# Value-enhancing pre-investment activities under uncertainty

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**Abstract**

Real options models of investment mostly concern the firm's stochastic environment as exogenously given and subject to constant parameters. We consider a firm that can sequentially invest to alter the growth rate of a project's revenues through a value-enhancing pre-investment activity, both when the change is fixed, and when the magnitude of the change can be optimally chosen by the firm, before entering the market. We find that this incentivises the firm to invest sequentially, first in revenue-enhancing activities and then to enter the market some later time. This is in contrast to the two-stage investment problem in Dixit and Pindyck (1994), wherein it is never optimal for the firm to invest sequentially. There is both an option value of waiting that delays investment in value-enhancing activities, as well as an accelerating effect from the change in growth rate, which increases the value of the project. Thus, the resulting effect of uncertainty is not straightforward, as increasing uncertainty can both delay or expedite the investment in revenue-enhancing activities, dependent on the cost parameters and the magnitude of the change in the growth rate. When the firm can optimally choose the amount of the value-enhancing activity, we find that the firm invests more in these activities when uncertainty is higher. When the marginal cost of the activity increases, the firm undertakes less revenue-enhancement, but the overall amount spent increases.

*Keywords:* Sequential investment, Real Options, Endogenous uncertainty, Optimal control

## 1. Introduction

In 2014, The Panasonic Corporation entered into a joint-venture with Tesla Motors Inc. on the *Tesla Gigafactory* project. The venture is a strategic alliance and R&D effort between the two firms that positions Panasonic for higher long-term growth in a novel market. The president of Panasonic, K. Tsuga, has stated that they *"see the rechargeable battery business as the biggest growth driver. So we are aggressively making an upfront and strategic investment here."*[1]. Through the alliance with Tesla, Panasonic has invested to obtain a

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[1] 11.01.2016, https://www.teslarati.com/panasonic-tesla-battery-gigafactory-investment-growth-driver/, accessed 11.13.2017

favorable position for capturing higher profits in the potential future of high-volume production of lithium-ion batteries for electric vehicles (EVs) and household electricity storage. Thus, Panasonic has taken an upfront and proactive stake in the development of the EV-market, possibly obtaining a larger profit growth than waiting passively for the market to develop and only supply EV-producers with battery-cells.

Strategic alliances, marketing campaigns, lobbyism, standard-captures, and other pre-launch activities may influence the growth potential of a project. Thus, an innovating firm can effectively be proactive in their existing and potential markets, influencing the expected growth of new projects before they are installed. The idea that a firm can enhance the potential revenue of a project by undertaking some strategic pre-investment actions is related to the *amplifying pre-investments* introduced in McGrath (1997). Such actions could be aimed at affecting the revenue potential of the product, the adoption rate, the likelihood of imitation, or competing products taking shares of the market. In this paper, we focus on actions that increase the revenue potential through active investments, changing the firm's environment favourably. We study two different scenarios: one where the revenue-potential is subject to a fixed change after the firm undertakes a pre-amplifying investment, and one where the firm can choose the magnitude of this change optimally.

This paper aims to add to the strategy literature by formally modelling value-enhancing pre-investment opportunities, and investigating their effects. Furthermore, we contribute to the real options modelling literature by including such dependence of the stochastic environment on the firm actions. The real options approach has been widely used to study different investment decisions under uncertainty, however mostly considering the uncertainty as exogenously given. Dixit and Pindyck (1994) overviews many of the early models, while Trigeorgis (1996) presents models of portfolios of different options on the same real asset. In the strategy literature, real options reasoning has been used in decision-heuristics, like the score-based questionnaire in McGrath and MacMillan (2000) of mapping a project's possibilities and threats, or the mixed decision-tree analysis and scoring of MacMillan et al. (2006). The field of real options analysis started with Myers (1977), who noted that the presence of uncertainty in cash-flows affects corporate expenditure decisions. A common assumption of the uncertainty in real option models is that the underlying price or demand is following an exogenous stochastic process, often geometric Brownian motion. Thus, the resulting resolution of uncertainty is purely a function of time, and beyond the control of the firm. Work on endogenous uncertainty is limited to problems regarding learning-type investments. In this strand of work, Pindyck (1993) regards projects with cost uncertainty and time-to-build, where the *technical uncertainty* can only be resolved through actually undertaking the project. Such uncertainty relates to the physical difficulty of completing a project, affecting for example the final amount of an input factor. Hence, technical uncertainty represents endogenous resolution of the uncertainty, dependent of the firm's action, where the uncertainty is not only resolved through time, but also through investment. The literature also models endogenous actions of the firm by allowing the exogenous stochastic process to be partly unobservable. The firm must then undertake costly learning activities to assess the true state of the market. Kwon and Lippman (2011) consider a firm that undertakes a small-scale pilot project to infer the full project's profitability. The firm observes a noisy profit flow from the pilot and from this updates the belief of the market state in a Bayesian fashion. The firm must then consider the decision to expand the pilot project or exit. Thijssen et al. (2004) consider a similar situation, where the firm at random times receives imperfect signals from the market and uses these signals in Bayesian belief updating. The trade-off for the firm is correspondingly between waiting longer to reduce the uncertainty of the market state and investing to reap potential profits. This approach is further investigated in a model by Harrison and Sunar (2015), where the firm can adopt different learning modes that affect the quality of the obtained market signals, incurring cost at appropriately different rates.

The aforementioned models are however all characterized by endogenous revelation of an exogenous uncertainty process. The firm takes an active role in learning about the uncertainty, but has no means of actually affecting its own environment. This gap in the literature of real options modelling in studying endogenous influence on the stochastic environment is noted by Adner and Levinthal (2004). They argue that firms take steps to affect the attractiveness of possibilities, either by changing the technical agenda of the project or altering the target market, and that the assumption of exogeneity can be seen as a "wait-and-see" approach to the investment problem. This also holds for the endogenous uncertainty resolution approaches, as the firm has no means to change the market state or adapt to it should the market belief turn out unfavourable. In a response to Adner and Levinthal (2004), McGrath et al. (2004) argue that the real options heuristics utilized in the strategy literature can give insights into how upside potential can be enchanced by strategic actions or redirecting projects. Nonetheless, the authors concur with Adner and Levinthal (2004) that further work on endogenous uncertainty resolution and influence is important in the real options modelling literature. In technical terms, this means allowing for the decision-maker to affect the stochastic process the firm is subject to, through undertaking some specified investments.

In this paper, the aforementioned shortcomings of dealing with endogeneity in a real options approach are addressed. We analyze how the opportunity for a firm to undertake strategic pre-investment actions to alter a project's growth potential, affects the investment behaviour and profits of the firm. This represents a shift from seeing the firm as a passive actor, subject to an exogenous market process, to the firm being proactive and effectively shaping its own growth potential through strategic investments. The work on real options subject to stochastic processes with changing parameters are generally very limited and to the best of our knowledge restricted to one fixed change in drift rate after a certain investment. The only two contributions here are Kwon (2010) and Hagspiel et al. (2016). Kwon (2010) studies a firm producing an aging product subject to a downward trending demand, with the possibility to innovate once. The uncertainty is modelled as a geometric Brownian motion, with a change in drift if the firm innovates. It might be optimal for the firm to cease operations and exit, or to innovate once to boost the profits. The new product would obtain a higher, but still negative, drift rate if undertaken, thus making an eventual exit of the market inevitable. Hagspiel et al. (2016) expands this setting to allow for capacity choice for the new product, while still holding the change in drift rate for the demand function as exogenously given.

We model the market as being characterized by an uncertain price, where the price follows a geometric Brownian motion with a change of drift at the time the firm undertakes the revenue-enhancing investment. We introduce two models: one where the change in drift is fixed, and one where the change is dependent on the amount of investment the firm undertakes. The first model is an optimal stopping problem subject to a changing stochastic process, while the second model is a joint optimal stopping and impulse problem, where the change in drift is controlled by the firm. We see that a fixed change in drift incentivises the firm to invest sequentially, i.e. to invest in revenue-enhancing activities initially and then wait and hold the option to actually finish the project. This is in contrast to the similar two-stage sequential investment model in Dixit and Pindyck (1994), who find that the firm will never invest sequentially when there is no time-to-build. The incentive is increasing with the size of the change in drift. We see that the effect of uncertainty is not straightforward. Increasing uncertainty can both delay or expedite the investment in revenue-enhancing activities. When the firm can influence the magnitude of the change in drift, we see that the firm invests more in revenue-enhancing activities when the uncertainty increases. Further, when the marginal cost of boosting the drift increases, the firm undertakes less revenue-enhancing activities, but increases the total amount spent on boosting the drift. We find that increasing the drift is very attractive for the firm, and that this impact on the stochastic environment by the firm affects its investment strategy.

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