. They have the ability to show the strategic value at each moment so that managers can take action (or not) at the very moment at which they become aware of what they are losing (or not earning). In addition, this approach can give up-to-date information at any point in time as anticipated data become real. Likewise, the option of going digital always remains; what changes is its value, which is directly related to the opportunity for companies to become leaders or followers.

Although a real options approach can bring a partial understanding to the process of digitalization, there are some areas of particular relevance for companies when considering digital technologies as an option to expand: artificial intelligence and cybersecurity.

With regard to artificial intelligence, machine learning can be considered as the main function with many applications in diverse areas such as autonomous driving, medical engineering, or even marketing. However, companies should master various aspects such as sourcing high-quality data or re-education of leaders, while considering them within the area of promoting experimental approaches to the use of artificial intelligence technology. Likewise, cybersecurity includes matters such as the theft of intellectual property, the loss of customer data, and other forms of cybercrime. Unfortunately, this tendency is increasing and can act as a strong deterrent. This may even confuse the issue concerning the suitability of digital technologies and discourage companies from adopting them.

The revolution in digital technologies has meant a breakeven in the competitiveness of companies. As a consequence, companies must be careful when deciding to invest; however, the time available for this is limited due to the frugality of the nature of digital technologies. This study proposes the real options approach through the binomial method as a useful assessment tool for this type of investment projects. From a theoretical point of view, this paper offers a new perspective since there is no a previous study covering this issue. Starting from the binomial model, we have implemented an intuitive equation which simplifies previous models [71,72,79]. This equation allows the calculation of the value of the option to expand the investment, rendering unnecessary the construction of binomial trees and the analysis of the option value at each node. Therefore, this study supposes a recognition of the suitability of the real options approach since it broadens the range of projects to which this methodology can be applied.

In addition, from a practical point of view, it offers practitioners (e.g., operations directors, IT managers, top management) strategic information (the value of the option itself in the future) to make calculations which are more reliable. This offers a significant advantage since it helps to reduce the response times so necessary in making decisions related to technology in general and it allows better-informed decisions. In doing so, practitioners can easily use this information, which simplifies the whole process. In addition, the versatility provided by the real options approach means that it could be used as a complement to other strategic tools such as the balanced scorecard.

Summarizing, this study highlights the use of financial-strategic assessment tools such as the real options approach, which, due to their suitability, can be adapted to the considerations required when investing in digital technologies (e.g., speed, immediacy, frugality). These investments have a very high degree of obsolescence, so they require adaptable and straightforward assessment tools which allow companies to make decisions and react quickly without losing their possible competitive advantage.

7. Conclusions

The implementation of digital technology in companies has been defined as a new technological scenario where a network of global information may constitute a source of competitive advantage. Investment in this kind of technological innovation incurs a particular risk, given its prominent level of flexibility. For this reason, the assessment of this kind of project by employing the traditional model is not accurate enough to consider all possible scenarios. In order to confront this problem, an innovative decision-making concept, the real options perspective, has been adapted to facilitate decisions concerning investment in digital technologies.

In consequence, we have developed an expression to determine the present value of a project with the option to expand by investing in digital technology. The employment of the real options approach, as an aid to taking an informed decision about the implementation of digital technology by allowing the consideration of strategic issues in their valuation, gives greater control in a dynamic way over the uncertainty surrounding the project. The theoretical model of real options shows the ease with which it can be implemented in comparison with traditional approaches. This applicability essentially makes this approach more accessible to real valuation and decision-making in the investment process and, in particular, in the investment in digital technology. This assessment has shown that following a strategy based on digital technologies is a useful option as it offers a substantial strategic value with an acceptable room for maneuver, that is to say, the value of the option is higher than its cost. However, this value gradually decreases with time. This reflects the current situation of the industry and the need for taking action as fast as possible.

With the information provided by the real options assessment, companies can make decisions about their process of digitalization. Thus, based on their initial position, they face the decision of carrying out a structural change (e.g., postal services need a radical rethinking of how organizations develop their business), or an adaptation of their business model adding value to products and services. In addition, companies have to consider the ideal combination of the strategy to follow and its execution as well as the early detection of the most representative issues. However, to have the opportunity to predict the trends in digital technology, it is necessary to be immersed in it, assuming its inherent risks.

The use of real options has some limitations, mainly related to the mathematical rigor and the availability of data. In this sense, the methodology can discourage its use, even when investment in digital technologies has been pointed out as one of the most relevant to competitive business practice. In addition, the valuation needs accurate estimations about the total number of companies applying digital technologies and also the inherent volatility. This needs more historical data to obtain more accurate results; however, that is not yet possible because of the novelty of the issue.

This study makes use of aggregated data which, to a certain extent, hinders particularizations. Thus, a limitation is obtaining access to specific information required by the real options approach since companies are reluctant to communicate sensitive information. However, greater access to information would allow the results to be circumscribed, not only in a general way, but also in other specific areas such as the sector or the supply chain.

Despite these limitations, this research has shown that the real options approach has the potential to improve the understanding of the value of implementing digital technologies in the industrial sector.

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