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# A Case Study of Investor R&D Evaluation using Game Theory

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## Abstract

This paper aims to identify an optimal investment strategy in cases of high-intensity R&D private micro entities. A game theory matrix is constructed using publicly available empirical data extracted from the financial statements of an R&D-intensive private micro-entity. The game theory matrix attempts to estimate the effect of the discretionary managerial choice to capitalise or expense the development cost of internally generated intangible assets; investors' risk appetite could be affected by the capitalisation signalling. The investment strategies are classified based on their risk into three categories. High risk is represented by equity. Medium risk is represented by long-term debt, and low risk is represented by short-term debt. The game theory matrix results indicate that in similar situations, the dominant strategy is the medium-risk approach through long-term debt. This strategy must be confirmed by solving more game theory matrices based on similar R&D-intensive firms. However, it is an easily constructed advisory indicator for retail investors considering investing in unaudited small private entities. They could use it to identify an optimal investment strategy when uncertain of the genuine intangible asset prospects signaled via development cost capitalization.

**Keywords:** intangibles; investment; strategy; matrices; R&D; capitalisation

**JEL classification:** G32, M21

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## Introduction

Research and development expenses are essential when innovating; however, according to Dugar and Pozharny (2021), the global accounting standards fail to capture the full value of R&D, thus resulting in an understatement of their value in the financial statements. Penman (2009), on the other hand, supports that the income statement can provide all the necessary information regarding internally generated intangibles without compromising the quality of the information while at the same time mitigating any risks deriving from asset capitalization.

Using game theory, this paper attempts to identify the most sensible investment strategy in entities primarily engaged in R&D activities. The data is empirical, and the investors' decision is evaluated in retrospect since events have already transpired; however, the optimal strategy for similar situations is identified based on those events. The three different strategies from the investors' perspective are low risk, medium risk, and high risk, expressed by short-term debt, long-term debt, and equity accordingly. Contrarily, management has a binary decision to make, which is to either capitalise on the development cost or to expense it.

The entity's management aims to secure as much capital as possible with the best terms for the entity; on the flip side, the investors aim to maximize their profit while assuming a reasonable amount of risk attributed to possible future gains. Although the two-game theory "players" are not directly competing with each other, indirectly, their agendas might differ regarding the success or failure of an R&D project. The entity investigated in the case study is a private micro entity based in the UK operating in the industry sector described as "other research and experimental development on natural sciences and engineering"; the corresponding SIC is 72190.

Dugar and Pozharny (2021) researched the value relevance of R&D expenses in the US and internationally. They concluded that current financial standards do not accurately estimate R&D-related activities. The results differed over time and for different industries, but the main conclusion was that "intangible capital intensity is related to changes in the value relevance of earnings and book value". That was their explanation for cross-sectional variation in stock price from 1994 to 2019 regarding the companies in their global sample. Also, the decline in the combined value relevance of earnings and book value was confirmed for the high-intangible intensity group in the US and internationally. No such decline was verified for companies in the low-intangible-intensity group.

One view regarding the financing of R&D during the creation of intangible assets hypothesises that when asset values are opaque to the external environment of the entity developing the asset, the use of debt is preferable, and the issuance of equity comes only out of necessity. On the other hand, such asymmetric information regarding the asset under development could raise investment risk, meaning increased debt issuance costs. As a result, equity will be issued to avoid those elevated debt issuance costs (Gatchev et al., 2009). Clausen and Hirth (2016) point out that without any capitalization of intangible assets, there would be no option to collateralize internally generated patents. Using intangible assets as collateral involves a certain risk, especially since the number of patents owned or successful patent applications does not necessarily indicate value.

According to Gatchev et al. (2009), entities choose to finance their projects on intangible asset development with equity rather than debt since these projects are characterized by high informational opaqueness, leading to high debt issuance costs. To finance 1\$ worth of R&D, 0,8\$ in equity is issued, and 0,26\$ in short and long-term debt. In terms of information asymmetries related to R&D projects, Gong and

Wang (2016) make a similar argument by stating that managers are better informed about the outputs of the projects than anyone from the entity's external environment. Also, they point out that IFRS allows managers to decide whether to capitalize on or expense development costs. Such a practice could lead to earnings management. If managers wanted to show higher earnings to shareholders, they would capitalize, and if they would like to take advantage of tax returns and benefits, they would expense. Within such a context, investors would disregard the valuation of R&D after IFRS implementation. When transitioning from a mandatory expense or capitalization framework to IFRS, the impact on value relevance is greater when a more robust investor protection regulation is present. The institutional factors play an important role as far as value relevance is concerned; convergence to a common financial reporting framework is not enough on its own. Ciftci and Zhou (2014) have found that high-patent entities with more successful innovations prefer the disclosure of patent information to asset capitalization as long as their legal environment provides sufficient intellectual property protection. Investor protection and intellectual property protection contribute to more information dissemination, information that would otherwise be available only to managers.

## Methodology

The case subject company was incorporated in 2002, and the game matrix was constructed using the financial statements from 2002 until 2015. The financial statements were downloaded from the UK Companies House (2021) is abbreviated, unaudited, and prepared following the financial reporting standard for small entities FRS 105 (ICAEW, 2021). The standard was amended in 2002, 2008, and 2016 within the relevant time frame, requiring the expense of all costs related to internally generated intangible assets according to the most recent amendment. However, capitalization was allowed and implemented from 2007, 2008, and 2011 to 2015. Understandably it would be preferable to construct the game matrix using internal information such as debt yields; however, this game matrix becomes more realistic by using only the information available to an external nonaccredited retail investor who wishes to choose an optimal strategy based on the game's solution.

Every game matrix needs to have a set of rules, so the following assumptions and concessions are necessary:

First, due to the entity's activity, investing in it involves a high amount of uncertainty and, consequently, risk; the directors of the company state in the notes to the financial statements that "the company is supported by its creditors who are aware that the company may not be able to pay its debts until the benefit of its research and development crystallizes". This, on its own, is an admittance that conducting R&D is the main driver of the company's value and income generation source.

Second, this is a private company, unlisted by default, so the investor protection framework regarding regulated market participants is not applicable.

Third: The game matrix focuses on the investors' strategy decision regarding the risk they are willing to assume under two different intangible asset value reporting schemes, expense or capitalization. No other factors affect their decision since the company's primary objective is, by definition, its activity to generate intangibles through R&D; any other factor is secondary and irrelevant to the game's solution.

Fourth, the investor profile is unknown, and as such, the game's solution will provide a dominant strategy or a mixed strategy irrelevant to the investor profile, the only information available from the annual return is that some of the shareholders are also directors of the company which is to be expected in a private company.

The mixed strategy can combine only two investment strategies since mixed strategies can only be calculated on a 2\*2 matrix.

Fifth, the following investment options are available to any interested investor: equity, long-term, or short-term debt. Practically, commercial banks and such institutions avoid direct investments in equity because they usually prefer debt which involves collateral or at least the right to charge assets of any kind; also, there might be regulatory constraints. However, although direct equity exposure is uncommon, commercial banks can gain exposure to equity investment through affiliated firms such as venture capitalists or investment funds.

Lastly, the three investment options are classified according to their risk in descending order; equity is the high-risk strategy, long-term debt is the medium-risk strategy, and short-term debt is the low-risk strategy. Such a classification is consistent with mainstream investment theory, which considers volatility and yield as indicators of risk (Vasiliou et al., 2009).

## Results

Table 1 below contains the raw data in a suitable format for constructing the game matrix.

Table 1

Extracted Formatted Data

<b>HUDOL LIMITED Private limited Company SIC 72190 - Other research and experimental development on natural sciences and engineering</b>					
<b>Capitalization Indicator</b>	<b>Year</b>	<b>Equity</b>	<b>Long Term Debt</b>	<b>Short Term Debt</b>	<b>Debt /equity</b>
EX	2002	£230,00	£32.681,00	£33.738,00	288,78
EX	2003	£230,00	£32.681,00	£11.328,00	191,34
EX	2004	£230,00	£32.681,00	£43.740,00	332,27
EX	2005	£230,00	£23.837,00	£80.057,00	451,71
EX	2006	£17.050,00	£29.037,00	£87.756,00	6,85
CAP	2007	£20.051,00	£29.037,00	£92.519,00	6,06
EX	2008	£20.051,00	£85.079,00	£105.181,00	9,49
EX	2009	£20.051,00	£200.511,00	£114.307,00	15,70
EX	2010	£20.051,00	£242.084,00	£64.829,00	15,31
CAP	2011	£20.051,00	£229.629,00	£52.490,00	14,07
CAP	2012	£20.051,00	£181.866,00	£112.422,00	14,68
CAP	2013	£41.851,00	£173.903,00	£97.005,00	6,47
CAP	2014	£41.851,00	£163.940,00	£108.176,00	6,50
CAP	2015	£41.851,00	£153.977,00	£118.142,00	6,50
<b>Total time-frame avg.</b>		£18.844,93	£115.067,36	£80.120,71	97,55
<b>Expenditure Annual Average</b>		£9.765,38	£84.823,88	£67.617,00	163,93
<b>Capitalization Annual Average</b>		£30.951,00	£155.392,00	£96.792,33	9,05
<b>Standard deviation EX</b>		10117,49	86239,62	40480,73	174,63
<b>Standard deviation CAP</b>		11940,35	67223,98	23709,43	4,13

Note: The annual averages of each of the three investment options are calculated for each corresponding managerial decision regarding the capitalisation of development costs

Source: Author's work

The average sums of investment funds have been calculated for the years during which development costs were expensed and for the years during which development costs were capitalized. At first glance, it is obvious that the entity is funded mainly by long-term debt, short-term debt, and equity. The debt-to-equity ratio skyrocketed during the initial years of the project when costs were mostly expensed, probably because of early-stage research. On the contrary, equity raises

are significant when capitalization comes into effect later, and then equity stabilizes during the last three years of the relevant time frame. The point here is exactly the shift in narrative expressed through development cost capitalization while exiting the research expense-only stage. On average, it is obvious that during the capitalization era, the entity manages to raise significantly more funds from equity while, at the same time, long-term debt is rising as if a signal was emitted calling investors to enter a “risk on” mode. The origin of the amassed long-term debt is not entirely certain; it could be new loans, a restructuring of short-term loans, or an increase from restructured default payments. The standard deviation is significantly higher than the average in the case of equity and long-term debt during the expense era, which indicates a rather noticeable diversity in terms of volatility.

The game matrix below is a 3\*2 matrix where the two columns represent the development cost treatment methods and the rows of the three different investment strategies classified by risk. The averages presented in Table 1 are being used as matrix values. The next step requires calculating the rows' maximum and minimum values and the columns' minimum and maximum values. When the calculated two numbers are the same, the game has a saddle point indicating the existence of a dominant strategy. If the game had no saddle point, it would be reconfigured as a 2\*2 matrix, and a more complex set of calculations would provide a mixed strategy based on possibilities. In this game, a saddle point dictates a dominant strategy. As a result, investing in long-term debt is the dominant strategy for investors in this entity. The dominant strategy means investing in long-term debt is the best option for an investor, regardless of the intangible asset development cost accounting treatment selected by the entity's management. Table 2 presents Game Matrix.

Table 2  
Game Matrix

HUDOL LIMITED Private limited Company SIC 72190 - Other research and experimental development on natural sciences and engineering						
Phase 1 Dominant Strategy		DEVELOPMENT COST TREATMENT			row maxi-min	£84.823,88
		EXPENSE	CAPITALIZE			
Investor decision (private, retail-investor commercial bank, etc.)	High risk (equity)	£9.765,38	£30.951,00		£9.765,38	
	Medium risk (LT-debt)	£84.823,88	£155.392,00		£84.823,88	
	Low risk (ST-debt)	£67.617,00	£96.792,33		£67.617,00	
	column mini-max	£84.823,88	£155.392,00			
		£84.823,88				
Saddle point		Medium risk (LT-debt)				

Note: The saddle point pinpoints the prevailing strategy for the investors, which in this case is medium risk, namely long-term debt; Source: Author's work

## Discussion

The matrix results show that, in this particular case, the dominant investment strategy would be exposure to long-term debt only. Just as in the case of technical analysis, historical data is used to construct instruments and indicators that assist in creating future performance projections, the game theory matrix utilizes past investor decisions to determine a future strategy.

A significant amount of information asymmetry affects the result of the game matrix. However, this is an expected trade-off between predictive accuracy and practicality associated with the simplicity of the matrix's construction. The fundamental principle is that a non-sophisticated retail investor can rely on past decisions of institutional and accredited investors equipped with the resources and knowledge to make a better-informed decision regarding the investment in a high-risk private entity. Thus, the quality of the due diligence conducted on the private entity's R&D potential by sophisticated investors determines the quality of the matrix's solution indicating the suggested dominant strategy.

Admittedly, the underlying information asymmetry is troubling; however, the lack of more cost-efficient instruments and the game theory matrix's practicality, which translates into a dominant strategy after a simple data input, qualifies the game theory matrix as a practical estimative tool when it comes to investing in R&D intensive private entities.

As always, an investor should not rely solely on any instrument or indicator; instead, the potential investor should do as much research as possible before assuming any risk. In this broad research context, the game theory matrix presented in this case study could be one of the tools used to define the optimal investment strategy, given that such a strategy exists.

## Conclusion

The result of the game theory matrix in the case study presented in this paper is that long-term debt is the most appropriate option when investing in R&D-intensive entities; the game's preset parameters always constrain it explained in the methodology section. Specifically, the rule set mentioned in the methodology section describes the assumptions of the game matrix. The literature on this issue supports that equity seems to be the best option in cases where development costs are mostly expensed, and disclosures are limited. This happens because debt issuance costs are high, and there is nothing valuable enough to serve as collateral when disclosures are limited and internally generated intangible assets are not capitalised. The debt issuance cost factor is not addressed directly by the game matrix; it is considered a factor in the managerial decision regarding the capitalisation or expense of development costs. However, in the presented case study, the entity alternates the development cost accounting treatment for a different number of reasons which are not disclosed in the financial statements; also, as mentioned in the fifth rule of the game, all three investment options are available to investors. The literature focuses more on the capital demand side of the market and less on the capital supply. So, assuming that under IFRS, the treatment of development cost remains static is not entirely accurate and choosing the preferable funding method, from the entity's perspective, is not always realistic; especially considering the management's discretionary decision regarding the imminent success or failure of projects that are under development. According to management, capitalization could be suitable for project A but not for project B, and investors might be willing to lend capital but not buy shares. The game matrix recognises the investor side as the predominant capital market force.

This is probably the main limitation of the investigated case presented here; however, in table 1, there seems to be a noticeable influence on investors by the signalling caused by the capitalisation of development costs. Of course, given that the matrix does not consider other factors that could have influenced investors' risk appetite, as well as debt accumulation and restructuring, it requires further confirmation. These other factors are additional limitations that could be addressed,

to a certain degree, by conducting similar game theory experiments using entities within the same industry sector and, ideally, partner or linked entities with similar managerial principles. If multiple matrix solutions would coincide, perhaps a best-suited investment strategy or risk trend could be identified. This does not imply an ideal strategy for all situations involving R&D-intensive investments; solving a similar game matrix could provide a generally accepted strategy with an acceptable risk trade-off, assisting retail investors without privileged information or R&D-focused knowledge.

By outlining a dominant strategy in situations where the investment is defined as high-risk R&D intensive, combined with data scarcity and information asymmetry; a project's "liminal" stage between research and development, which hinges on the managerial decision of capitalization or expense, could be neutralized by making that decision irrelevant.

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