Agency Costs of Equity and Accounting Conservatism:

A Real Options Approach

Tan (Charlene) Lee

University of Auckland Business School, Private Bag 92019,

Auckland 1142, New Zealand

Abstract

This paper investigates how conservative accounting system can mitigate the agency problem between the manager and shareholders of a firm, which arises from information asymmetry. In this study I assume that the firm has a privileged right to engage in an irreversible discrete project, i.e., it possess a valuable option to delay investment. Using standard real options arguments, I first show the manager tends to invest earlier than optimal, when she owns information advantage over shareholders of the firm. In other words, the firm incurs agency costs of equity because the manager tends to overinvest. I then demonstrate that the application of accounting conservatism will induce the manager to report his private information more truthfully, and thus reduce the agency costs of equity. In addition, the reduction on agency costs will be more profound when the cash-flows of the investment project are highly uncertain.

I would like to gratefully acknowledge the helpful comments from Yehning Chen at National Taiwan University, Taiwan, Chen Chen at the University of Auckland, New Zealand, and Karen Jingrong Lin at University of Massachusetts Lowell, the United States.

1. The model

I extend the infinite stochastic model of Dixit (1992) and McDonald (2000) to examine how accounting conservatism affects the investment decisions of a firm. In order to highlight the conflict of interests between the manager and equityholders, I establish my model to a stylized form and abstract from other important aspects on a firm's investment behavior, such as taxes, the difference in manager's and shareholders' risk attitude, agency costs of debt financing, and the possibility that the firm can exit the product market with some scrap value. The main assumptions of this model are as follows:

(i) A firm has the privileged right to take on an irreversible investment project. However it does not have any leeway to abandon the project.

(ii) The firm is all equity financed. Shareholders delegate the investment decision to a manager who is assigned to maximize the equity value of the firm. Both parties have the same risk attitude.[1]

(iii) When the firm invests under the situation where there is no information asymmetry between the manager and shareholders, I refer it as the first-best (henceforth FB) strategy.

(iv) When the manager possesses private information regarding the expected value of the investment project, she suggests the time to invest following the second-best (SB) strategy.

(v) The firm invests at the adjusted second-best (ASB) timing when the manager has private information regarding the expected investment value, but is also subject to

[1] Following McDonald (2000), I assume that when deciding the value of the project, the firm employs the cost of equity derived by using the capital asset pricing model (CAPM) as the discount rate, i.e., a typical assumption used in the discounted cash flow (DCF) analysis. By contrast, the firm employs the risk-neutral approach when calculating the option value to delay investment. My assumption can be more plausible than Dixit & Pindyck (1994, chapter 4) which assumes that the cost of equity is risk-free, same as the discount rate used to value the option to delay investment.

recognize earnings/costs as required by the conservative accounting system.

Consider a firm with a perpetual right to undertake an investment project, which requires an upfront investment cost, K. After exercising this project, at each point in time the firm receives a unit of operating cash flows, denoted by $C(t)$, which follows a geometric Brownian motion as[2]:

$$dC(t) = C(t)\alpha dt + C(t)\sigma d\Omega(t), \tag{1}$$

where α is the expected growth rate of $C(t)$, σ is the instantaneous volatility of that growth rate, and $\Omega(t)$ is a standard Wiener Process. I assume that the firm does not pay corporate taxes and is totally equity financed.

Equityholders of the firm hire a manager to facilitate the operational aspects of the investment project. The manager receives two parts of remuneration; one is a fixed component, m_0, that the manager receives immediately after making a contract with the firm. Another part is the incentive component, which is proportional to the amount of the instantaneous cashflows generated by the investment project. Without loss of generalization, I assume that the equityholders would pay for the manager's fixed salary, m_0.[3] As a result, upon investment, the equity value, which is the expected value of the operating cashflows netting of the manager's flexible component of salary:

$$V(t) = (1 - m_1)\frac{C(t)}{(\rho - \alpha)} \ , \tag{2}$$

where m_1 denotes for the incentive proportion of the manager's salary, and ρ

[2] In other words, I assume the firm always achieves the operating cash flow break-even (B/E) point as $C(t)$ is positive in the process. This is plausible as firms are able to implement this B/E level before they achieve the other two B/E points, i.e., accounting and financial B/E levels (Ross, Westerfield, and Jaffe, 2013; Chapter 7).

[3] Alternatively, I can assume the manager's compensation package includes another fixed component that she receives at each instant immediately after she makes a contract with the firm, which shall come out from the cashflows generated by the project after investment. I do not employ this alternative assumption so as to keep the model simple.

denotes for the risk-adjusted discount rate derived by using CAPM. Eq. (2) indicates that the value of the project, *V*(*t*), is in proportional to the instantaneous operational cash flows, *C*(*t*).

2.1 Optimal investment timing strategy when there are no agency costs of equity

Supposing that there is no conflict of interests between the manager and shareholders, the firm's objective is to maximize the equity value, *V*(*t*), which also follows a geometric Brownian motion since:

$$\frac{dV(t)}{V(t)} = \frac{dC(t)}{C(t)}. \tag{3}$$

For ease of exposition, I henceforth denote *C*(*t*) / *V*(*t*) by *C* / *V*.

In this study I only consider the special case where the investment cost, *K*, is totally irreversible.[4] Using standard techniques employed in the real options literature (e.g., Dixit and Pindyck, 1994; Chapter 4) as shown in Appendix A, the investment rule for a perpetual project is to invest when the project value, *V*, reaches a critical threshold value denoted by V_H, as given by:

$$V_H = \frac{\beta_1}{(\beta_1 - 1)} K, \tag{4}$$

where $\beta_1 = (\frac{1}{2} - \frac{r-\delta}{\sigma^2}) + \sqrt{(\frac{1}{2} - \frac{r-\delta}{\sigma^2})^2 + \frac{2r}{\sigma^2}} > 1,$ (5)

r denotes for the risk-free discount rate, and $\delta = (\rho - \alpha)$. Since δ is the difference between the risk-adjusted rate and growth rate of the project cashflows, it is analogous to the dividend yield of the value of the underlying asset, i.e., the project value, *V*. It is required that $\rho > \alpha$ so that the value of the project won't divergent; or analogously, the dividend yield of the project, δ, is required to be positive such that the firm will exercise the project.

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[4] This assumption also implies that the firm does not have the option to abandon the investment project since the scrape value of the project is zero. It is possible to consider the abandonment option of the project if I assume this project is partially irreversible or partly debt-financed, or both.

A more practical way to establish the rule of investment is to derive the hurdle rate associated with V_H in Eq. (4), as shown in Appendix A:

$$\gamma_H = \alpha + (\rho - \alpha)\frac{\beta_1}{(\beta_1 - 1)}, \qquad (4)'$$

where γ_H denotes for the optimal hurdle rate associated with V_H. This expression is similar to Dixit (1992) and McDonalds (2000). I define the investment timing decisions as shown by Eqs. (4) and (4)' as the FB strategy as they are made without the possible conflict of interests between the manager and shareholders of the firm.

The expected growth rate of project cash flows, α, is one of the key factors which affect the investment timing decision of the firm, as shown by the following propositions.

Proposition I (*Expected growth rate of cashflows and investment*): The firm accelerates (defers) investment when the expected growth rate of project cashflows is smaller (greater). In others words, both V_H and γ_H increase with α.

Proof: See Appendix B.

The reason for Proposition I is as follows. If the growth rate of the project cashflows becomes higher, on the one hand, as indicated by Eq. (2), the present value (PV) of the project if the firm invests immediately increases. On the other hand, the option value to delay investment is also larger due to the following two effects. First, the PV of the project increases, which is analogous to an increase in the underlying asset value of the option to delay investment. Second, the probability to exercise the option also increases with the growth rate. As a result, it is optimal for the firm to delay investment since the increase in the option value outweighs the magnitude of the increase in the PV of project, according to Eq. (B1), and thus it is not worth giving up the valuable option to exchange for gain of the PV for the investment project.

Intuitively speaking, when a firm possesses a valuable option to delay investment, it advances (postpones) the time to exercise the option if the firm expects that the cashflows will grow slower (faster) in the future. In other words, the firm will wait until the expected PV of investment, V_H, is larger; or equivalently, the firm revises up its hurdle rate, γ_H, when the firm expects the grow rate of the investment project to be larger.

Proposition II (*Cashflow volatility, expected growth rate of cashflows and investment*): The positive relation between the growth rate of project cash-flows and the investment trigger / hurdle rate will be magnified (less significant) when the cash-flow volatility is higher (lower).

The reason for the result outlined in Proposition II is as follows. Consider an extreme case under which the investment project generates almost certain cash-flows, i.e., the volatility of the cash-flows of the investment project is extremely low. Now suppose that, e.g., the firm expects the cash-flows of the investment project will grow faster, i.e., α is larger. The firm will postpone the time to engage in the project; or equivalently, the firm raises its investment trigger, V_H, because a higher growth rate increases the option value to delay investment with a larger magnitude than that the increase in the PV of the cash-flows of the project, according to Proposition I. However, for this nearly certain investment project, the increase in the option value to delay investment, and thus the increase in the investment trigger are relatively small because the option value decreases with cash-flow volatility. By contrast, one can expect that when σ is larger, the above positive relation between α and V_H will be more significant.

Similar arguments can be applied to the relation between expected growth rate of project cash-flows, α, and the hurdle rate, γ_H, since both Eqs. (4) and (4)' are derived under the same investment rule which emphasizes the option value to delay investment, as shown in Appendix A. Using both propositions in this sub-section, I can then investigate the main research question in this article, i.e., how accounting conservatism affects the investment strategies of a firm, and thus the agency costs of equity, in the following section of this article.

2.2 Investment timing strategies when the manager possesses private information regarding the value of the investment project

The first-best (FB) strategy of investment which maximizes equity value, as described in the previous subsection, is highly unlikely to be implemented in practice. This is because, the manager may possess information advantage regarding the key determinants which influence the value of the investment project. In other words, for a high chance that the manager is more informed than shareholders of the firm. We assume that there is conflict of interests between the manager and sharesholders due to information asymmetry. Therefore, in the real world, a firm tends to conduct the second-best (SB) investment strategy as described in this subsection.

To differentiate the SB strategy from the FB investment criterion, I employ an assumption in regards to the manager's private information in the following. Now suppose that the expected growth rate of the project cashflows, α, is uncertain with two possible values, α_D or α_U, denoting for a low or high growth rate with the probability p or $(1-p)$, respectively. I then redefine the expected growth rate of project cash-flows, α in Eq. (1), to be a weighted average of the above two possible values as expressed as:

$$\alpha = \bar{\alpha} = p\alpha_D + (1-p)\alpha_U . \tag{6}$$

The firm conducts the FB strategy after the firm learns the value of α to be α_D or α_U. In other words, when there is no information asymmetry between the manager and sharesholders, on average, the firm invests *as if* the growth rate of project cashflows is α. This strategy, at least *ex-ante*, yields the same conclusion as the FB solution in last subsection.

However, when there are conflict of interests between the manager and shareholders of the firm, I assume that only the manager can privately observe whether the value of α is α_D or α_U. By contrast, the firm's shareholders only possess the information regarding the two possible values of α. As a result, the manager tends to report to shareholders that the expected growth rate of the project cashflows is α_D, so as to start receiving the variable component of his gross salary, $m_1 C(t)$. I call this the second-best (SB) strategy since the firm will speed up the investment as compared to the FB strategy; since as implied by Proposition I in Section 2.1, the firm should invest earlier when the growth rate of cash-flows is expected to α_D, which is smaller than $\bar{\alpha}$, i.e., the expected growth rate of project cash-flows when a firm implements the FB strategy.

In theory, shareholders of the firm can simply raise the compensation so as to induce the manager to report the true expected growth rate. That is, shareholders should compensate the manager when she reports the expected growth rate of cash-flows to be α_U. The pecuniary compensation should be amounted to offset the manager's utility loss when she truthfully reports α_U; i.e., it should make the manager indifferent between "reporting α_D so as to start receiving the variable component of salary early", and "truthfully reporting α_U and obtaining a reward for revealing her private information".[5] However, in this study I suppose that the shareholders do not incur any compensation/auditing costs to design the truth-telling mechanism as stated above mainly because in practice it is difficult to distinguish the case where the manager suggests an expected growth rate which substantially deviates from the realized one simply because her judgment is poor, from the case where the manager intends to report the growth rate untruthfully. Therefore, in this study I focus on the issue that how a common practice, i.e., the conservative accounting system may align the interests of both the manager and the shareholders of the firm since under this accounting policy, shareholders of a firm require the manager to follow certain accounting criteria for cost/benefit recognition.

After the firm adopts the accounting conservation policy, the manager is obliged to recognize unfavorable costs early, and postpone the recognition of favorable revenues. I further assume that the firm can neglect the extra lump-sum costs to apply for conservative accounting policy since the firm incurs costs/revenues as frequently as before the firm adopting the new system. However, after the firm adopts accounting conservatism system, shareholders change their perception regarding the growth rate of project cashflows to be either $\alpha_D + d$ or $\alpha_U + d$, where $d > 0$. I.e., shareholders perceive that the growth rate of the investment project should be higher since now on the one hand, the firm postpones the recognition on revenues to the future and thus push up the expected growth rate of project cash-flows. On the other hand, the expected (future) growth rate becomes higher since firm recognizes costs early.

Under accounting conservatism system, shareholders of the firm will only accept

[5] It is also possible to design a mechanism, e.g., incur some auditing cost to induce the manager to truthfully reveal her private information (see, e.g., Shibata (2009) which assumes a manager reports the true investment costs if her company applies a well-designed auditing structure).

the manager to report that the growth rate of project cash-flows to be $\alpha_D + d$. According to Proposition I, the firm will then invest earlier than when it conducts the FB strategy, but later than when the firm conducts the SB strategy. I refer to this investment rule the Adjusted-second-best (ASB) strategy.[6] Apparently, although ASB strategy deviates from the FB solution which maximizes the equity value of the firm, the distortion in investment is smaller than when the firm conducts the SB strategy.

The deviation from the FB solution of investment is due from the information asymmetry between the manager and shareholders of the firm. I can then define this agency costs of equity as the difference between investment triggers, i.e., *AC*(SB) = $(1-p)(V_H\big|_{\alpha=\alpha_U} - V_H\big|_{\alpha=\alpha_D})$[7] for the case when the firm conducts the SB strategy, and *AC*(ASB) = $(V_H\big|_{\alpha=\alpha_U} - V_H\big|_{\alpha=(\alpha_D+d)}) - p(V_H\big|_{\alpha=\alpha_U} - V_H\big|_{\alpha=\alpha_D})$[8] for the case when the firm conducts the ASB strategy, respectively. It is obvious that the agency costs the firm incurs will be smaller when the firm conducts the ASB strategy, as compared to when it conducts the SB strategy. In other words, *accounting conservatism reduces the agency costs of equity*. Moreover, an alternative measure for the agency costs is to compare the hurdles rates (γ_H) the firm employ when adopting strategies deviated from the FB strategy.[9] The conclusion will remain the same since according to Proposition I in Section 2.2, both the investment trigger of the firm, V_H, and the hurdle rate, γ_H, increase with the expected growth rate of project cash-flows, α.

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[6] I also assume that d < (1-p) (α_U - α_D) to prevent from an extreme case that the accounting conservatism may cause the firm to under-invest; i.e., it invests later than the FB strategy.

[7] I.e., the difference between the investment triggers of the *ex-post* FB strategy, $p\,V_H\big|_{\alpha=\alpha_D} + (1-p)V_H\big|_{\alpha=\alpha_U}$; and the SB strategy, $V_H\big|_{\alpha=\alpha_D}$.

[8] Similar to Footnote 7, I use the ex-post FB strategy as the benchmark case for measuring the agency costs of equity. *AC*(ASB) is positive under the assumption of Footnote 6.

[9] One can easily obtain the alternative definitions for the agency costs using the hurdle rates as the measurement by substituting all V_H in the definitions of the agency costs with γ_H, respectively.

Although Proposition II implies that a higher cash-flow volatility magnifies the impact of the expected growth rate of cash-flows on the investment timing trigger/hurdle rate, it is still unclear that how the size of cash-flow uncertainty affects the relation between accounting conservatism and agency costs of equity, since we need to compare the magnitude of the agency costs when the firm conducts the ASB strategy, with the case where the firm conducts the SB strategy, taking the FB strategy as the benchmark reference. I thus need to use a numerical example to investigate this issue in the following section.

3. Numerical analysis, discussions and the conclusion

I employ plausible variable values as shown in Table 1 so as to contrast different investment strategies of a firm, i.e., first-best (FB), second-best (SB) and adjusted-second-best (ASB) investment rules and report the results in Panel A of Table 2. In Table 2 I also show how conducting the ASB strategy helps a firm reduce its agency cost of equity, and then demonstrate how an increase in the volatility of expected growth rate of project cash-flows, σ, affects magnitude of the reduction on agency costs in both Figure 1 and all Panels of Table 2. At last, by employing the benchmark parameter values as shown in Table 1, I generate a possible evolution of the cash-flow rates of an investment project in Figure 2 so as to show a special case under which a firm chooses different timings when conducting the above three investment strategies, before I offer a conclusion to this article.

Tables 1 and 2 here

Substituting all central-case parameter values as shown in Table 1 into Eqs. (4)

and (4)’, respectively, yields three different investment triggers and their associated hurdle rates as shown in Panel A of Table 2. First, the numerical results in Panel A are consistent with Proposition I which indicates that both the investment triggers and hurdle rates of a firm increase with the expected growth rate of cash-flows of the investment project, i.e., both V_H and γ_H increase with α. Second, it shows that accounting conservatism mitigates the agency problems between the manager and shareholders of a firm since the values of V_H(ASB) and γ_H(ASB) lie between V_H(FB) and V_H(SB), and between γ_H (FB) and γ_H(SB), respectively.

My numerical results of investment hurdle rates for conducting SB and ASB strategies are in line with the empirical findings of Chen, Hu and Lin (2013). Using the general method of moments (GMM) after controlling for relevant variables which also affect the investment decision of a firm, Chen et al. (2013) shows that American public listed firms[10] which apply for accounting conservatism (i.e., analogous to firms adopting the ASB strategy in my model) tend to have higher investment hurdle rates, as compared to firms do not apply for the conservative accounting system (i.e., firms adopting the SB strategy). In other words, their empirical results also imply that accounting conservatism reduces the agency costs of equity.

For my purpose to compare firms adopting accounting conservatism with those without adopting the system, I define a ratio of the agency costs when a firm conducts the ASB strategy, to the agency cost when a firm conducts the SB strategy, i.e., AC(ASB)/AC(SB) by either employing the comparison between the investment triggers or between the hurdle rates, i.e., (V_H(FB) -V_H(ASB) / (V_H(FB) -V_H(SB)) or (γ_H(FB)-γ_H(ASB)/(γ_H(FB)-γ_H(SB)). Using these definitions, Panel A of Table 2 shows that, under the central case where the volatility rate of project cash-flows, σ,

[10] Their sample includes firms listed on the NYSE, AMEX and NASDAQ exchanges during 1982-2009.

is 30% per year, a firm applying the ASB strategy only incurs 56.94% (53.94%) agency costs of equity, when using the investment triggers (hurdle rates) as the measurement, while taking the case where a firm conducts the SB strategy as the reference for comparison. In other words, consistent with the theoretical prediction in Section 2, *accounting conservatism reduces the agency costs of equity*.

Figure 1 here

It is also worth investigating whether a change in the cash-flow volatility affects the above impact of accounting conservatism on the agency costs of equity. I report in Panels B to E of Table 2 the cases when the volatility of the expected grow rate of project cash-flows, σ, varies from 20% to 40% per year, holding the values of all other variables as in the benchmark case as shown in Table 1. Both Table 2 and Figure 1 demonstrate the agency costs of equity of the ASB strategy decrease with the cash-flow volatility. In other words, when the business environment is more volatile, *adopting the conservative accounting system can reduce the agency costs of equity with a larger magnitude*. This result holds no matter if I measure the agency costs by using the "investment triggers" or "hurdle rates" definitions. [11]

In order to make this numerical example more vivid, I generate a hypothetical evolution of the instantaneous cash-flow rate, $C(t)$, by using Eq. (1) assuming the parameter values are held as in the central case, as shown in Table 1. I then transform various investment triggers, V_H, into their associated threshold cash-flow rates, C_H, by using Eq. (2) and report the results in Figure 2, in which I demonstrate the timing

[11] This result remains the same if I vary the volatility rate of cash-flows in the region from 0% to 60% per year.

of the above three investment strategies; i.e., FB, SB, and ASB criteria as follows. First, ideally the optimal *ex-post* investment strategy for a firm is not to engage in the project until the cash-flow rate, $C(t)$, reaches \$0.21872 ($> C_H$ (FB), \$0.2178); this is equivalent to that the firm waits for 11.90 months to invest if the initial cash-flow rate, $C(0)$, is \$0.136.[12] As discussed in Section 2, the firm conducts the "FB" strategy when both the manager and equityholders share the same information regarding the true value of the expected growth rate of project cash-flows, α, to be either α_D (= -1%) or α_U (= 1%), and act to maximize the equity value of the firm after the revelation of α. By contrast, the firm will conduct the "SB" strategy when the manager has the information advantage over shareholders of the firm. That is, the firm invests when $C(t)$ reaches \$0.20952 ($> C_H$ (SB), \$0.2093), or it invests after 9.07 months starting from now (Time 0). As compared to the FB rule of investment, the firm is induced to "overinvest" (i.e., invest "too early") since the manager reports to shareholders the minimum possible value of α, α_D = -1%.

Figure 2 here

Figure 2 also shows that the firm will conduct the "ASB" strategy after the firm applies for the accounting conservatism system, since the shareholders perceive that the minimum possible value of α to be $\alpha_D + d$ = -0.5%. As a result, the firm will then invest when $C(t)$ reaches \$0.2146 ($> C_H$ (ASB), \$0.2093), or it waits for 10.98 months to invest because the shareholders only accept the manager to report the

[12] The firm should have invested when $C(t)$ is \$0.1333 had it follow the NPV rule to invest immediately when the PV of investment equals the up-front investment cost, \$1. I do not show this case in the Figures as the initial instantaneous cash-flow rate of the benchmark numerical case is set to be \$0.136.

expected cash-flow rate to be -0.5%. Although the firm still overinvests when conducting the ASB strategy, it incurs smaller agency costs of equity since the time discrepancy between ASB and FB investment strategies (i.e., 0.92 months), is shorter than that between the SB and FB strategies (i.e., 2.83 months).

In sum, I obtain two main results from my model. First, it shows that the application of accounting conservatism reduces the agency costs of equity since the system requires the manager of a firm to adjust the recognition of accounting revenues/costs, which induces the manager to report his private information more truthfully when she possesses information advantage over the shareholders.

Secondly, my simulation analysis indicates that the above effect is even more profound when the cash-flows of the investment project are more volatile. An intuitive explanation for this phenomenon can be derived from Proposition II: the impact of a change in the expected growth rate of project cash-flows is more significant when the volatility of the project cash-flows is larger. As a result, the adoption of accounting conservatism can induce a larger reduction on the agency costs when the firm operating a highly uncertain environment. This effect, however, requires further investigations by employing more in-depth empirical studies.

Table 1: Benchmark variable values in the numerical analysis

Variable values		Denotations
ρ =	12%	Risk-adjusted rate
r =	8%	Risk-free rate
α_D =	-1%	Minimum expected growth rate of the instantaneous cash flow of investment, $C(t)$
p =	50%	The probability that the project has the minimum growth rate
α_U =	1%	Maximum expected growth rate of the project cash-flows
α =	0%	Average expected growth rate of the project cash-flows
$\alpha_D + d$ =	-0.5%	Minimum expected growth rate of the project with accounting conservatism
δ =	12%	Dividend yield, the difference between risk-adjusted rate and the expected growth rate of project cash-flows
σ =	30%	Volatility of the growth rate of project cash-flows
m_1 =	10%	Incentive salary rate to the manager
K =	\$1	The up-front investment cost for the discrete project
$C(0)$ =	\$0.136	The initial value of $C(t)$

Table 2: Cash-flow volatility, investment trigger / hurdle rate, and the agency costs under the conservative accounting system

A: $\sigma = 30\%$ (Benchmark case)	V_H	γ_H	Agency cost (%) for the ASB strategy*
SB	\$ 1.5694	19.40%	
ASB	\$ 1.6000	19.50%	56.94% (53.94%)
FB	\$ 1.6404	19.61%	
B: $\sigma = 20\%$	V_H	γ_H	Agency cost (%)
SB	\$ 1.2935	15.82%	
ASB	\$ 1.3123	15.90%	58.08% (55.81%)
FB	\$ 1.3384	16.02%	
C: $\sigma = 25\%$	V_H	γ_H	Agency cost (%)
SB	\$ 1.4235	17.50%	
ASB	\$ 1.4480	17.60%	57.37% (54.70%)
FB	\$ 1.4811	17.72%	
D: $\sigma = 35\%$	V_H	γ_H	Agency cost (%)
SB	\$ 1.7310	21.50%	
ASB	\$ 1.7680	21.60%	56.66% (53.38%)
FB	\$ 1.8163	21.71%	
E: $\sigma = 40\%$	V_H	γ_H	Agency cost (%)
SB	\$ 1.9083	23.81%	
ASB	\$ 1.9522	23.90 %	56.47% (52.95%)
FB	\$ 2.0091	24.01%	

* These percentages represent the ratio of the agency costs when a firm conducts the ASB strategy to the agency costs when a firm conducts the SB strategy, using the investment triggers (hurdle rates) to measure the above agency costs, i.e., *AC*(ASB)/*AC*(SB), where details of the two agency costs were defined in Section 2.2.

Figure 1: FB/SB/ASB investment triggers when the cash-flow volatility, σ, varies from 20% to 40%

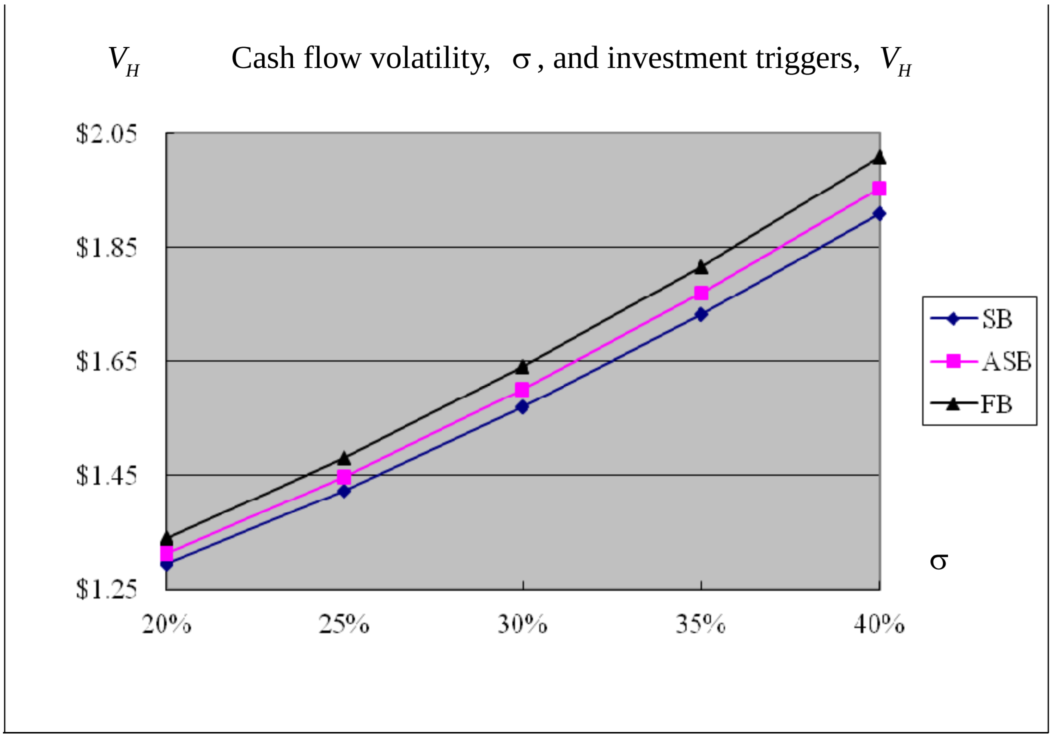
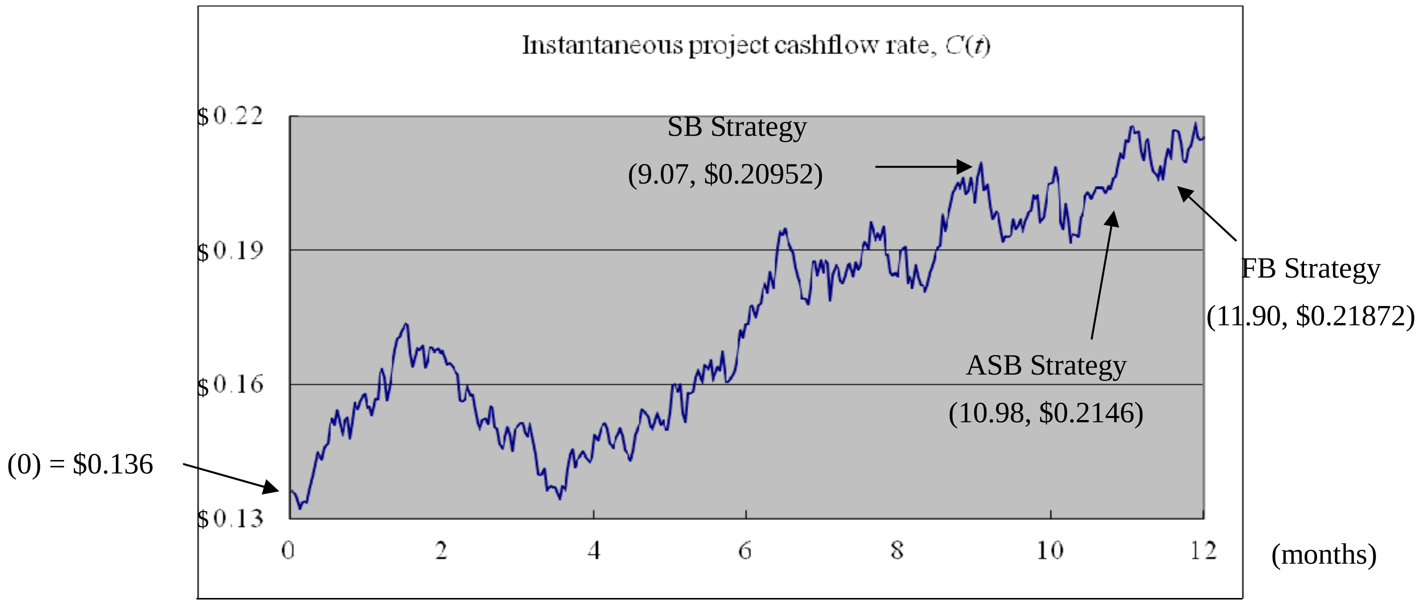


Figure 2: FB/SB/ASB Strategies when the volatility rate of project cash-flows, σ, is 30%



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Appendix A: Derivation of Eqs. (4) and (4)'

Suppose that $F(V)$ denotes for the firm's option value to delay investment, which is analogous to the value of a perpetual dividend-paying financial call option. Applying Itô's lemma and using the standard risk-neutral valuation arguments (Dixit and Pindyck, 1994), we obtain the following differential equation for the option value of delaying investment, $F(V)$:

$$\alpha V \frac{\partial F(V)}{\partial V} + \frac{1}{2}\sigma^2 V^2 \frac{\partial^2 F(V)}{\partial V^2} - rF(V) = 0. \tag{A1}$$

An intuitive interpretation to Eq. (A1) is that if we treat $F(V)$ as an asset value, then the expected appreciation on this asset, the first two terms on the LHS of Eq. (A1), should be equal to the normal return on the asset, $rF(V)$, the absolute value of the third term on the LHS of Eq. (A1).

The general solution of Eq. (A1) is given by:

$$F(V) = a_1 V^{\beta_1} + a_2 V^{\beta_2}, \tag{A2}$$

where a_1 and a_2 are constants to be determined, β_1 is defined in Eq. (5) in the main text of this article, and

$$\beta_2 = (\frac{1}{2} - \frac{r-\delta}{\sigma^2}) - \sqrt{(\frac{1}{2} - \frac{r-\delta}{\sigma^2})^2 + \frac{2r}{\sigma^2}} < 0. \tag{A3}$$

Suppose that V_H denotes for the critical value of the firm which triggers investment. We can then solve for V_H, together with the two constants, a_1 and a_2 in Eq. (A2), by using the boundary conditions as follows:

$$\lim_{V \to 0} F(V) = 0, \tag{A4}$$

$$F(V_H) = V_H - K, \tag{A5}$$

$$\frac{\partial F(V)}{\partial V}\Big|_{V=V_H} = 1. \tag{A6}$$

Eq. (A4) states that the option value to delay investment, $F(V)$, becomes worthless as the gross value from investment, V, approaches its minimum permissible value zero. Eq. (A5) is the "value-matching" condition stating that at the optimal timing of investment, the firm should be indifferent between remaining waiting or investing immediately. Eq. (A6) is the "smooth-pasting" condition which prevents the firm from obtaining any arbitrage profits. Solving Eqs. (A4) to (A6) simultaneously yields the investment trigger, V_H, in Eq. (4) in the main text.

Another way to express the investment strategy is to find the hurdle rate associated with V_H in Eq. (4) as follows. According to Eq. (2), if the firm invests immediately when the net present value (NPV) of investment equals zero, i.e., by following the NPV rule, it invests when the gross value of the firm:

$$V = K = (1 - m_1)\frac{C}{(\rho - \alpha)}, \tag{2)'$$

where ρ denotes for the hurdle rate of investment following the NPV rule. However, as indicated by Eq. (4) in the main text, the firm should invest when $V = V_H$ instead, since it owns an option to delay invest. This implies that the firm should revise its investment trigger to $V = V_H$ by multiplying V in Eq. (2)' with the "option value multiple", $\beta_1/(\beta_1 - 1)$, as shown by:

$$V_H = \frac{\beta_1}{(\beta_1 - 1)}K = (1 - m_1)\frac{\beta_1}{(\beta_1 - 1)}\frac{C_H}{(\gamma_H - \alpha)}, \tag{2)''$$

where C_H and γ_H denote for the respective instantaneous cashflows rate and hurdle rate which are associated with the revised investment trigger, V_H.

Substituting the proportion between any V and C, as indicated in Eq. (2)' i.e., $V_H / C_H = (1 - m_1)/(\rho - \alpha)$, into Eq. (2)'' and rearranging terms yield γ_H as shown in Eq. (4)' in the main text. **Q.E.D.**

Appendix B: Proof of Proposition I

For ease of exhibition, I use b_1 to denote for $(\frac{1}{2} - \frac{(r - \delta)}{\sigma^2})$ in the following. Partially differentiating V_H in Eq. (4) w.r.t. α yields:

$$\frac{\partial V_H}{\partial \alpha} = \frac{-1}{(\beta_1 - 1)^2} \frac{\partial \beta_1}{\partial \alpha} > 0, \quad \text{(B1)}$$

since $\frac{\partial \beta_1}{\partial \alpha} = \frac{\partial b_1}{\partial \alpha}(1 + b_1(b_1^2 + \frac{2r}{\sigma^2})^{\frac{-1}{2}}) < 0$ as $\frac{\partial b_1}{\partial \alpha} = -\frac{1}{\sigma^2} < 0$.

Partially differentiating γ_H in Eq. (4)' w.r.t. α yields:

$$\frac{\partial \gamma_H}{\partial \alpha} = \underset{(-)}{(1 - \frac{\beta_1}{(\beta_1 - 1)})} + \underset{(+)}{\delta \cdot \frac{\partial V_H}{\partial \alpha}}, \quad \text{(B2)}$$

where $\delta = (\rho - \alpha) > 0$.

The sign of Eq. (B2) is positive although the first term on the RHS is negative. This is because, e.g., when the volatility rate of the expected growth of project cash-flows, σ, approaches infinity, the first term on the RHS of Eq. (B2) reaches its smallest permissible value as the option value multiple, $\beta_1 / (\beta_1 - 1)$, approaches its largest permissible value. However, $\partial V_H / \partial \alpha$ in the second term on the RHS of Eq. (B2) approaches infinity when σ approaches infinity since β_1 approaches one. As a result, the second (positive) effect thus more than offsets the first (negative) effect on the RHS of Eq. (B2). **Q.E.D.**