Real Options: Added Returns *versus* Added Risk

The assessment of a firm's risk is often conducted by evaluating the variance of the net cash-flow forecasted for the unchanged allocation of that firm's resources to its business. This approach to assessing a firm's risk may not be quite accurate for the following reason. Multiple resource reallocation strategies, or real options, that firms have and often use over time to flexibly alter the allocation of their resources in response to changing market conditions are rarely factored in such assessments. Examples of such real options include (a) the option to redeploy, or switch, the firm's resources to another product or geographic market; (b) the option to temporarily idle, or shut down, the use of the firm's resources with the possibility to reengage the idled resources in the future; (c) the option to divest, or to abandon, the firm's resources by selling them on a secondary market; and (d) the option to grow the firm by acquiring additional resources for its existing business. Some research speculated that real options may help firms reduce their risk (Belderbos, Tong, and Wu, 2014; Chatterjee and Lubatkin, 1990; Miller and Reuer, 1998; Pantzalis, Simkins, and Laux 2001; Reuer and Leiblein, 2000; Tong and Reuer, 2007), even though only few of these studies corroborates that idea empirically. Accordingly, a thorough theoretical analysis of how real options affect firms' risk was missing but was necessary to better know the predictions to be tested empirically, in the first place. One reason for this theoretical gap was that the assessment of risk in the presence of the noted real options is analytically difficult because their flexible use includes the choice of the optimal time for their exercising. Meanwhile, such analysis has recently started for the redeployment option (Sakhartov, 2022; 2023) and can be extended to other real options to reflect their impact on a firm's risk.

An additional important motivation for considering how real options change a firm's risk is that risk is an important measure of the firm's performance that has prominently featured as such in strategic management research since Andrews (1971). Accordingly, risk affects the attractiveness for the firm to have real options, just as the return to such a possession does. Meanwhile, many real options models (*e.g.*, Kogut and Kulatilaka, 1994; Sakhartov and Folta, 2014; 2015; Triantis and Hodder, 1990) followed the risk-neutral approach of Black and Scholes (1973) and Merton (1973), thus focusing on the expected returns to real options and remaining agnostic regarding how real options affect a firm's risk.

This study follows Sakhartov (2022; 2023) to develops four semi-analytical models: each model evaluates a firm's risk (*i.e.*, variance of the accumulated net cash flow) and a firm's return (*i.e.*, expected value of the accumulated net cash flow) when that firm can use one of the four American-type real options (*i.e.*, can be exercised at any time before the firm's resources fully depreciate) listed above. This development provides a more inclusive evaluation of a firm's risk, thus facilitating better-informed risk management in firms. Risk associated with each option is related not only to the respective return but also to the essential determinants of that option raised in previous research. Thus, one determinant that is uniformly present in each of the four options is the cost of implementing that option. The idling option has an additional cost of reopening that captures the cost of reactivating resources previously idled by the firm. Another determinant that was also universally applied to all real options is return volatility that captures uncertainty in the context in which the options are situated. Because the redeployment cost is bivariate (*i.e.*, it involves random returns in two businesses), uncertainty for that option is operationalized with an additional parameter of return correlation that captures the tendency for the returns in the two businesses to converge to each other, or to be in phase. Some additional determinants for each option are omitted from this proposal but will be presented at the conference. A more detailed

technical description of the model is also omitted from this proposal and will also be presented at the conference.

Results for the four real options are illustrated in the respective Figures 1−4. The first panel in each figure allows a comprehensive evaluation of the risk-return relationship involved in the firm's operations when that firm counts on the use of real options. The universally upward slope of the solid blue line reflecting the curvilinear (*i.e.*, the second-order or quadratic) trend for the relationship between risk and returns indicates that, in the presence of real options, that relationship tends to be positive. This means that the additional return that the firm expects to receive from the use of real options tends to be accompanied by a higher risk associated with such use. However, positions of the actual datapoints connected with the solid redline in the first panel in each figure reveal that, with some configurations of option determinants, the firm manages to achieve high or moderate-to-high return while incurring low risk. This pattern is seen in Figures 2−4 (*i.e.*, for resource idling, resource divestiture, and resource acquisition) where some datapoints are located at the bottom margin and close to or at the right margin, but not in Figure 1 (*i.e.*, for resource redeployment) where all datapoints located at the bottom margin are very distant from the right margin.

Another important part of the analysis that is enabled by the developed formal models is whether the same determinant of an option can have oppositely directed effects on risk and return in the firm. In two out of the four real options, the costs of implementing such options have such oppositely directed effects on risk and return. Specifically, with the idling option in Figure 2, both the idling cost (*i.e.*, Panel B) and the reopening cost (*i.e.*, Panel C) negatively affect return, while positively affecting risk in the firm. Likewise, with the divestiture option in Figure 3, the divestiture cost (*i.e.*, Panel B) negatively affects return, while positively affecting risk in the firm. This tendency relates to the possibility that the firm manages to achieve both high return and low risk with these options. By contrast, the costs of implementing the redeployment option (*i.e.*, Paner B of Figure 1) and the growth option (*i.e.*, Panels B of Figure 4) negatively affect both risk and return in the firm. (That the growth option can still lead to the combination of high return and low risk happens due to a very specific combination of return volatility, the acquisition cost and an additional parameter that is not shown in Figure 4 but will be reported in the next stages of this project.) Although Panel D in Figure 1 contains an increment where negative return correlation simultaneously reduces risk and increases return, this pattern is dominated by the more general tendency for return correlation to reduce both risk and return and, thus does not turn into the possibility that the firm manages to achieve both high return and low risk with the redeployment option.

The final set of results is currently available only for two options, the redeployment option and the divestiture option, but will be developed for the two other options to be also presented at the conference. This result is concerned with the key question of how the presence of real options affects the firm's risk. Panel B of Figure 1 contains a part where both risk and return stay at their lowest values regardless of the increase in the redeployment cost further to the right in the panel. This pattern demonstrates the case where redeployment is prohibitively expensive and is never used, thus being equivalent to the case where the redeployment option is absent at all. This is noteworthy that, outside that part (*i.e.*, where the redeployment option is used), the firm's risk is always higher than without that option. By contrast, Panel B of Figure 3 contains a part where risk stays at its highest value but return stays at its lowest value regardless of the increase in the divestiture cost further to the right in the panel. This pattern represents the case where divestiture

is prohibitively expensive and is never used, thus being equivalent to the case where the divestiture option is absent at all. This is noteworthy that, outside that part (*i.e.*, where the divestiture option is used), the firm's risk is always lower than without that option. The juxtaposition of these results enables the conclusion that presence of some real options can lead to the reduction of the firm's risk, whereas presence of other real options increases that risk.

Risk in a firm is not just the variance of its accumulated net cash-flow with the unchanged allocation of that firm's resources to its business. Multiple resource reallocation strategies, or real options, not only change a firm's return but also alter that firm's risk. This study has explored how real options change risk in firms and has come to the following tentative conclusions. First, the presence of real options generally entails the tendency for a positive risk-return relationship in firms. Second, despite this general tendency, at least some options allow firms to receive high returns and low risk at once. Third, some option determinants have oppositely directed effects on risk and on return. Finally, some real options can reduce a firm's risk, whereas other real options always increase that risk.

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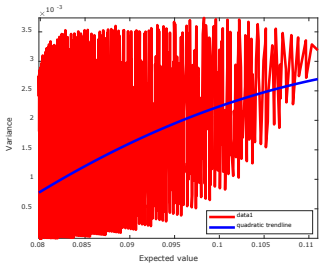
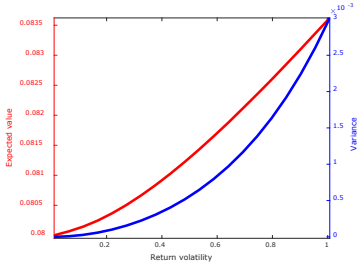
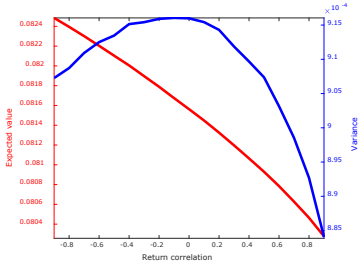


A. Risk-return relationship

B. Effects of redeployment cost

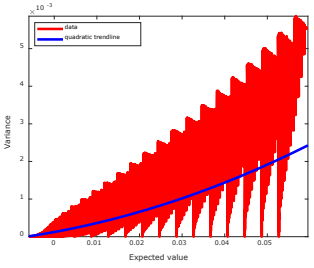


C. Effects of return volatility



D. Effects of return correlation

Figure 1. Resource redeployment



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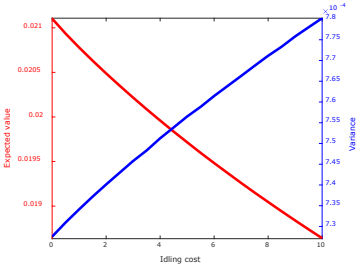
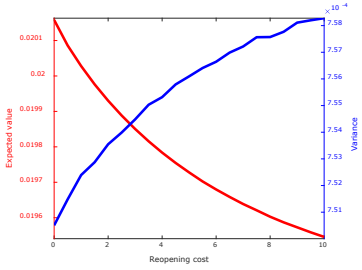
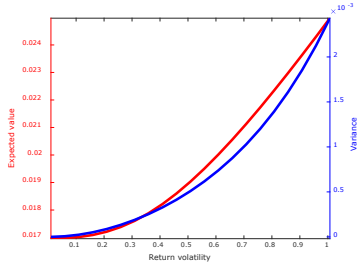


B. Effects of idling cost

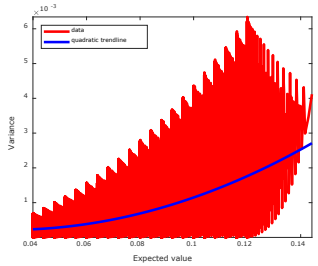


C. Effects of reopening cost



D. Effects of return volatility

Figure 2. Resource idling



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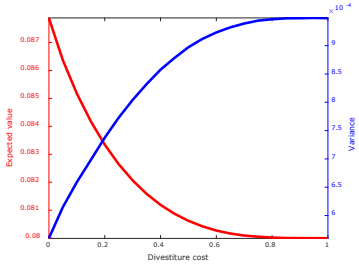
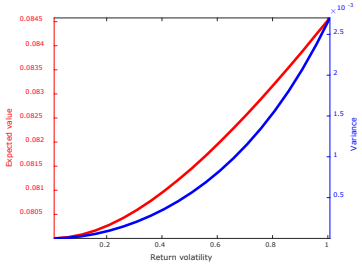
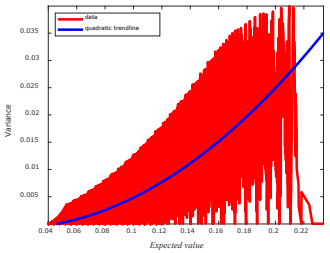


B. Effects of divestiture cost

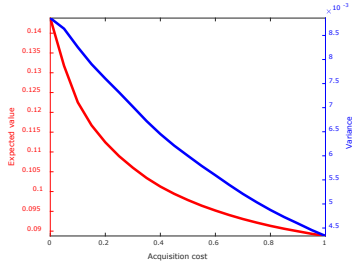


C. Effects of return volatility

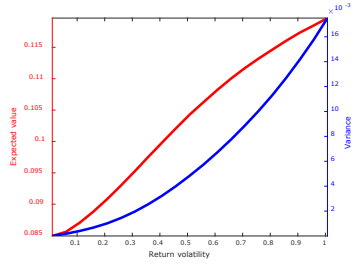
Figure 3. Resource divestiture



A. Risk-return relationship



B. Effects of acquisition cost



C. Effects of return volatility

Figure 4. Resource acquisition