Investing in the Internet of Things: a real option approach

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Abstract

This paper provides a methodology to assess the implementation of digital technologies by using the real options approach. Specifically, the option to expand a project may reflect the investment in digital technologies. Currently, the study of this kind of investments is very important given that companies are increasingly implementing digital technologies to be more competitive in a globalized market where the technological development is ever more rapid. The application of this specific approach brings the understanding of digital technologies investment. It claims the action as quickly as possible by companies if they want to get the best likely performance.

Keywords: digital technology, real options, financial assessment

Introduction

In recent years, companies have had to face an extreme competition because of changes in technological and global issues. This has accelerated the pace of innovation with reference to its discovery, implementation, introduction, and diffusion into the market. Therefore, globalization of manufacturing has arisen through a faster transfer of materials, complex payment systems, and compression of products' life cycle (Caputo et al., 2016). Eventually, companies need technologies to be able to meet the increasingly sophisticated customers' needs in an integrated way. In doing so, companies can anticipate future trends by developing new concepts (ideas, products, services, etc.) which allow them to differentiate from competitors as they can give their customers a bespoke experience. This ability may be considered crucial for the development of sustainable competitive advantage (Porter, 1985).

Although the internet has been one of the main technological disruptions, 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 (Anaya et al., 2015; Tian et al., 2002). In this way, the Internet of Things (hereinafter, IoT) has become a new dominant paradigm for companies to revise the implementation of their operations and improve their efficiency (Ferretti and Schiavone, 2016). This has made that IoT has questioned how to act in the competitive arena, leading companies to reshape their organizational and operational structures.

The revolution of IoT comes from their ability to interconnect different objects which have the capability of identification, sensorization, and processing. It allows the enrichment of different devices through integrated computing which maintains them connected at all times. IoT comprises, among others, Radio Frequency Identification (RFID), sensors, wireless communications, cloud computing, or 3D virtual reality technology (Miorandi et al., 2012). 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). Thus, companies will obtain its potential from the IoT implementation when connected devices are able to be communicated with each other. In addition, it needs to be integrated, among others, with inventory systems, customer support systems, business intelligence applications, and business analytics (Lee and Lee, 2015). Eventually, the purpose of these 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 (Henning, 2013).

Therefore, despite some requirements, IoT is giving companies the opportunity to achieve a certain level of interconnectedness. In short, since it provides more accurate 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 (Nair and Boulton, 2008). Therefore, IoT allows for an increasing competitiveness by sharing specific knowledge and social value in the long term (Del Giudice, 2016). Here, the most important fact is to take full advantage of the information and data generated by the development of digitalization to improve the operational efficiency and then support interorganizational relationships.

This engaging scenario makes IoT an attractive option for companies as it allows to redesign factory workflows, improve tracking of materials, and optimize distribution costs. Moreover, it optimizes production systems, services and decision-making processes (Curtin et al., 2007; Del Giudice and Straub, 2011). Therefore, the adoption of digital technologies is rapidly gaining consistency and relevance as a technological, societal, and competitive pressure to innovate and maintain the level of transformation.

Although the aforementioned reasons constitute incentives for companies to implement any kind of IoT technology, this is inherently in tandem with a certain level of risk because when they fail to adapt to digital technologies, painful consequences may result (e.g., established companies may lose their leadership positions to new entrants). Thereby, it becomes vital for companies to previously understand the potential of deploying IoT technologies.

Deciding whether or not to implement IoT technologies is no longer a future trend because for most of the companies it is a current issue as they are at the core of their strategic and research agendas. The process of transforming companies into digital-based companies implies them to make the choice of which specific technology has to be selected. In view of that these technologies require novel approaches and new competencies (Kassicieh et al. 2002), companies have to consider the development and

the availability/suitability of different resources in their external and internal environment. Therefore, on the one hand, having close relationships with partners within the supply chain, they previously developed, IoT acts as a guarantee of the adequacy of the technologies needed in the industry. Likewise, the development of the own capabilities to implement those technologies is going to determine a flawless use and exploitation of them. On the other hand, the availability of technologies may constrain the development of digitalization itself. Similarly, going further with the digitalization process implies companies to make an effort in the proposal of investments. This might be crucial at the beginning of the making-decision process, especially in those companies of smaller size which usually have less access to resources. In this vein, companies face important investment decisions, involving great challenges to the IoT application progress (Zhou et al., 2017).

Hence, obtaining a satisfactory progress of the digitalization process and its associated capabilities depends on the current situation of each company and the special risk around this kind of projects. As IoT technologies advance and an increasing number of companies are adopting it, IoT cost-benefit analysis will become a subject of great interest (Lee and Lee, 2015). Thereby, making a self-assessment of the individual possibilities of success turns into essential to companies. This implies a way of identifying where companies are excelling at the present moment with the intention of redirecting the efforts while the capabilities improve.

Considering all these circumstances, a reasonable and informed evaluation has to assess the implementation of digital technologies. In effect, the application of an appropriate measure which accurately evaluates risks and rewards is necessary before carrying out any investment. This is of special relevance when dealing with digital technologies because of their higher inherent flexibility compared to another kind of technologies, given that they are increasing at a dizzying rate and they change of direction quickly.

Real options play a noteworthy important role in the assessment and justification of investments on technology projects. As shown by Lee and Lee (2015), real options approach may be applied in order to make informed decisions with respect to IoT investments. To some extent, this financial assessment foresees the degree of success so that companies are ready to set their boundaries and to apprehend their potential.

Thus, it seems that investment in IoT technologies are a desirable choice as they bring with operational and financial benefits. However, due to the uncertainty surrounding them, some problems arise as to when it would be better for companies to carry out the investment they imply. Therefore, it is worth wondering what the strategic value of the option of carrying out the investment in IoT technologies is in the immediate future.

The purpose of this study is twofold. On the one hand, it aims to determine and classify those different resources needed for a successful implementation of IoT technologies. On the other hand, it examines a real options approach valuation applied to IoT investment.

A real option approach to Investment in the Internet of Things

Companies with the intention to implement IoT technologies are expecting different benefits which eventually will define the basis for their decision. Therefore, companies will be tentative to invest in IoT due to benefits such as transparency and visibility of information and materials flows within business processes (Haddud *et al*., 2017), improvement in products tracking and traceability (Costa *et al*., 2012), better inventory management and control (Fan *et al*., 2015), and improving productivity and cost savings (Ferretti and Schiavone, 2016).

In general, IoT technologies represents investment opportunities for companies, however only the most sophisticated remain at their experimental stage. Therefore, according to Lee and Lee (2015), companies are expected to take advantage of the wave of IoT innovations in the coming years. In this sense, companies could choose between the immediate investment or delay it for learning from the development of the specific technology the company is interested in. Nevertheless, one of the main problems is the difficulty of securing funding and stakeholder buy-in, as the economic benefit case of digitization is not always easy to calculate (Global Industry 4.0 Survey, 2016).

Based on this, real options assessment is positioned as a tool that fits the conditions, both economic and strategic, under which investment in digital technologies is developed. Given the inherent flexibility that this kind of projects involves, the assessment with real options supposes an important novelty over the traditional methods: the incorporation of uncertainty as an element which adds value to the project (Dixit and Pindyck, 1995), provided that this flexibility is identified and used to respond to any additional information which may arise (Bérard and Perez, 2014).

Real options represent the right to carry out an investment during a period of time. However, this does not imply the execution as the company is not obligated. In this vein, it is considered that previous investment in technologies (not necessarily digitals) is compulsory to develop digital technologies. That is, digital technologies need a technological ground acting as a base upon which to progress. Otherwise, an investment in digital technologies would end in a failure. Thereby, digital technologies investment can be treated as an expansion of the previous technology by companies when dealing with making-decision processes.

Valuating digital technologies projects

Based on Cruz and Sánchez (2017), the Net Present Value (NPV) formula can be used to make real options familiar to all companies. Specifically, 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:

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

where:

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

The aforementioned formula implies the consideration of different possibilities of the project considering what management believe them to be (Lee and Lee, 2015). Consequently, the multiplicative binomial process is used. This is a discrete process based on an accurate reconstruction of each potential future scenario and its respective probability of occurrence. More specifically, it is assumed that the cash flow at an 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 a lower value $v^- := dv$ ($d = 1/u$), with probabilities $p = \frac{(1+r_f)-d}{u-d}$ and $q = 1-p$, respectively (Cruz and Sánchez, 2016).

Thus, the upper value would define the profitable scenario whilst the lower value would define the non-profitable one.

In this way, following the development of Cruz and Sánchez (2017), the value of the corresponding option to expand at instant n (denoted by $O_E^{(n)}$) is given by:

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

(Eq. 1)

A real application: Internet of Things in the world

Here, 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 in the global industrial sector.

The analysis has been based on the Global Industry 4.0 Survey (2016) which contains the information of 2,000 companies from the nine major industrial sectors in 26 countries.

The variables necessary to apply the model have been presented in a disaggregated way. Thus, their values have been calculated both directly or indirectly using data from the Global Industry 4.0 Survey (2016) 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-years bond (consulted on January 11, 2018)	$r_{f=}$ 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 other treatment. Thus, we have carried out the following considerations:

- Following Fama and French (2017), the risk-free interest rate has been calculated based on the United States 5-years bond (consulted on January 11, 2018):
- In the survey, it is remarked that the annual digital technologies investment revenue for the next five years across the industrial sector will add up to US$493 billion and the cost reductions are expected to be US$421 billion. This means that companies will add US$914 every year, adding US$4.570 in the total of the five years studied. Furthermore, to calculate the project present value, it should be considered the annual investment in digital technologies (I_E = US$907 billion p.a., which sums US$4.535 in the total of the five years).
- The survey reinforces the idea that about 33% of the industrial companies have already invested in digital technologies (p. 11), which means that there is a 67% of companies that have not applied them yet. Besides, it is proposed that in five years ahead, the percentage of companies that will have invested in digital technologies will be of the 72% (p. 11). Therefore, by supposing that the number of companies that apply digital technologies increases every year at a constant rate, called *r*, based on the companies that are operating without applying digital technologies yet, we may build up the following equation to calculate the average percentage of investment in digital technology for the entire period:

  $$0{,}33 + 0{,}67r + 0{,}67(1-r)r + 0{,}67(1-r)^2 r + 0{,}67(1-r)^3 r + 0{,}67(1-r)^4 r = 0{,}72$$

  being: $r = 0{,}160121$.

  Consequently, every year a 16,0121% of the companies that are running out without applying digital technologies yet, will decide to implement them. Therefore, by employing the aforementioned data, the cash flow of the project of investing in digital technologies to those companies that are thinking of investing in the studied period (which represent the 39% of the companies of the industrial sector) is equal to:

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\$4,570 $\cdot P_n$	Expenditure (2) US\$4,535 $\cdot P_n$	**Cash flow (1) – (2)**
Year 1	$P_1 = \frac{0.67}{0.39} r = 0.107281$	US$1,257.11	US$1,247.49	**US$9.63**
Year 2	$P_2 = \frac{0.67}{0.39}(1-r)r = 0.090103$	US$1,055.82	US$1,047.74	**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

- The survey stated 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" (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.

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

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

Year	Real option value (see Eq. (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$39.89 bn.
3	Given that $u^2dxV_0 \leq I_E^{(3)} < u^3xV_0$, the option to expand in three periods is: $\frac{p^ku^kxV_0 - p^kI_E^{(3)}}{(1+r_f)^3} =$ US$32.9 bn.
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$27.67 bn.
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$23.95 bn.

Source: Own elaboration

No company invests in technology without a 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 breakthrough technologies (Lee and Lee, 2015). The higher level of risk and uncertainty in comparison to traditional technologies projects make them less attractive if these kinds of projects are assessing by traditional methodologies that do not consider the value of the strategy.

With the application of the real options approach based on factual information is highlighted the value of tenure of said option for each moment. 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 the year 1 the strategic value of carrying out digital technologies is expected to be US$47.06 billion, however, if companies wait until the year 3, this strategic value drops to US$32.90 billion, which represents a loss of US$14.16 billion on average.

Even though there might be several causes behind this decrease, it is worth highlighting the following facts: (a) the early investors can exploit the advantage of novelty; (b) the follower investors may reduce the uncertainty level as companies

progressively obtain a better knowledge of the specific technology and can realize of their development, successful or not, in other companies. This uncertainty reduction implies limiting the losses and, in the same way, the profits; (c) the increase in obsolescence so that the strategic value diminishes, what is more, likely when the implementation is delayed; (d) the appearance of other brand-new technologies that replace the existing ones.

In a general sense, the results show that the investment in IoT is a good strategic option despite the challenges it may pose to companies individually. When considered as a whole, the forecast shows that digital technologies are going to be a reference in industrial sectors and dominate business relations in the medium and long-term. However, first adopters and those companies that already started with a digital business model have the advantage of not having to manage a real implementation of digital technologies as they have been built around them. Then, they usually focus on creating the better customer experience. Thereby, at any point, being a follower implies to cope with a lesser development of digital capabilities.

Discussion

Companies developing digitalization faster than the rest are obtaining a sensitive higher performance as they are creating much more value in their industries. This situation generates a calling effect on the industry which increases the pressure of companies to go digital. However, companies should define a strategy that fits them and, what is more important, rigorously execute it to get succeed.

This means that companies should act as faster as possible to consider opportunities and threats available in their digital transformation process. In this way, real options approach allows companies finding the optimal investment facing the expansion opportunity which eventually facilitates the adoption of emerging digital technologies.

Every industry is showing companies already involved in the digital transformation and can be considered as a referent for those facing the challenge of going further. Therefore, companies can absorb some transformation patterns from the pioneers' and use it as a base for the development of their digital strategy. However, this advantage is diminishing as time goes by because the novelty in technologies is frugal.

The adoption and implementation of IoT continue their expansion and it is expected to have a significant impact both on the economy and the society. Companies are considering the IoT essential and of great relevance as it is expected that the level of digitalization can reach a double level in the near future.

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 is making companies reorganize priorities as one of the most relevant objectives in the competitive arena is to lead the digital landscape. Developing the capabilities needed to take full advantage of digital technologies takes long time. Under these circumstances, it becomes almost compulsory to maintain the advantage of being a first-mover as this position weakens too quickly if not properly managed, being the consequences of losing it quite harmful. Besides, this development needs the help of top management commitment and significant implementation investments (Global Industry 4.0 Survey, 2016).

Taking the decision of going digital has to be made under a holistic approach to harness all the conceivable possibilities. Defining where the company wants to go is an excellent starting point and has to be demarcated with no limits based on current constraints. Decisions surrounding this transformation are so important that once the company goes ahead, there is no going back because they can change the core business. At this point,

financial decisions take a relevant place as most of the time they represent real constrictions.

In this sense, real options approach has proven to be a relevant tool to help managers in the making-decision process. They have the ability to show the strategic value at every moment so that managers could take action (or not) at the same time that they know what they are losing (or not winning). Besides, this approach can give up-to-date information throughout the time as foreseen data become real. Likewise, the option of going digital always remains there, what changes is its value that is directly related to the opportunity for companies to become leaders or followers.

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

Within artificial intelligence can be considered the machine learning as the main topic with a lot of applications in diverse areas such as autonomous driving, medical engineering or even marketing. However, firms should master various aspects like sourcing high-quality data or re-education of leaders, while considering them under the thinking of promoting experimental approaches to the use of artificial intelligence technology. Likewise, cybersecurity comprises incidents of stolen intellectual property, lost customer data, and other forms of cybercrime. Unfortunately, this tendency is increasing and can act as a distracting element. Eventually, this can generate a blurry perception of the suitability of digital technologies and discourage companies entering them.

Conclusions

The implementation of digital technology in companies has been defined as a new technology paradigm where information global network may constitute a source of competitive advantage. The investment in this kind of technology has a special risk given its high level of flexibility. In this way, the assessment of this kind of projects by employing the traditional model is not accurate enough to consider all the possible scenarios. In order to solve this problem, the real options approach has been adapted to justify the investment in digital technologies.

In this way, 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 a complement to take an informed decision about the digital technology implementation increases its control over the uncertainty around the project.

This assessment has proven that following a strategy based on digital technologies is a constructive option as it provides a substantial strategic value with an acceptable room for maneuver. However, this value is gradually decreasing as time goes by. This reflects the current situation of the industry and an attention call for taking actions as faster as possible.

With the information provided by real option assessment companies can make decisions about their digitalization. Thus, based on their initial level, 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 models adding value to products and services. Besides, companies have to consider the perfect 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 trend of digital technology it is necessary to be immersed in it, assuming its inherent risks.

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