How can real options help define optimal timing in business model dynamics?
An application to the mobile telecommunications industry

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Résumé :

Lorsqu'une technologie de rupture apparaît, il est difficile pour les nouveaux entrants, comme pour les entreprises en place, de s'imaginer quel est le modèle d'affaires le plus approprié pour extraire tout le potentiel économique de la nouvelle technologie. La littérature a établi qu'il est peu probable de définir le bon modèle d'affaires dès le départ, puisque les firmes ne disposent pas de données sur des marchés qui n'existent pas. Les firmes doivent plutôt procéder à des expériences, et progressivement mettre au point un modèle d'affaires en suivant un principe d'essai – erreur.

Cependant, la recherche actuelle ne dit pas sur quels critères il faut fonder les décisions d'investissements nécessaires pour réaliser ces expériences. Dans le cas d'une technologie de rupture, le premier investissement à réaliser est le lancement commercial de la nouvelle technologie. Cette décision soulève deux problèmes : *(1)* un problème de temps: lorsque le succès du futur modèle d'affaires repose sur des sources d'incertitude exogènes, est-il préférable de lancer la technologie rapidement pour être en avance sur la concurrence, ou faut-il attendre pour éviter de déployer une technologie qui ne décollera jamais ? *(2)* un problème d'échelle : est-il préférable de lancer la technologie à grande échelle pour obtenir des résultats représentatifs, ou bien sur un périmètre limité pour réduire les coûts du test ?

Dans cet article, nous montrons que les options réelles peuvent être utilisées comme aide à la décision d'investissement lorsqu'une firme souhaite tester un nouveau modèle d'affaires, et en premier lieu lorsqu'elle doit décider s'il faut déployer commercialement une nouvelle technologie de rupture. La question du temps peut être appréhendée par l'option de report, qui prend en compte l'incertitude exogène. La question de l'échelle peut être appréhendée à travers l'option d'apprentissage, qui prend en compte l'incertitude endogène.

Nous illustrons notre approche avec le cas de la téléphonie mobile en Europe, dont le modèle d'affaires a été profondément changé suite à l'introduction de la technologie 3G.

Mots-clés : Technologie émergente; Incertitude endogène; Incertitude exogène; Apprentissage; Option de report

INTRODUCTION

When a disruptive technology emerges, it is difficult for the inventor as well as for incumbents to figure out the unique business model that will enable to fully realize the economic potential of the new technology. The literature has established that it is hardly possible to design the right business model from the outset, as firms do not have data on markets that do not exist. Rather, firms should conduct real experiments, and progressively refine their business model through “trial-and-error” learning.

However, little is said in the current research on how to conduct these experiments. Business model experimentation requires investment. In the case of a disruptive technology, the first investment required for the experimentation of the business model will be the costs generated by the market introduction of the new technology. The decision to launch the new technology is facing two issues:

(1) a *timing* issue: when the success of the business model depends on exogenous sources of uncertainty that are beyond the control of the innovative firm, is it better to launch the technology early, in order to experiment the business model ahead of other competitors, or should the firm better wait to avoid deploying a technology that will never take-off ?

(2) a *scale* issue: is it preferable to launch the technology and experiment the business model on a large scale to improve the fidelity of the test, or should the technology deployment rather take place on a limited scale in order to reduce the cost of the test ?

In this paper, we argue that real options can help support decisions regarding the investment necessary for business model experimentation, and in first place regarding the deployment of the new technology. Compared to traditional valuation tools based on Discounted Cash Flows (DCF), which are deterministic in nature, real options take uncertainty and managerial flexibility into account, and therefore appear to be a relevant framework to cope with business model dynamics.

We show that the timing issue in the technology deployment decision can be supported by calculating the value of the option to wait. This option takes into account exogenous sources of uncertainty, which affect the efficiency of the business model, yet are beyond the control of the innovative firm. The scale issue can be supported by calculating the value of the option to learn. This option takes into account endogenous sources of uncertainty, which the innovative firm can resolve to fine-tune its business model.

We illustrate our framework with the case of the 3G technology in the European mobile telecommunications industry. 3G is an interesting case in point, because this technology profoundly transformed the business model of European telecommunications operators[1]. Operators were initially confronted with a timing issue regarding the deployment of 3G, whose success was questionable due to uncertainties in key elements of its business model. Moreover, operators faced difficulties in learning a new business model that would capture value from 3G. In fact, the market capitalization of European telecommunication operators has fallen by 28% between 2006 and 2012[2], which suggest their difficulty in managing business model transition following the emergence of the 3G technology. Drawing on Siggelkow (2007), we use the case of 3G to show how theoretical constructs translate in real life, and to show that theoretical mechanisms which have been devised in a speculative way, apply in real situations.

The uncertainties raised by the business model of 3G and their consequences in terms of deployment are analyzed at several levels of analysis. First, we focus on the timing and scale decisions made by *Mobitel*, a major European Network Operator, by using some real data that were available thanks to a research project (see methodology in Appendix 1). We then reflect on how Mobitel's decisions were similarly faced by the main European telecommunications operators. The comparison with other operators is interesting, since the options under study were not available to all operators. The analysis of the strategy followed by other European operators was performed by using secondary data. This approach is in line with Yin (1984), who points out that qualitative research can rest on multiple levels of analysis within a single industry. In the context of this paper, it may be all the more useful to conduct an analysis both at industry and firm level, as the business model is emerging as a new unit of analysis (Zott, Amit et al. 2011).

The paper is structured in four parts. In the first section, we review how the literature has addressed the issue of uncertainty in the process of building a new business model. In section 2, we show how the option to wait and the option to learn can help to support decisions regarding the deployment of a disruptive technology in case of high business model uncertainty. We then apply this framework to the mobile telecommunications industry in order to find the optimal date (section 3) and pace (section 4) of the deployment of the 3G technology.

[1] In contrast, this is not the case with the 4G technology, which was deployed quite swiftly by European operators, and does not fundamentally change their business model.

[2] Source: Arthur D. Little

1. TECHNOLOGY DECISIONS IN THE CASE OF HIGH BUSINESS MODEL UNCERTAINTY

This paper concentrates on business model dynamics in the case of disruptive technologies. Whereas *sustaining* technologies improve the performance of established products for mainstream customers, *disruptive* technologies "*bring to a market a very different value proposition than had been available previously*" (Christensen 1997). As the value proposition is the corner stone of a business model, a disruptive innovation will by definition introduce a new business model on the market.

1.1. Level and nature of business model uncertainty when a disruptive technology emerges

The literature has highlighted the high level of uncertainty surrounding the business model when a disruptive technology emerges.

From the innovator's point of view, it has long been recognized that firms need to find a proper business model in order to unlock latent value from early stage technology. However, the innovator does not know from the outset what the appropriate business model will be. For example, when 3Com was spinned-off from Xerox, its business model did not emerge fully formed (Chesbrough and Rosenbloom, 2002). Chesbrough and Rosenbloom found out that the spin-offs from Xerox that were successful had gone through an extensive exploration phase before discovering an economically attractive business model. In contrast, those ventures which conducted a limited search for an effective business model failed.

Similarly, incumbent players are facing the difficulty of coming up with a renewed business model when an early-stage technology emerges and threatens to destroy their existing business model. Managers know that a new business model will emerge, but it is not at all clear what the eventual "new" business model will turn out to be (Chesbrough 2010). McGrath (2010) compares this to the "era of ferment" that can be observed in the history of technology. There are periods during which several technologies compete at the same time, until a "dominant design" is eventually victorious. Similarly, when a new technology threatens an existing business model, incumbents and new entrants multiply initiatives to develop a new business model. However during this period of ferment, nobody knows what the winning business model will be. For example, Bourreau *et al.* (2012) describe seven business models that are explored simultaneously by record labels following the introduction of digital music. They cite the Internet and the electric car as other examples of innovations which have conducted firms to experiment radically different business models.

Research in business model dynamics has highlighted that business models evolve following firms' conscious managerial decisions, but also to a large extent as the consequence of changes in the firm's environment, which are beyond the control of the firm. In particular, modifications of a business model can be triggered by sociological changes (e.g. growing appeal of "green" offers, reduced acceptability of smoking), macro-economic changes (e.g. increased level of petroleum prices), regulatory changes, arrival of a new technology, changes in the behavior of competitors and complementors (McGrath, 2010; Demil and Lecocq, 2010). Using the same line of reasoning, we can expect that the future business model involving a disruptive technology will be subject to two types of uncertainty: (1) endogenous sources of uncertainty, on which firms can have an influence[3] and (2) exogenous sources of uncertainty, which are beyond the control of the innovative firm.

For example, the attractiveness of the value proposition may depend on macro-economic factors, like the price of commodities: Boeing's "Sonic Cruiser" project was developed with the objective of significantly increasing flight speed, and thus of offering much reduced flight times to business travelers, who are the most profitable customers of airlines. Unfortunately, Boeing had to shelf the project because, among other reasons, the Sonic Cruiser had a very high fuel consumption, which became very unattractive for airlines following the continuous raise of oil prices (Reginato 2009). Other exogenous sources of uncertainty on the effectiveness of a business model may be regulation, environmental factors, the availability of complementary goods and services, etc. For example, two exogenous sources of uncertainty affecting the business model of the electric car for automakers are the availability of a dense network of charging stations and the willingness of customers (influenced by public subsidies) to buy low carbon-dioxide emitting vehicles.

On the other hand, there are a number of parameters that firms can manipulate and combine in order to come up with an efficient business model. The optimal setting of these parameters is not known in advance, but at least the firm can have an influence on them – on a short to medium term. These endogenous sources of uncertainty affecting the business model can for

[3] Please note that at this stage, we assume that technological uncertainty has been resolved. This paper concentrates on cases where the main source of uncertainty is dealing with uncertainty on the business model, i.e. on the potential value that can be created by the technology and how the firm can capture it.

example correspond to the price level and price structure, the decision by the firm to conduct some activities externally, rather than internally (or vice-versa), the partnerships that the firm can form with other players of the value network, investment in assets, development of new competences, etc.

1.2. Resolving business model uncertainty with experimentation

For firms, it is very difficult to invest in a disruptive technology, for which no reliable financial projections can be made (Christensen 1997). Incumbent firms display remarkable capabilities in forecasting the evolution of established markets, and may therefore invest large amounts of money in sustaining technologies. By contrast, it is particularly difficult to deal with markets that do not exist.

Amid so much uncertainty, Chesbrough (2010) and McGrath (2010) argue that firms simply lack data to support any strategic decision on the implementation of a new business model. To generate new data, both authors consider that firms need to make some experiments around new business models. Firms should not strive to analytically identify the right solution from the outset. Instead, they may better refine their business model through "trial-and-error" learning (e.g. Sosna, Trevinyo-Rodríguez et al., 2010).

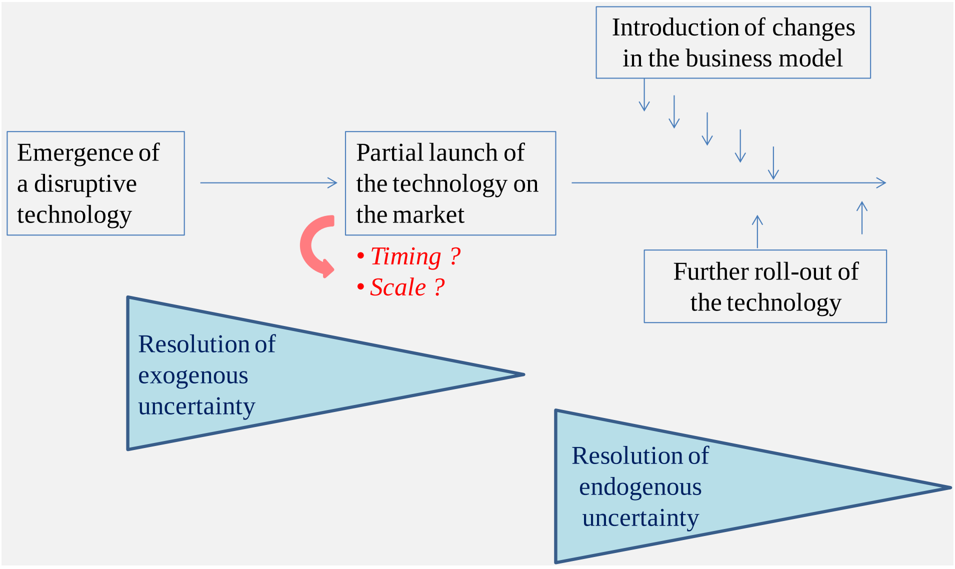
However, the literature hardly tells how firms should conduct experiments in a new business model. This is a serious issue, as designing a new business model is a lengthy and potentially risky process.

Ideally, firms should test a business model on a very limited scale, and then scale it up only when the concept has been proven. Chesbrough (2010) advises managers to engage in "*high fidelity, low cost, quick performing and usefully informative experiments*" (p.362). In some cases, it is possible to conduct the business model exploration phase on a limited scale, and leverage the business model through large scale replication once it is stabilized, e.g. through the operation of a large number of similar outlets (Winter and Szulanski 2001).

Unfortunately, this incremental approach is not very likely to be feasible when the business model innovation involves a disruptive technology. In this type of situation, a necessary condition for the testing of the business model is to launch on the market the new product or service using the disruptive technology. This will therefore involve building manufacturing capacity in the case of a new product, or deploying the necessary infrastructure in the case of a service, and conduct a partial roll-out of the product / service. Whenever possible, firms will endeavor to limit the scale of the market introduction in order to contain the risk exposure.

But even if the firm builds only a pilot plant or conducts a partial roll-out of the service, the commercialization of the new technology will require a substantial investment. Only once the technology has been commercialized will firms be able to conduct experiments in the various components of the business model (value proposition; organization of the internal and external value chain; investments in key resources and competences) (see Figure 1).

Figure 1: Impact of uncertainty resolution on business model experimentation



The investment decisions necessitated by the business model experimentations will have to address two issues: (1) a timing issue: when should the technology be launched? and (2) a scale issue: on what scale should the technology be launched (and subsequent business model experiments conducted)?

1.3. The timing issue raised by business model experimentation

Experimenting a new business model is a lengthy process. According to Chesbrough (2007), it takes much more time than the typical two-year to three-year rotation time of top managers to formulate and conduct business model experiments, collect data, interpret them and derive the appropriate conclusions on how to reframe the business model. Similarly, Sosna and colleagues (2010) describe a five-year phase of experiments and exploration as part of a business model innovation conducted by a Spanish dietary products business.

Several reasons contribute to explain this long maturation process. First, a business model is a complex combination of elements that interact with each other. For example, in Demil and Lecocq's (2010) RCOV model, a business model is made up of three interelated components:

Resources and Competences (RC), internal and external Organization (O) and Value Proposition (V). A change in one component will entail (voluntary or unintended) changes in other elements of this component, as well as with the other components. Therefore, one can expect that it will take time until the whole business model “stabilizes”. These dynamics are further complicated by two properties of the causal relationships between the elements of a business model (Casadesus-Masanell and Ricart, 2010). First, there may be some feedback loops that strengthen the model at every iteration. Second, some changes may have *flexible* – i.e. rapid – consequences on other elements of the business model, while other will have *rigid* consequences on other elements, i.e. consequences that appear only progressively over time. In the later case, the impact of an experiment on the efficiency of the business model will be particularly difficult to assess within a short time frame.

When business model experimentation is dealing with a disruptive technology, there is an additional layer of complexity stemming from the dynamics of customer needs. The literature on new product development has established that identifying customer needs for a new technology is difficult, and all the more so as their preferences change in the process of discovering and experiencing a new product technology (Carpenter and Nakamoto 1989). Therefore, it is necessary to establish links between the dynamics of customer needs on the one hand, and the dynamics of product innovation technology on the other hand (Bohlmann, Spanjol et al. 2013). If we apply this reasoning to business model characteristics instead of new product features, we can expect that changes in the business model (e.g. distribution network, price structure, product offering – which can be enriched thanks to strategic partnerships with complementors) will affect customers preferences. The evolution of customer preferences should in turn be taken into account for later business model changes. This interplay between customers needs dynamics and business model dynamics entails that experimenting a new business model in the case of a disruptive technology is a lengthy process.

If it takes a long time to craft a business model, it may make sense for firms to launch early on the new technology, and undertake experiments on various elements of the business model. They will progressively nurture a unique business model that will enable them to fully realize the commercial potential of the new technology once it takes off. In terms of competitive dynamics, an early market entry can enable a firm to learn a new business model ahead of the rest of the market (Chesbrough 2010), and even potentially shape customers preferences regarding the key elements of the value proposition.

Christensen's (1997) case studies, in particular in the disk-drive and in the mechanical excavator industry, seem to confirm the importance of first-mover advantage in the case of a disruptive technology. Incumbents who had not invested early enough in disruptive technologies failed; at best, they could expect to have a stake in the new market by selling the disruptive technology to their traditional customer base. In contrast, the timing of investment in sustaining innovations, even if those were radical, did not seem to be critical. Christensen provides examples of incumbents who invested quite late in radical innovations (e.g. thin film head in the disk drive industry), yet managed to catch-up.

On the other hand, firms may be wary of committing significant amounts of money in partially deploying the technology if there is a risk that the technology never takes off. Testing a new business model in the case of a disruptive technology requires significant investments, which are to a large extent irreversible. For example, Hewlett-Packard could not recover the cost of building significant manufacturing capacities for the "Kittyhawk" disk-drive, which was targeting the Personal Digital Assistants (PDA) market (Christensen 1997). Similarly, in the mobile telecommunications industry, some European operators had to write-off their investment in a 3G license due to the slow take-off of this technology (Whalley and Curwen 2012). When the business model of an emerging technology is subject to a high level of exogenous uncertainty, on which firms do not have any control, it may be advisable to delay the partial roll-out of the technology, and possibly leapfrog to the next technological generation.

1.4. The scale issue raised by business model experimentation

Suppose now that the exogenous sources of uncertainty have reduced in a favorable manner, the question is on which scale the new technology should be introduced in order to make some business model experiments.

On the one hand, Christensen (1997) stresses that firms should not invest too much at once in experiments in case of high business model uncertainty. For example in the case of the Kittyhawk, very few units were sold, as the PDA market failed to materialize substantially in spite of very optimistic predictions from the main industry stakeholders. Later, it appeared that companies producing mass-market video games systems would buy very large volumes of Kittyhawk if Hewlett-Packard could make available a much less sophisticated and lower priced version. Unfortunately, Hewlett-Packard had already invested aggressively in

Kittyhawk with PDAs as the original target, and no more money was left to adapt the product to other markets.

On the other hand, experiments should take place on a representative scale. Building on Thomke's (2002) works on testing new products, Chesbrough (2010) argues that a good experimentation relies on high fidelity, i.e. it should take place in "real conditions" that are representative of the larger market. In addition, there are a number of cases in which the experiment should be large enough to provide reliable results. In particular, that may be the case (1) in market showing large network externalities, like telecommunications or video-games, in which the value of a product or service is increasing with the number of users, (2) in market relying on complementary goods or services, in which the potential market should appear large enough to raise the interest of complementors or (3) in markets where high scale economies can be achieved - and therefore low selling prices offered - only in the case of a large manufacturing output.

To sum up, designing the business model of a disruptive technology demands experimentation, which in turn requires investment (McGrath 2010). The related investment decisions will have to be made by resolving two issues. The first issue is dealing with the timing of the experiment. It involves making a trade-off between (1) the risk of committing large sunk-costs to a technology that will never take-off, and (2) the necessity to experiment early-on the business model of the technology in order to benefit from prime-mover advantage. The second issue concerns the scale of the experiment, and involves resolving a trade-off between the cost and the fidelity of the experiment.

To support these decisions, managers will need appropriate financial tools. A disciplined decision process will be all the more necessary, as managers may face strong institutional pressures, given the amounts of money at stake, the complexity of the decision and the high level of uncertainty. For example, mimetic processes may induce organizations to invest massively in the deployment of an early-stage technology following similar decisions made by competitors. Or, to the contrary, cognitive bias and lock-in effects may induce organizations to ignore an emerging technology that is going against their dominant logic. (e.g. Amit and Zott, 2001; Chesbrough, 2007; Chesbrough 2010; Christensen, 1997).

In this context of high uncertainty, firms will need to get familiar with decision tools that make sense in an experimental world, like real options reasoning, and rely less on deterministic approaches such as the net present value (McGrath, 2010). In the following section, we present the real options approach. We explore how this framework may produce not only go / no go recommendations, but also optimal recommendations regarding the date and pace of deployment of a new technology in a context of a high level of business model uncertainty.

2. INVESTMENT TIMING IN A CONTEXT OF HIGH UNCERTAINTY: THE REAL OPTIONS APPROACH

The term "real options" corresponds to the application of financial options theory to investment decisions made by firms. The main benefit of real options compared to conventional strategic investment valuation tools like the NPV (Net Present Value) and other DCF (discounted cash-flows) methods was to recognize that investment projects can be adapted to economic circumstances, and that this managerial flexibility has value. Thanks to real options, it is possible to reconcile the strategic and the financial analysis, i.e. to understand why some large projects are undertaken for "strategic" reasons despite a negative NPV, and vice-versa (Myers 1984). Compared to conventional decision valuation tools, real options represent a richer decision framework as they also produce some recommendations on the optimal investment timing.

Depending on the type of flexibility involved in the investment project, there are different categories of real options. As far as timing is concerned, two main types of real options are at stake: the option to defer the investment (option to wait) and the option to sequence the investment in several phases (option to learn).

2.1. The option to wait

McDonald and Siegel (1986) posited that a firm having the opportunity to postpone an uncertain investment holds an option to wait (also known as option to defer). If this firm decides to invest immediately in spite of the high level of uncertainty, it "kills" the option to wait. As a consequence, the firm should invest immediately only if the NPV of the project is greater than the value of the option to wait. Their main contribution was therefore to demonstrate that when the level of uncertainty is high it may be preferable to postpone the decision of investing in a project even if its expected NPV is strictly positive.

Later, scholars better took into account the impact of competitive forces, and more generally speaking of foregone earnings (e.g. Lander, 2000). More sophisticated models thus showed that it is not necessarily optimal to wait, even if uncertainty reduces as time passes. On the one hand, there is usually an incentive to invest early, either because the firm might be preempted by competitors (entailing a reduction of the project's value) or because the lifespan of the project will be reduced – and as a consequence the numbers of years during which cash-flows are generated and contribute to recoup the initial investment. This may happen for example if the firm needs an operating license (e.g. for a mine, an oilfield, telecommunications spectrum, air-traffic, etc.) or if the project's life can be reduced by technical obsolescence. On the other hand, a high level of uncertainty prompts management to postpone the investment until the level of uncertainty is reduced. Therefore, one of the major contributions of the real options approach is to help managers make a trade-off between the risks and the rewards of waiting.

2.2. The option to learn

The option to learn is useful to understand why the value of a project may increase when it is sequenced in several phases. For example, let us consider a firm planning to launch a new product on the market. As the success of the new product is highly uncertain, the firm contemplates the construction of a pilot plant, in order to test the new product on a limited scale during three years. On the one hand, it is more costly to invest in several phases (in our example, build the pilot plant, and later the large plant), compared to all at once. On the other hand, it might be preferable not to launch a large project at once in order to adapt the course of action to economic circumstances: if after three years the results of the pilot plant fail to live up to expectations, the firm will not build the large plant. The value of this managerial flexibility corresponds to the value of the option to learn, acquired by the firm through the construction of the pilot plant. Therefore, it is worth "investing" in learning as long as the value of the project with flexibility (the option value) minus the "cost of flexibility" (the building of the pilot plant) is greater than the value of the project without flexibility (building the large plant from the outset).

Pennings and Lint (2000) developed a real options model to investigate whether it is preferable to introduce a new product in a phased roll-out, compared to a worldwide launch. Their model also determines the optimal size of the roll-out area. The authors start from the result of a survey conducted by the consultancy Booz Allen and Hamilton (1982) finding that about 35% of all newly introduced products fail, although the NPV was positive at the moment of the market introduction. They also cite the example of Lever's failed pan-European introduction of the new Persil detergent. Under these circumstances, and despite the extra-cost of partially rolling-out the new product instead of a worldwide launch, it may be optimal to "learn from the market" by phasing out the introduction of the new product.

Let us note S_0 the expected value of the project corresponding the world wide launch of the new product, and I the corresponding investment cost. If the new product is tested with a partial roll-out on an area representing *x%* of the total investment cost I during a period of T years, then:

i. The value of the partial-roll out equals to $x\ (S_0 - I) + x\ Vp$, where Vp is the put option corresponding to the abandonment value of the project if the launch of the new product is not pursued;

ii. The value of the remainder of the project corresponds to the option to learn Vc on the rest of the territory (1-x): (1-x) Vc.

The decision rule is therefore to perform a partial roll-out of size x as long as:

$x\ (S_0 - I) + x\ Vp + (1-x)\ Vc > c$, with c corresponding to the cost of the partial roll-out, and the values of Vp and Vc both increasing as T increases.

2.3. Types of uncertainty addressed by the option to wait and the option to learn

Scholars have shown that the option to wait and the option to learn are each affected by one specific type of uncertainty. The value of the option to wait depends on exogenously resolved sources of uncertainty, for which uncertainty is reduced as time passes (Folta 1998). For example, in the context of R&D projects, Huchzermeier and Loch (2001) show that the value of the option to wait depends only on sources of uncertainty on which it is possible to gather information before taking the decision to invest. In contrast, the value of the option to learn through staged investment is only affected by endogenously resolved uncertainty, i.e. "uncertainty that can be decreased by actions of the firm" (Folta, 1998, p.1010). For instance in the case of foreign market entry, Cuypers and Martin (2010) argue that Joint-Ventures can be viewed as an option to learn only if the main sources of uncertainties involved are endogenous, like cultural uncertainty, and not exogenous sources of uncertainty like macroeconomic and institutional variables.

One strategic decision can be affected both by the option to wait and the option to defer. For instance, this applies to the optimal timing for technology adoption when firms are confronted with sequential innovations. Firms face the dilemma of investing early in a new technology and benefit from efficiency gains on the one hand, and on the other hand of taking the risk of investing in a new technology that may quickly become obsolete if a superior technology emerges soon after. This dilemma is analyzed through real options analysis by Grenadier and

Weiss (1997) and Leiblein and Ziedonis (2007). The main source of exogenous uncertainty, captured by the option to wait, is the date of arrival of the future innovation. The main source of endogenous uncertainty, captured by the option to learn, corresponds to the efficiency gains achieved from using the new technology.

While this stream of the literature is concentrating on technological uncertainty, our paper is dealing with the uncertainties regarding the future business model of a disruptive technology. In the two following sections, we apply the option to defer and the option to learn to the decision of deploying the 3G technology in the telecommunications industry.

3. THE OPTION TO DEFER TECHNOLOGY DEPLOYMENT IN CASE OF HIGH BUSINESS MODEL UNCERTAINTY: THE CASE OF A 3G TELECOMMUNICATIONS NETWORK

At the beginning of the 2000s', European Mobile Network Operators (MNOs) were facing an increased pressure on their margins because of the high level of competition spurred by the National Regulatory Authorities. Revenues from voice services were stagnating, and MNOs moved enthusiastically towards what was presented as "the next big thing": mobile Internet, offered by 3rd generation (3G) networks. Most European countries offered 3G spectrum licenses with an auction process, and the price paid by MNOs was very high: in some countries, the 3G licenses cost more than the accumulated investments in the second generation of mobile telecommunication systems (Dunnewijk and Hultén 2007).

It was initially hoped that increasing data ARPU (Average Revenue Per User) would compensate for the decline of voice ARPU. In fact, it turned out that the potential value from 3G created for the client was poor: marketing studies revealed that subscribers were not ready to pay the extra-price to benefit from mobile Internet services. In addition, European MNOs were heavily in debt following the purchase of 3G licenses. As a consequence, they were uncertain on whether and when to deploy 3G mobile telecommunication networks, which approximately represented an investment cost as high as the price paid for 3G licenses.

We studied the decision of Mobitel, a major European MNO, to deploy a 3G mobile network. Mobitel's top management was torn between the risk of investing massive sunk costs in a technology that would not be profitable, and the risk of being pre-empted by its arch-rival Comptel. The strategic decision was whether the network roll-out should start immediately, or whether the decision should be deferred by one year.

Financial projections estimated that in case of early market entry, the 3G network would generate a slightly positive NPV of 106 MU (Monetary Units) for an investment cost of 1 280 MU (see Table 1). In fact, there was considerable uncertainty around that value, as the business model for mobile Internet was not established yet.

Particularly at stake was the offer by two types of complementors: (i) the handset manufacturers and (ii) the content and applications providers. At that time, existing 3G handsets did not offer the necessary features for a user-friendly utilization of mobile Internet services. The devices were heavy and had very limited battery autonomy. The screens were fragile and their size was small. Their price was very high, as experienced later by the "3 Group", a green-field operator who pioneered 3G in Europe: the 3 Group initially sold handsets at a price between €600 and €680 in the UK. But due to disappointing sales it halved the price to €300 (Dunnewijk and Hultén 2007). On the content side, no application provider had come up with a "killer application" that would convince the customers of the necessity to switch to 3G. Multi-media services such as video conferencing or the mobile consultation of e-mails or weather forecasts were considered of a marginal interest.

The uncertainty regarding the offer from complementors translated into a great uncertainty on two key parameters of the value proposition component: (i) the speed of penetration of the 3G technology and (ii) ARPU (Average Revenue Per User).

It was very difficult to anticipate the pace at which 2G subscribers would switch to 3G offers. For those switching to 3G, what would be the ARPU level? ARPU can be split into two components: voice ARPU and data ARPU, the later corresponding to SMS for 2G, added by MMS for 2.5G and Internet traffic for 2.75G and 3G. Based on the successful experience of the Japanese operator NTT DoCoMo, who had launched i-mode (the equivalent of 2.5G) as early as February 1998, it was expected that the rise of data ARPU would compensate for the continued decrease of voice ARPU. However, it was difficult to anticipate whether the European subscribers would follow the same consumption patterns as their Japanese counterparts, and to what extent an upgraded technology (from 2.5G in Japan to 3G in Europe) would lead to a further increase of data ARPU. The disappointing results obtained by KPN after its introduction of i-mode in 2002 in its core markets of the Netherlands, Germany and Belgium suggests that these fears were justified.

As a result, the uncertainty on the value of the 3G project was very high. A sensitivity analysis on the value of the two key parameters – speed of 3G penetration and ARPU –

showed that the NPV of the 3G project could vary between -600 and +500 MU. There was little doubt that over the long term, mobile Internet would take off. But the question was: at which pace would all the components of the mobile Internet business model set up? If the time to maturity was long, it would probably be more profitable to reinforce the 2G network to prevent any capacity shortage, and then leapfrog to the next technology (3.5G or 4G).

On the other hand, postponing the network roll-out entailed the risk of being preempted by Comptel. In that case, Mobitel would incur a significant decrease of its market share, as well as a reduction in the ARPU due to the loss of high-end customers. As a result, the project NPV would become negative, down to -42 MU. However, Comptel could also postpone the deployment by one year. In that case, it was estimated that the project NPV would amount to 107 MU, nearly the same project value as that obtained with the "early entry" scenario.

Table 1: Summary of the 3G network NPV (in MU)

Scenario	**Project value (*S*)**	**Investment (*K*)**	**NPV**
Early entry	1 386	1 280	106
Late entry			
Preemption (50% probability)	1 078	1 120	- 42
No preemption (50% probability)	1 227	1 120	107
Average value of late entry scenario	1 152	1 120	32

At a level of 50% of probability for preemption, the NPV of the late entry scenario amounted to 32 MU. This value remained significantly lower than the NPV of the early entry scenario. The NPV rule therefore recommended deploying the 3G network immediately.

3.1. Real option analysis of the investment decision

The NPV approach assumed that if Mobitel chose the deferment route, the operator would automatically invest in 3G one year later. In fact, Mobitel had the choice between 3G, and the alternative technology EDGE (Enhanced Data range for GSM Evolution). EDGE was slightly less powerful (and therefore was considered as 2.75G), but much less costly to deploy than 3G.

In other words, Mobitel held an option to wait. Exercising the option meant deploying the 3G network. The time to maturity T was one year: beyond this date, the operator would have to invest, in order to address the looming capacity shortage of its network. The option could be valued with the Black and Scholes formula, which is the standard model used to evaluate simple options (see Table 2).

Table 2: Valuation of the Option to Defer with the Black & Scholes Formula

Parameter of a Financial Option Value	Application to Mobitel's Investment Project	Value in Monetary Units (MU)
Underlying asset (stock) price (*S*)	Cash-flows generated by the 3G network	50% * 1,078 + 50% * 1,227 = 1,152 MU
Exercise price (*K*)	Investment cost necessary to deploy a 3G network	1,120 MU
Time to expiration (*T*)	Period during which the investment can be postponed	1 year
Risk-free rate interest (*r*)	Risk-free interest rate	5% p.a. (based on interest rate of treasury bills)
Volatility of the underlying asset (σ)	Volatility of the cash-flows generated by the 3G network	20% (estimated with Monte Carlo simulations on *S*)
Value of the option to defer (*C*): $C = S * N(d_1) - K e^{-rT} * N(d_2)$, where $d_1 = [\ln S/K + (r + \sigma^2/2) * T] / \sigma \sqrt{T}$ and $d_2 = d_1 - \sigma \sqrt{T}$ *N(.)* = cumulative standard normal distribution function ***C* = 139 MU**		

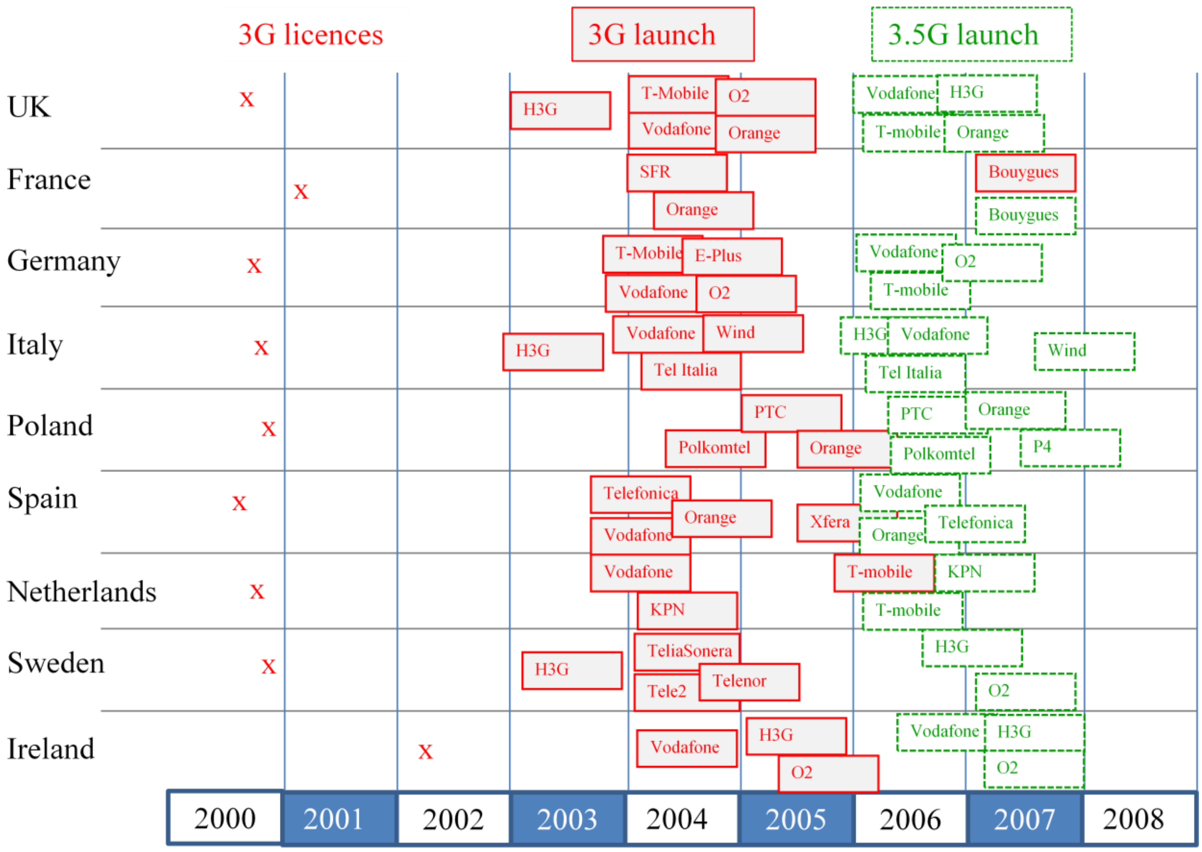
Using the real options approach, the value of the late market entry scenario was revised to 139 MU. This was higher than the value of the early entry scenario (106 MU), suggesting that it was preferable to postpone the investment decision until the conditions for the mobile Internet business model became more clearly established.

3.2. Discussion

The 3G example suggests that when the exogenous sources of uncertainty of the business model have not been resolved favorably, it may be preferable to postpone the market introduction of a disruptive technology. In the case of mobile Internet, the business model could initially not get established, because the necessary complementary goods and services (convenient mobile handsets and content services) were not available.

As a greenfield operator, the 3 Group could not use a 2G network like incumbent operators, and therefore had no option to wait. Thus, it deployed 3G much ahead of competition, as early as at the beginning of year 2003 in three European markets: Italy, UK and Sweden (see Figure 2). The value proposition of the 3 Group targeted the high-end of the market. The operator developed a sophisticated offer that included numerous multimedia services. For example in the UK, it offered video mobile services including highlights of the Barclays Premiership, full-length music videos, comedy, games, news and financial information. In Sweden, the 3 Group created the most successful service for downloading music in the country (Dunnewijk and Hultén, 2007). However, the subscribers' base remained very low, and the 3 Group had to reduce subscriptions prices several times, even proposing less expensive offers than many 2G subscription plans. Eventually, the 3 Group managed to generate a higher ARPU than the average of the market[4], but the subscribers' base remained low. In all, the success of the 3 Group in Europe was patchy, and the group would probably have exited the industry, had it not be supported by a deep pocketed parent company (Curwen and Whalley 2006). In short, the ecosystem for mobile internet was not ripe yet in 2003, and the 3 Group could not create the conditions for the success of the 3G technology on its own.

Figure 2: 3G and 3.5G launches in key European telecommunications markets



Source: Ofcom / IDATE (2010)

[4] For example in 2003, 3 UK ARPU was €68, against an ARPU of €51 for Vodafone UK (source: 3gnewsroom.com)

In contrast, the majority of European MNOs – including Mobitel - deployed 3G networks only from 2004 onwards, although they had acquired 3G licenses as early as in 2000 / 2001 (Figure 2). As calculated in the case of Mobitel, the deployment dates of the main European MNOs suggests that the value of the option to wait for favorable external conditions was greater than the benefits from implementing early a business model based on mobile internet.
The 3G example illustrates that, compared to the static NPV calculations, the real options approach enables firms to take the value of flexibility into account. They can thus resolve the trade-off between the benefit of investing early on the one hand, and the value of staying flexible in the face of a high level of uncertainty.

4. THE OPTION TO LEARN A NEW BUSINESS MODEL THANKS TO THE PARTIAL DEPLOYMENT OF A NEW TECHNOLOGY

4.1. The option to learn in the investment decision

Similarly to the example of the pilot plant, Mobitel had a learning option, which consisted in deploying the 3G network on a limited area, instead of covering the whole territory. Compared to a scenario in which Mobitel would have again postponed the launch of 3G services, and later leapfrogged to the next generation (3.5G), the roll-out of a 3G network on a portion of the territory was more costly for two reasons: first, it entailed the payment of a high investment cost, which could have otherwise been postponed by several years. Second, it implied the coexistence on the same network of several technologies (2 / 2.5 / 2.75G, 3G and later 3.5G), which would lead to significant higher network operating costs.

On the other hand, this extra-cost gave Mobitel the opportunity to learn in the crafting of a new business model based on mobile Internet. Partially deploying a 3G network was the necessary condition enabling to conduct "live" experiments on the new business model. In contrast, a much cheaper testing method consisting of surveying potential users of future services would bring only quite hypothetical insights. For example, the operator 3 Group deployed its 3G network all at once in the main three European countries in which it had acquired a 3G license. Prior to that, the operator conducted extensive surveys, as in the UK where the 3 Group surveyed over 15,000 consumers from 150 focus groups between July 2001 and November 2002. This market research revealed that a subscription fee of €105/month was the most promising tariff. In fact it turned out once the commercial offer was launched that this price was too high, and the 3 Group had to lower several times its subscription fees. As said earlier, the 3 Group finally lured clients with very low subscription prices for voice. Surprisingly, these customers made a high usage of non-voice services, so that according to the 3 Group, its ARPU in 2005 was actually much higher than the average ARPU of other MNOs in Sweden (Dunnewijk and Hultén, 2007).

To determine whether the extra-cost entailed by a partial roll-out of the network is justified by the value from the option to learn, we can use the model by Pennings and Lint (2000) presented in section 2. We present below the results from a calculation assuming that the test would be conducted during a period T of 3 years on an area x representing 35% of the territory. Obviously this numerical application can be completed by a sensitivity analysis on the value of the main parameters. We also assume that in case of failure, other MNOs would not be interested in purchasing the 3G network; for this reason we can consider the abandonment value of the network Vp as negligible.

Therefore, the value of the cash-flows generated by the test equals x (S_0 – I), with S_0 and I being the value and the investment cost of the project. For S_0 and I, we take the values of the "late entry" scenario, and obtain 35% (1 152 – 1 120) = 11.2 MU. The value of the remainder of the project equals to (1-x) Vc. Vc is the value of the option to learn, which can be estimated with the Black and Scholes formula, by using the following parameters value: S_0 =1 152; K = I = 1 120; T = 3 years; r_f = 5%p.a.; σ = 20%. We thus obtain (1 - x) Vc = 168 MU.

Therefore, the value of the project with partial roll-out equals to 11.2 + 168 = 179 MU.

The cost of the partial roll-out is estimated by reducing the EBITDA margin by 7 points during the 3 years of the test, and by 1 point (because of the increased complexity of network operating costs) starting from year 4 onwards. We thus obtain a cost of the partial roll-out of 93 MU.

The net value of the project with partial roll-out thus equals to 179 – 93 = 86 MU. This value is greater than 32 MU, the value of the project without learning flexibility. This means that according to the real options approach it is worth deploying partially the network on 35% of the territory, and test it for three years.

4.2. Business model experiments conducted by European MNOs

As a number of European MNOs, Mobitel opted for a progressive migration strategy: it initially deployed 3G only in the most densely populated areas of the country, and used the

EDGE (2.75G) technology in the rest of the territory. Following the early deployments of 3G, European MNOs conducted numerous experiments on all components of the business model.

4.2.1. Learning in the value proposition component

One of the major challenges faced by European MNOs was to come up with a completely renewed value proposition. Indeed, the 2G business model essentially consisted in voice telecommunications, while the revenues from data were limited to SMS (Short Message Service), and later MMS (Multimedia Messaging Service, supported by 2.5G and 2.75G). As 3G enabled both a higher speed and a richer content, the question for MNOs was to determine which new multimedia services to offer, and at which price. On the medium term, MNOs also had to address the issue that 3G constituted a threat for their voice core business.

First, 3G offered access to Internet and the possibility to send and receive data. The challenge was to determine the appropriate pricing structure and pricing level for these data services that did not exist before. Initially, MNOs usually offered an unlimited access to data. As data traffic started to rise significantly, MNOs later introduced the notion of “fair use”, whereby subscribers would have to pay additional charges if they were consuming data beyond a given “reasonable” level. Following the further increase in data traffic, some MNOs are now considering pricing schemes based on a “pay for use” principle.

Beyond the offering of an Internet connection, another source of value creation with 3G was the provision of content. With the increased penetration of mobile telecommunications and the increased level of competition, it became more and more difficult for MNOs to attract and retain subscribers. Therefore, a number of operators tried to enrich their offer by proposing free access to specific content, in particular music and TV. For example, Orange (in France and in the UK) and Belgacom (in Belgium) reached a deal with the music streaming provider Deezer to include Deezer’s premium offer (at €4.99 per month) into the price of their premium subscription plans. MNOs also tested content as a source of additional revenues. For example, with “Orange TV mobile”, Orange offered for €9 per month the access to 68 TV channels as well as to its two own channels Orange Sports and Orange Movies (also available separately for €6 per month each).

Finally, two other innovations took place in the “value proposition” component: first the apparition of “SIM only” subscription, whereas MNOs traditionally propose subsidized handsets as part as the mobile subscription, and second the apparition of “quadruple play offers”, bundling a mobile subscription with a landline “triple play” (telephone, Internet and TV) subscription.

4.2.2. Learning in the organizational component

In terms of organization, two main innovations affected the internal value chain of European MNOs: first, the necessary integration of fixed and mobile services for operators proposing bundled "*quadruple play*" subscriptions, and second, modification of the distribution channels, as SIM-only subscriptions are sold directly over the Internet, and not through the MNO retail network or independent retailers.

But it is mainly the external side of the organizational component that has been the object of the most intensive experimentation. Indeed, the increased complexity of the value proposition lead to a business model resting on a much more complex ecosystem than the traditional mobile telephony ecosystem. New players entering the mobile telephony value network included: application providers, application aggregators, content providers (TV channels, video games producers) , content aggregators ("practical life" aggregators like Picassa, portal and search motors like Yahoo, video providers like YouTube (purchased by Google) or Dailymotion (took over by Orange)), social networks, middleware / platform vendors (e.g. Apple, Android-Google) and Voice Over IP providers (Google Voice, Skype - which was purchased in 2011 by Microsoft).

Within this new value network MNOs were (and still are) facing two main challenges. On the value capture side, the main challenge was to find out how to share value with these new players, in particular with so called "Over The Top" (OTT) players (like YouTube), which derive value from telecommunication networks, yet do not invest in them. On the value creation side, the challenge was to identify which categories of complementors would best enhance the value proposition from the MNOs, and then to preempt competitors in the closing of exclusive partnerships with the most promising complementors. In France for example, SFR learned from the successful partnership between Orange and the music streaming provider Deezer, which started in 2010: about 6 months later, SFR formed an alliance with Spotify, Deezer's main competitor.

4.2.3. Learning in the resources and capabilities component

In order to enrich and differentiate their value proposition, some MNOs decided to develop a capability in the provision of contents. In particular, Orange created two TV channels Orange Sports and Orange Cinema Series (OCS), respectively specialized in sports and movies / TV series. It turned out that the necessary investments to acquire sports and movies diffusion rights were very high, and the two channels accumulated €700m losses between 2008 and

2011. Eventually, Orange decided to close down the sports channel, and to stop the exclusivity of the movie channel (OCS). Despite Orange failure, both BT and Deutsche Telekom invested in sport TV in 2012. In contrast, Orange scaled up other "tests" in the provision of content. In particular, Orange purchased 49% of the video provider Dailymotion. As the collaboration between Orange and Dailymotion was a success, Orange purchased the 49% remaining stake of Dailymotion in early 2013, and developed a number of operating synergies with Dailymotion.

4.3. Discussion

The case of the 3G technology in Europe confirms the benefits of conducting real experiments of a business model, and the importance of choosing the right scale for these experiments.

The example of the 3 Group shows the difficulty to predict the validity of a value proposition before effectively launching the new product or services. The fact that customers of the 3G group initially rejected high subscription prices, and eventually paid a higher ARPU than the average because of their use of data services, also illustrates the complex dynamics in customer needs in the case of a disruptive technology.

However, the very mixed results of the 3G group illustrate that in this context of high business model uncertainty, firms should better engage in business model experiments on a limited scale: the optional strategy followed by most European MNOs consisting of partially deploying a 3G network has been more successful than the "bet" of the 3G group, which deployed its network all at once.

Finding the appropriate scale of business model experiments is a difficult decision, which can be facilitated by taking into account the value of the option to learn.

In terms of real option valuation, it should be recognized that the calculations for the option to learn have been greatly simplified. For the purpose of clarity, the calculation of the option value Vc has been performed by considering the parameters S (underlying asset value), K (exercise price) and σ (volatility) as having the same value as the for the calculation of the value of the option to defer studied one year earlier. In fact, firms have to regularly update the value of the parameters used for the option calculation. For example, the value of the underlying asset, which corresponds to the cash-flows generated by the 3G network, had increased, because the National Regulatory Authority had extended the lifetime of the 3G license by 5 years. In addition, sequencing the deployment in several phases had numerous consequences on the business plan that have been overlooked. For example, the potential cash-flows generated by the test were underestimated, as Mobitel contemplated deploying 3G first in the most densely populated areas, which are also the most profitable ones.

On the other hand, the major obstacle in the diffusion of the real options approach is the complexity of option valuation models (Lander and Pinches, 1998; Hartmann and Hassan, 2006). It is therefore important not to cloud the decision with too complex models, and the example of Mobitel shows that a simple calculation of the option to learn captures the main aspect of the "scale dilemma" in the deployment of a new technology.

CONCLUSION

We analyzed and illustrated the benefit of the real options approach to help determine the optimal timing of technological deployments in a context of a fast evolving business model. The contributions of the paper are twofold.

First, we highlighted that the real options approach contributes to enrich the literature on business model dynamics by taking into consideration the management of uncertainty in the evolution of business models. While it has been recognized that it is necessary for innovative firms to undertake experiments in order to develop an economically efficient business model, current research does not tell how these experiments should be conducted. In this paper, we show that the real options approach can help managers to make decisions on the appropriate timing and scale of the investments required for the experimentation of the business model. The focus of this paper is on the case of high uncertainty regarding the future business model of a disruptive technology. However, some findings of this paper could be extended to other contexts. For example, the option to learn could be taken into account in cases where the test of the business model requires a significant investment (e.g. testing of a new distribution network).

Conversely, the use of the business model lens enabled to enlarge the traditional perspective of the real options literature regarding the optimal timing of large technology investments. Compared to the existing literature, we concentrated on the business model as the major source of uncertainty, as opposed to the technological efficiency and the date of arrival of the succeeding technologies.

The insights of this article have been illustrated with a longitudinal analysis in the mobile telecommunications industry. We studied a real investment decision, analyzed as part of a research contract with the focal firm, and then extended the analysis to other European MNOs. This reinforces the validity of the article, as the various European telecommunication

markets display common features, yet are independent national markets showing significant differences in terms of market structure (e.g. total number of competitors, market share of the historic provider), consumption patterns (e.g. ARPU, propensity to send SMS), level of retail and wholesale prices and regulatory policies, which are conducted by National Regulatory Authorities (Dunnewijk and Hultén, 2007). Nevertheless, this article is limited to the analysis of a single industry, and further analyses of investment decisions in a context of high business model uncertainty are clearly needed.
Another limit of the paper is that it does not address the possibility for firms to operate several business models simultaneously, which can be a successful strategy (Casadesus-Masanell and Tarziján 2012).

This research could also be extended by focusing on the implementation side of real options. The real options framework raises serious implementation issues, and it is a challenge to find the right balance between the simplicity of the valuation model, and the need to keep valuation realistic. A fruitful area for future research would be to test whether in spite of the limits of the option valuation, real options *reasoning* indeed help managers to make decisions in context of high business model uncertainty. In particular when firms experiment new business models, it would be interesting to study in details the chronology of decisions, and analyze to what extent real options can help managers stop experiments when it appears to be a failure, or on the contrary can be a tool to reduce cognitive biases and find the necessary resilience (Chesbrough, 2007; Sosna, Trevinyo-Rodríguez *et al.*, 2010) during the process of business model transformation.

Finally, a future area of research would be to develop more dynamic real options analysis models. We have highlighted the need to adapt financial valuation models to the specificities of real options, and in particular to the fact that the information revelation process is usually progressive and incomplete. Real options models could also be combined with game theory to take into account the fact that technology deployment decisions will not only affect the focal firm, but also presumably (1) its competitors because of well-known mimetic processes, (2) complementors who will have the opportunity to renew their offer based on the new technology. A technology adoption decision made by one player may therefore dramatically accelerate the evolution of the dominant business model in the industry, and the incorporation of such dynamic effects into the real option analysis could constitute an interesting research avenue.

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APPENDIX 1: Research Methodology

The real options framework presented in this article is the result of a series of research contracts conducted during 2.5 years with a major European telecommunications operator. The objective of the research was to test the applicability and benefits of real options to support investment decisions under uncertainty.

We analyzed in details three real investment decisions involving network as well as R&D investments, and taking place either in monopolistic or competitive environments.

Our research contract, and the possibility to occupy an office for the first author, provided us direct contact with managers, opportunities for interviews and on-site access to relevant information. To preserve confidentiality, the names of the competitors and the dates have been changed, the scales have been altered, and results are expressed in monetary units (MU).

We worked on investment decisions that were examined by Mobitel at that time. This conveyed three main advantages: getting the interest and involvement of concerned managers, easing access to relevant data and avoiding retrospective rationalization of the investment decision.

For the analysis of the UMTS network decision, particular attention was paid to framing the investment decision, and making sure it followed an optional logic. This was performed through the analysis of internal documents as well as through the analysis of brokers and industry reports. This work was supplemented by semi-structured interviews within Mobitel.

We validated the first phase analysis by giving two separate presentations to the strategy and finance departments of Mobitel.

Second, we estimated the value of the deferment option and of the option to learn. We used the analysis performed in the first phase to establish the characteristics of the option under study. Key to the option valuation is the estimation of the parameters. We were given access to internal data to evaluate parameters like the value of the underlying asset, exercise price or dividend rate. To calculate the value of the volatility parameter, we performed Monte-Carlo simulations. The distribution of the main sources of uncertainty was determined by compiling projections found in brokers and industry reports. All the assumptions were then checked by giving a presentation to the finance department.