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OPTIMISING INVESTMENT DECISIONS IN R&D INTENSIVE PRIVATE MICRO-ENTITIES USING GAME THEORY

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ABSTRACT

In this article, three small private R&D intensive European entities have been used in a case study involving game theory combined with content analysis in an attempt to identify an optimal investment strategy. A game theory matrix is constructed for each entity based on previous exposure of investors to the entities' capital sources. The basic concept is that the investment exposure's size is affected by the capitalisation of internally generated intangible assets; in other words, investors consider capitalisation of intangible assets as a positive signal regarding the future economic benefits associated with the intangible asset, and as a result, they adjust their investment positions accordingly. The matrices aim to identify an optimal investment strategy in high-intensity R&D private micro entities.

The game theory matrices are constructed using publicly available empirical data extracted from the financial statements of three R&D intensive private micro-entities. The game theory matrix attempts to estimate the effect of the managerial discretionary choice to capitalise or expense the development cost of internally generated intangible assets; the risk appetite of investors could be affected by the capitalisation signalling. The investment strategies are classified based on their risk in 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 results of the game theory matrices indicate that if a potential investor were to select an investment strategy after the end of the investigated time frame, end of 2015 for one entity and 2016 for the other two, the dominant strategy would be a medium risk through long-term debt for one company and low risk for the other two. These dominant strategies are then evaluated ex-post by reviewing the financial positions of the entities according to the most recent financial statements and additional relevant documentation.

KEY WORDS

intangibles, investment, strategy, matrices, R&D, capitalisation

CLASSIFICATION

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INTRODUCTION

Research and development expenses are essential when innovating; however, 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 [1]. On the other hand, 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 capitalisation [2].

Some researchers seem to support the capitalisation approach, while others support conservatism, expressed through the expenditure of development-related costs [2, 3]. Indeed, capitalisation reduces information asymmetry, encourages innovation, reduces debt issuance cost and mitigates under-investment [3-6].

All these positive attributes of internally generated assets' capitalisation rely on genuine signalling, which is based on the managerial discretionary choice to capitalise on development costs. This article aims to investigate if simple game theory matrices can assist in navigating investment decisions in cases of R&D intensive private entities. The case of private entities is investigated, considering that financial data is more limited than publicly traded entities. Also, the primary factor affecting the players' decision is development cost capitalisation and its embedded signalling of project success or underlying managerial earnings manipulation [7].

The structure of the article is as follows: The next chapter describes the methodology used to construct the matrices. The second chapter explains and presents the basis of the calculations involved. The third chapter presents the entities chosen as case study subjects. Their profiles are presented along with information regarding the nature of their business and affiliations; their business and managerial ties are directly related to their eligibility as case study subjects. The fourth chapter contains the results; two tables are created for each entity. One table contains the data extracted from the financial statements in a format that can be used to create a game theory matrix. The second table per entity is the game theory matrix itself, accompanied by the solution of the game and its interpretation. At the chapter's end, another table summarises the results and contrasts them with the entities' current status to identify the results' accuracy. The final chapter contains the conclusion and a discussion regarding the article's contribution and the limitations of the game matrices.

Capitalisation of R&D expenses is contingent upon the likelihood of future economic benefits materialising, with a threshold of over 50 % probability, according to the Australian Accounting Standards Board [8]. However, measuring the inputs and outputs of intangible assets presents challenges for managers, making it difficult to match expenditures to outcomes [8] accurately. Based on the probability of future economic benefits, the discretionary decision to capitalise on development costs carries risks such as earnings management, misrepresentation, personal financial gain for managers, and potential delays in disciplinary action [7-10].

These factors indicate that the managerial decision regarding the probability of future economic benefits is a potential point of failure, which can be addressed using the income statement. R&D expenditures can be expensed while accompanied by voluntary non-financial disclosures in the financial statement notes [2, 11].

This article aims to determine the most rational investment strategy for three entities engaged in R&D activities using game theory. Empirical data is utilised, and the evaluation of investment decisions is retrospective, based on events that have already occurred within the investigated time frame. The optimal strategy is identified by considering a reasonable level of R&D progress and the management's decision to capitalise on the intangible asset after completing the research phase. For example, if an investor is considering investing in an R&D-

intensive private micro-entity in the 8th year of project development, provided that the management has chosen to capitalise the intangible asset and the research phase is finalised, the three strategies from the investors' perspective are categorised as low risk, medium risk, and high risk, represented by short-term debt, long-term debt, and equity, respectively. On the other hand, management faces a binary decision: to capitalise on the development cost or to expense it.

The entity's management aims to secure capital with favourable terms, while investors seek to maximise their profits while considering the associated risks. Although the management and investors are not in direct competition, their agendas may differ regarding the success or failure of an R&D project.

The case study focuses on private micro-entities in the U.K. operating in the industry sector of "other research and experimental development on natural sciences and engineering", categorised under SIC 72190.

A relevant research study examined the value relevance of R&D expenses in the U.S. and internationally [1]. The study concluded that current financial standards do not accurately capture the value of R&D-related activities. The results varied across time and industries, but the main finding was that "intangible capital intensity is related to changes in the value relevance of earnings and book value". This finding explained their global sample's cross-sectional variation in stock prices from 1994 to 2019. The study also confirmed a decline in the combined value relevance of earnings and book value for companies with high intangible intensity, both in the U.S. and internationally. In contrast, no such decline was observed for companies in the low-intangible-intensity group.

Regarding the financing of R&D and the creation of intangible assets, one view suggests that when the values of assets are not transparent to the external environment, debt financing is preferable, and equity issuance is only done when necessary. However, the asymmetric information associated with asset development can increase investment risk, leading to higher debt issuance costs. As a result, equity may be issued to avoid these elevated costs [5]. It is worth noting that without the capitalisation of intangible assets, there would be no option to use internally generated patents as collateral [10]. However, using intangible assets as collateral entails a certain level of risk, as the number of patents owned or successful patent applications does not necessarily indicate their value [11].

Another team of researchers suggests that entities choose to finance their intangible asset development projects with equity rather than debt due to the high informational opaqueness associated with these projects, which results in higher debt issuance costs. According to their findings, for every $1 spent on R&D, $0,8 is financed through equity issuance and $0,26 through short and long-term debt [5]. Regarding information asymmetries in R&D projects, it is argued that managers have better knowledge about the project outputs than external stakeholders [12]. Additionally, it is noted that under International Financial Reporting Standards (IFRS), managers have the discretionary right to decide whether to capitalise or expense development costs based on their estimation of the probability of future economic benefits. This practice can lead to earnings management, as managers may choose to capitalise expenses to show higher earnings to shareholders or expense them to take advantage of tax benefits. As a result, investors may disregard the valuation of R&D after implementing IFRS. When transitioning from a mandatory expense or capitalisation framework to IFRS, the impact on value relevance is more significant in the presence of robust investor protection regulations. Institutional factors play a crucial role in value relevance, and convergence to a common financial reporting framework alone is insufficient. High-patent entities with successful innovations prefer disclosing patent information rather than asset capitalisation, especially when their legal environment provides adequate intellectual property protection [13]. Investor

protection and intellectual property protection contribute to greater information dissemination, making information available to stakeholders beyond just the managers.

METHODOLOGY

In the case study, three small private R&D intensive European entities were analysed using game theory and content analysis to determine an optimal investment strategy. A game theory matrix was constructed for each entity based on investors' previous exposure to the entities' capital sources.

The main concept underlying the matrix is that the capitalisation of intangible assets influences the size of exposure. Investors perceive the capitalisation of intangible assets as a positive signal indicating potential future economic benefits associated with developing these assets. Consequently, investors adjust their investment positions based on this signal.

The game theory matrix aims to assess the impact of managerial discretion in choosing whether to capitalise or expense the development costs of internally generated intangible assets. The capitalisation decision can affect investors' risk appetite and their investment strategies. The investment strategies are categorised into three risk levels: high risk, represented by equity; medium risk, represented by long-term debt; and low risk, represented by short-term debt.

The game theory matrix is structured as a 3 × 2 matrix, with the two columns representing the treatment methods for development costs (capitalisation or expense) and the rows representing the three different investment strategies classified by risk. The values within the matrix are the averages of equity, long-term debt, and short-term debt corresponding to the expenditure under each treatment method (expense or capitalisation).

The average equity under capitalisation is expressed as

$$\bar{e_{cap}} = \frac{\sum e_{capi}}{n_{cap}}, \tag{1}$$

where $\bar{e_{cap}}$ is the average equity under capitalisation, $\sum e_{capi}$. The sum of equity for the years where intangible assets are recorded on the balance sheet and $n_{cap}$is the number of years with capitalised intangible assets.

The average long-term debt under capitalisation is expressed as

$$\bar{L_{cap}} = \frac{\sum L_{capi}}{n_{cap}}, \tag{2}$$

where $\bar{L_{cap}}$ is the average long-term debt under capitalisation, $\sum L_{capi}$ the sum of long-term debt for the years where intangible assets are recorded on the balance sheet, and n_{cap} is the number of years with capitalised intangible assets.

The average short-term debt under capitalisation is expressed as

$$\bar{S_{cap}} = \frac{\sum S_{capi}}{n_{cap}}, \tag{3}$$

where $\bar{S_{cap}}$ is the average short-term debt under capitalisation, $\sum S_{capi}$ the sum of short-term debt for the years where intangible assets are recorded on the balance sheet, and n_{cap} is the number of years with capitalised intangible assets.

The relevant averages are calculated if the development expenditures are expensed or the capitalised intangible asset is eliminated from the balance sheet for any reason, such as impairment.

The average equity under expensing is expressed as

$$\bar{e_{ex}} = \frac{\sum e_{exi}}{n_{ex}}, \tag{4}$$

where $\bar{e_{ex}}$ is the average equity under expensing, $\sum e_{exi}$ the sum of equity for the years where intangible assets are not recorded on the balance sheet, and n_{ex} is the number of years without capitalised intangible assets.

The average long-term debt under expensing is expressed as

$$\bar{L_{ex}} = \frac{\sum L_{exi}}{n_{ex}}, \tag{5}$$

where $\bar{L_{ex}}$ is the average long-term debt under expensing, $\sum L_{exi}$ the sum of long-term debt for the years where intangible assets are not recorded on the balance sheet, and n_{ex} is the number of years without capitalised intangible assets on the balance sheet.

The average short-term debt under expensing is expressed as

$$\bar{S_{ex}} = \frac{\sum S_{ex,i}}{n_{ex}}, \tag{6}$$

where $\bar{S_{ex}}$ is the average short-term debt under expensing, $\sum S_{ex,i}$ the sum of short-term debt for the years where intangible assets are not recorded on the balance sheet and n_{ex} is the number of years without capitalised intangible assets on the balance sheet.

The six numbers in the matrix are considered projections of investors' reactions to the capitalisation or expensing of intangible assets. Averages were chosen as the metric because they consider the invested amounts during the years when alternative valuation methods for intangible assets were implemented. Using averages ensures that if the signalling effect caused by intangible asset capitalisation does not significantly impact equity, the average equity during the years of expensing will not differ from the average equity during capitalisation.

This case study aims to determine the most sensible investment strategy using game theory for entities primarily involved in R&D activities. The analysis is based on empirical data, and investors' decisions are evaluated retrospectively based on past events. The optimal strategy for similar situations can be identified by examining these events, assuming that the project has progressed beyond the research phase. The three investment strategies from the investors' perspective are categorised as low, medium, and high, represented by short-term, long-term, and equity, respectively. On the other hand, management faces a binary decision of whether to capitalise or expense the development costs.

The case study focuses on understanding how investors should react to the managerial decision of expensing or capitalising intangible asset development costs. The three entities selected for the case study have common individuals exerting significant control throughout a substantial portion of the period under consideration. Therefore, a multiple case study approach, primarily exploratory, has been chosen to determine if game theory can provide an optimal investment strategy.

The three entities participating in the case study are R&D-intensive companies classified under SIC code 72190 ("Other research and experimental development on natural sciences and engineering"). These entities are private limited companies whose financial statements are abbreviated and unaudited, prepared following the financial reporting standard for small entities, FRS 105. [14]. The publicly available information for these entities, particularly for unsophisticated investors, is limited and opaque. Hence, if the case study produces reliable results, similar game theory matrices could be useful for guiding investment strategies.

While it is desirable for the solutions of the game theory matrices to be similar to confirm a replication pattern, it is important to consider the contextual factors at play. The results of the case study may have the potential for generalisation [15]. However, it is crucial not to overlook the specific context in which the case study occurs. This includes factors such as the type of

entities involved, the nature of internally generated intangible assets, and the specific restrictions or concessions applied to the game theory matrix.

Assumptions and concessions are essential for the game theory matrix to function effectively. These assumptions and concessions set the rules and framework for the matrix. They provide a structure within which the decision-making process can be analysed. The specific assumptions and concessions made in the case study should be clearly stated to ensure transparency and understanding of the game theory analysis. By acknowledging the following assumptions and concessions, the limitations and scope of the case study can be properly assessed.

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 crystallises". This, on its own, is an admittance that conducting R&D is the main driver of the company's value and income generation source. Thus R&D is the most important factor determining the entity's financial performance, overshadowing every other asset.

Secondly, these are private companies, unlisted by default, so the investor protection framework regarding regulated market participants is not applicable.

Thirdly, the game matrices focus on the investors' strategy decision regarding the risk they are willing to assume under two different intangible asset value reporting schemes, expense or capitalisation. 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. Given that the primary objective of the companies is to generate intangible assets through their R&D activities, the game matrices prioritise this specific aspect and its associated reporting methods. The matrices do not explicitly consider other factors that may affect investment decisions, such as the companies' financial performance, market conditions, or industry dynamics. By isolating the decision to expense or capitalise the development costs of intangible assets, the game matrices provide a simplified representation of the investment strategy. This allows for a focused analysis of the implications of the reporting schemes on the investors' risk appetite and decision-making process without the interference of other potentially less relevant factors.

Fourthly, 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, by definition, mixed strategies can only be calculated on a 2×2 matrix if needed.

Fifthly, the following investment options, equity, long-term, or short-term debt, are available to any interested investor. 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 capital 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 risk indicators [16].

Through this case study, the development cost capitalisation can be observed during a timeline to identify how the investors' behaviour is affected by the signalling in terms of investment strategy selection.

The drawback of the case study is the inability to expand the game matrices' results beyond the restrictive context where they are set [15]. Also, a certain amount of operational time frame is required to construct and implement the game theory matrices, so apparently, this method cannot provide useful insights in the case of startups or before the completion of the research phase. In other words, the fact that the case study evolves around a specific population is an inherent limitation of the case study method. Also, the fifth concession regarding the availability of all three investment options seems borderline biased regarding equity. However, there is no indication from the shares allotment filled with the UK companies' houses that equity is not an option for potential investors [17].

The game theory matrices' case study also contains elements of content analysis. The financial statements and additional related documentation, such as annual return statements, return of share allotments, confirmation statements, and Patent-scope-related documentation, have been studied to extract data, but also additional information that would assist in revealing certain managerial attitudes. The content analysis has been mostly descriptive and was used mainly to identify the persons with significant control over the three case study entities and, if possible, the nature of intangible assets developed by the entities and the relevant timeline. It was essential to demonstrate that the same standard industrial classification and similar or familiar managerial mentality and culture bind the three entities. That common managerial way of thinking would create the necessary conditions, evolving into a behavioural decision pattern regarding the capitalisation of internally generated intangible assets' development costs and not a mere coincidence.

The content analysis was used to establish the existence of linkages or partnerships among the three observed entities based on the criteria of capital participation and ownership. Furthermore, content analysis was used to identify changes in managerial positions and important events such as notices of capital increase or even notices of gazette strike-offs. Additionally, through content analysis, the nature of developed patents could be identified along with their intellectual property standing level, meaning whether patent grants have been awarded or not and the nature of these patents.

Practically, the content analysis expanded to far more entities than just the three included in the case study. This action was optional but instrumental in portraying the business environment and managerial liaisons among companies with extensive R&D activities. Although additional linked entities were found with the corresponding standard industrial classification code SIC 72190-Other research and experimental development on natural sciences and engineering, no capitalised development costs, so they were excluded from the case study population.

CASE STUDY SUBJECTS' PROFILES

In this section, the profiles of the 3 companies will be presented along with additional information regarding the companies' ownership and group formations based on linkages and partnerships.

The first entity is Hudol Thermal Ltd, the company was incorporated in 2002, and the game matrix was constructed using the financial statements from 2002 until 2015; its corresponding standard industrial classification code is SIC 72190 (Other research and experimental development on natural sciences and engineering). Company statements are abbreviated,

unaudited and prepared per the financial reporting standard for small entities FRS 105 [14, 17]. 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, capitalisation was allowed and implemented between 2007, 2008 and 2011 to 2015.

The second entity is Hudol Thermal Ltd, and the company was incorporated in 2003, initially under the name Celtus Ltd., until 2006, when it was renamed Hudol Thermal Ltd. The game matrix was constructed using the financial statements from 2005 until 2016; its corresponding standard industrial classification code is SIC 72190 (Other research and experimental development in natural sciences and engineering). Company statements are abbreviated, unaudited and prepared following the financial reporting standard for small entities FRS 105 [14, 17]. 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, capitalisation was allowed and implemented from 2008, 2009 and 2011 to 2016. The years before 2005 have not been included since the entity seems to have been in limbo or inactive during 2003 and 2004.

The third entity is Dyfodol Energy Ltd, and the company was incorporated in 2004, initially under the name Alurec Ltd., until 2005, when it was renamed to Dyfodol Energy Ltd. The game matrix was constructed using the financial statements from 2007 until 2016, and its corresponding standard industrial classification code is SIC 72190 (Other research and experimental development on natural sciences and engineering). Company statements are abbreviated, unaudited and prepared following the financial reporting standard for small entities FRS 105 [14, 17]. 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, the capitalisation was allowed and implemented during the years 2008 to 2015 included. The years after 2016 have not been included in any case study companies since, technically, after the latest amendment of the FRS 105, the managerial discretionary choice of development cost capitalisation would not be available.

The three companies are linked through indirect ownership; two natural persons seem to hold combined percentages of voting rights in all three companies above 25 % and up to 60 %; these percentages are not stable throughout the studied time frame; share ownership is constantly shifting. However, a relatively safe assumption, deriving from the shares' allotment reports, would be that these two individuals acting jointly can exercise significant influence and control on all three entities during much of the investigated period. This fact demonstrates, to a certain extent, that the managerial mentality is the same in all three entities. It is important to note that both these directors are scientists according to the annual return statements; one is a chemist, and the other an engineer. These facts are significant because, as directors, these individuals seem to have the ability as scientists to adequately evaluate the progress of the entities' projects and thus the probability of any future economic benefits flow and technical feasibility insights. The decision to capitalise on internally generated intangible assets is subject to the same managerial judgement and critical thinking; in other words, the future economic benefit probability is estimated under an identical way of thinking in all three companies. As a result, the amount of optimism or pessimism around projects has a common baseline. Investors face the same management in all three companies regarding signalling success through development cost capitalisation. All three companies are operating within the same industry and are R&D intensive; undeniably, research and development is their primary value driver. From a legal standpoint, Hudol Thermal Ltd received a compulsory strike-off notice in 2022, which was later discontinued; from its most recent financial statements, the entity has undergone

restructuring and appears dormant in 2021. Subsequently, this entity alone is functioning now under different management.

Although there are no disclosures in the notes to the financial statements regarding the nature of the intangible assets capitalised, patent-scope is used to identify the nature of the assets [17]. Two out of the three entities have successfully published a patent in more than one jurisdiction, and in one of these cases, a patent grant has been obtained in more than one jurisdiction; Hudol Thermal Ltd seems to be the only one without a record on patent-scope.

RESULTS

In this section, the game theory matrix solution will be applied to the three entities to identify if there is a consistency in the results regarding optimal strategies. There is a trade-off between practicality regarding the matrices' construction and efficiency, which is interpreted as prediction capability.

The first hypothesis is that a dominant investment strategy exists in the case study and is formulated as follows.

H_1: The solution of the game matrix will provide a dominant investment strategy, either high risk, medium risk or low risk.

If the first hypothesis is rejected, the matrix will be transfigured into a 2×2 matrix, and the second hypothesis will come into play.

H_2: The solution of the matrix will provide a mixed strategy, which will be a combination of high-risk and mid-low-risk investment allocation.

The first step will be the data presentation; the data from the financial statements have been extracted and formatted to be utilised to construct the game theory matrices.

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

The averages of invested funds per funding source category have been calculated for the years during which development costs were expensed and for the years during which development costs were capitalised, accordingly. Those sums are, by solving for formula (1) 30 951, formula (2) 155 392, formula (3) 96 792,33, about the capitalisation method and on the other hand, formula (4) 9 765,38, formula (5) 84 823,88, formula (6) 67 617 for the expense method. At first glance, it is obvious that the entity is funded mainly by long-term debt, followed by short-term debt and equity for most of the period under investigation. 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 capitalisation comes into effect later, and then equity is stabilised during the last three years of the relevant time frame. The point here is exactly the narrative shift expressed through development cost capitalisation while exiting the research expense-only stage. On average, it is obvious that during the capitalisation era, the entity manages to raise significantly more funds from equity. 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, restructuring 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, indicating a rather noticeable volatility diversity.

Table 1. Extracted Formatted Data for Hudol Thermal Ltd..

CAPITALISATION INDICATOR	YEAR	EQUITY, £	LONG TERM DEBT, £	SHORT TERM DEBT, £	DEBT/EQUITY
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
Total time-frame average		18.844,93	115.067,36	80.120,71	97,55
EXPENDITURE ANNUAL AVERAGE		9.765,38	84.823,88	67.617,00	163,93
CAPITALISATION ANNUAL AVERAGE		30.951,00	155.392,00	96.792,33	9,05
STANDARD DEVIATION EX		10117,49	86239,62	40480,73	174,63
STANDARD DEVIATION CAP		11940,35	67223,98	23709,43	4,13

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

The financial statements do not provide detailed information regarding the nature of the capitalised assets on the balance sheet; under the header of intangible assets, the corresponding description is additions. The capitalised amounts are not large; they begin at 3 346£, reaching up to 29 355£. However, it is the signal caused by the capitalisation of the issue and not the capitalised amount necessarily. The nature of the intangible asset is identified using Patenscope. Fortunately, multiple publications were found, including two patent grants for the invention called "Gasification apparatus and method" designated WO/2004/078879 in the international application; so from a technical perspective, an intangible asset exists, although its financial success and future economic benefits are not guaranteed just by obtaining patent status [11, 18]. Initially, the New Zealand regional office granted the patent on 10/05/2007 and subsequently by the European Patent Office on 30/05/2012. The capitalised value corresponds to something protected by intellectual property rights; the issue now is how that capitalisation signal affects investors' strategies.

The game matrix presented in Table 2 is a 3×2 matrix where the two columns represent the development cost treatment methods and the rows represent the three different investment strategies classified by risk.

The averages that were presented in Table 1, calculated using formulas (1)-(6), are being used as values of the matrix in Table 2. The next step requires calculating the rows' maximum among minimum values and columns' minimum among maximum values. When the calculated two numbers are the same, the game has a saddle point indicating the existence of a dominant strategy; that would confirm the first hypothesis. If the game had no saddle point, it would be reconfigured as a 2×2 matrix to explore the second hypothesis. A more complex set of calculations would provide a mixed strategy based on

Table 2. Game Matrix for Hudol Thermal Ltd..

		DEVELOPMENT COST TREATMENT, £		
		EXPENSE	CAPITALISE	row maxi-min
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	
	Saddle point	Medium risk (LT-debt)		

Note: The saddle point pinpoints the prevailing strategy for the investors, which is medium risk, namely long-term debt 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. The first hypothesis is thus confirmed.

The same game matrix method will be applied now to Hudol Thermal Ltd, beginning with the data in Table 3.

Table 3. Extracted Formatted Data for Hudol Thermal Ltd.

CAPITALISATION INDICATOR	YEAR	EQUITY, £	LONG TERM DEBT, £	SHORT TERM DEBT, £	DEBT/ EQUITY
EX	2005	970,00	0,00	0,00	0,00
EX	2006	870,00	0,00	235,00	0,27
EX	2007	870,00	0,00	143.960,00	165,47
CAP	2008	1.740,00	0,00	532.406,00	305,98
CAP	2009	1.740,00	0,00	417.894,00	240,17
EX	2010	1.740,00	0,00	269.844,00	155,08
CAP	2011	1.740,00	0,00	273.473,00	157,17
CAP	2012	1.740,00	0,00	291.346,00	167,44
CAP	2013	1.740,00	0,00	259.861,00	149,35
CAP	2014	1.740,00	72.049,00	320.865,00	225,81
CAP	2015	1.740,00	49.248,00	826.886,00	503,53
CAP	2016	1.740,00	26.447,00	839.276,00	497,54
Total time-frame average		1.530,83	12.312,00	348.003,83	213,98
EX AVERAGE		1.112,50	£0,00	103.509,75	80,21
CAP AVERAGE		1.740,00	18.468,00	470.250,88	280,87
STDEV EX		420,98	0,00	129978,52	92,56
STDEV CAP		0,00	28252,26	241211,58	145,07

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

The averages of invested funds per funding source category have been calculated using formulas (4)-(6) for the years during which development costs were expensed and formulas

(1)-(3) for the years during which development costs were capitalised, accordingly. At first glance, it is obvious that the entity is funded mainly by short-term debt, followed by long-term debt and lastly, equity. The debt-to-equity ratio rose significantly in 2007 and stays elevated; it peaked in 2015 and showed signs of major debt accumulation; the debt relief in 2016 is rather insignificant. On the contrary, equity raises are significant when capitalisation comes into effect later on and remains stable until the end of the relevant time frame, just as in Hudol's case presented previously. Once again, the shift in narrative is expressed through development cost capitalisation after the end of the research expense-only stage. During the capitalisation era, the entity managed to raise a significantly larger amount of funds from equity, although it was still relatively small compared to other sources of capital. Long-term debt only started to increase in the last three years of the period under study. This could be a debt restructuring attempt rather than an increase in risk undertaken by the investors. Unfortunately, there is no way to know for certain. However, capitalisation may also be relevant to debt restructuring if it provides collateral that could convince investors to postpone their claims. Therefore, the game theory matrix can still provide insights into the investors' strategies.

It is worth noting that the standard deviation is significantly higher than the average for long-term debt during the capitalisation era, indicating a noticeable diversity in terms of volatility. All other standard deviations suggest relatively low volatility. There is an important discrepancy in the financial statements of 2008 and 2009. They have been amended, and it appears that patents were misclassified as tangible assets with a depreciation straight-line method over 20 years. For the game matrix, these two years have been included in the capitalisation category since the asset was included in the balance sheet but misplaced. From 2011 onwards, patents and licenses have been correctly classified as intangibles.

Interestingly, no patent grants were awarded to Hudol Thermal Ltd or published by the entity in PatentScope [18]. This might indicate that the entity failed to deliver results or acquired licenses for inventions tied to its research but did not follow through with the research. However, this can only be speculation, and the absence of any records in PatentScope is not an encouraging sign regarding the research progress. The nature of the patents and licenses on the balance sheet remains unknown.

The corresponding matrix of Hudol Thermal Ltd is presented in the following table, designated in Table 4.

Table 4. Game matrix solved for Hudol Thermal Ltd (Former Celtus Ltd.).

		DEVELOPMENT COST TREATMENT, £		
		EXPENSE	**CAPITALISE**	**row maxi-min**
INVESTOR DECISION (PRIVATE, RETAIL-INVESTOR COMMERCIAL BANK ETC)	**High risk (equity)**	1.112,50	1.740,00	1.112,50
	Medium risk (LT-debt)	0,00	18.468,00	0,00
	Low risk (ST-debt)	[(103.509,75)]	470.250,88	[103.509,75]
	column mini-max	(103.509,75)	470.250,88	
	Saddle point	Low risk (St-debt)		

Note: The saddle point pinpoints the prevailing strategy for the investors, which is low-risk, namely short-term debt.

The averages that were presented in Table 3, calculated using formulas (1)-(6), are being used

as values of the matrix in Table 4, just as in the case study of Hudol Thermal Ltd.. The next step, as demonstrated in the first case, is calculating the rows' maximum among minimum values and the columns' minimum among maximum values. When the calculated two numbers are the same, the game has a saddle point indicating the existence of a dominant strategy; there is a saddle point in this case, meaning that a dominant strategy is present. Subsequently, investing in short-term debt is the dominant strategy for investors in this entity. The dominant strategy means that investing in short-term debt is the best option for an investor. Regardless of the intangible asset development cost accounting treatment selected by the entity's management, the matrix advises investors to assume a low-risk position. This result does not seem to contradict the overall feedback provided by Table 3; if more astute investors were to examine Table 3, they would observe that most investments are consistently placed on short-term debt over time. This suggests that the game matrix demonstrates a certain level of predictability, although it should be noted that it is based on historical data.

The next game theory matrix solution could provide additional information about how the matrices function and their implications.

Table 5 shows the corresponding data for the case of Dyfodol Energy Ltd., the last of the three entities.

Table 5. Extracted Formatted Data for Dyfodol Energy Ltd. (Former Alurec Ltd.).

CAPITALISATION INDICATOR	YEAR	EQUITY, £	LONG TERM DEBT, £	SHORT TERM DEBT, £	DEBT/ EQUITY
EX	2007	1.000,00	81.000,00	211.400,00	292,40
CAP	2008	1.000,00	136.347,00	220.982,00	357,33
CAP	2009	1.000,00	121.943,00	219.781,00	341,72
CAP	2010	1.000,00	106.202,00	225.860,00	332,06
CAP	2011	1.000,00	90.461,00	240.606,00	331,07
CAP	2012	1.000,00	74.719,00	239.260,00	313,98
CAP	2013	1.000,00	58.978,00	234.546,00	293,52
CAP	2014	1.000,00	43.237,00	253.775,00	297,01
CAP	2015	1.000,00	27.496,00	253.853,00	281,35
EX	2016	1.000,00	11.755,00	254.418,00	266,17
Total time-frame average		1.000,00	75.213,80	235.448,10	310,66
EX AVERAGE		1.000,00	46.377,50	232.909,00	279,29
CAP AVERAGE		1.000,00	82.422,88	236.082,88	318,51
STDEV EX		0,00	48963,61	30418,32	18,55
STDEV CAP		0,00	38286,92	13416,40	26,39

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

As in the previous cases, the averages of invested funds per funding source category have been calculated for the years during which development costs were expensed and for the years during which development costs were capitalised. At first glance, it is obvious that the entity is funded mainly by short-term debt, followed by long-term debt and lastly, equity, just as in the previous case. The debt-to-equity ratio was elevated in 2007, indicating extreme leverage and remains elevated. Generally speaking, this entity appears overleveraged throughout the investigated period. On the contrary, equity remains stable until the end of the relevant time frame at a nominal value of just 1000 British pounds. The shift in narrative represented by the capitalisation of development costs after transitioning from the research expense-only stage does not seem to impact equity investments significantly. However, during the capitalisation

era, the entity can secure more funds through long-term debt, while short-term debt remains the primary funding source. This suggests that investors maintain a cautious approach towards the entity regardless of the capitalisation signalling. Therefore, the game theory matrix should indicate a more cautious investment strategy in this case, based on the data presented in Table 5. The standard deviation for long-term debt during the expensed cost era is slightly higher than the average, which is expected given that the expense data set only includes two years (the initial and the last year). On the other hand, the standard deviations for other investment options suggest relatively low volatility.

Intangible assets are recorded on the balance sheet as additions. However, according to the patent scope, there is a patent application and publication by the entity under the details of GB2458690 for treating waste plastics material, published on 30/04/2008 [18]. It is worth noting that this coincides with the capitalisation year. Further analysis of the application suggests that the patent has been published but not yet granted, and the international patent application seems to have been withdrawn. Although a published patent is not officially granted, it can still be monetised through licensing, albeit at a lower price than a granted patent. This indicates that there are still potential economic benefits associated with the published patent.

The next game theory matrix solution could provide additional information regarding the matrices' functionality. Table 6 below is the game matrix for Dyfodol Energy Ltd., the last of the three entities.

Table 6. Game matrix solved for Dyfodol Energy Ltd. (Former Alurec Ltd.).

		DEVELOPMENT COST TREATMENT, £		
		EXPENSE	**CAPITALISE**	**row maxi-min**
INVESTOR DECISION (PRIVATE, RETAIL-INVESTOR COMMERCIAL BANK ETC)	**High risk (equity)**	1.000,00	1.000,00	1.000,00
	Medium risk (LT-debt)	46.377,50	82.422,88	46.377,50
	Low risk (ST-debt)	[(232.909,00)]	236.082,88	[232.909,00]
	column mini-max	(232.909,00)	236.082,88	
	Saddle point	Low risk (St-debt)		

Note: The saddle point pinpoints the prevailing strategy for the investors, which is low-risk, namely short-term debt.

Just as before, the averages calculated using formulas (1)-(6) presented in Table 5 are being used as values of the matrix in Table 6. Again, the next step is calculating the maximum among the minimum values of the rows and the minimum among the maximum values of the columns. The calculated two numbers are the same, meaning that the game has a saddle point indicating a dominant strategy. In the third and final case, investing in short-term debt is the dominant strategy for investors in this entity. This result confirms the cautious investor sentiment in the data presented in Table 5. As commented previously, the obvious strategy implemented by investors in Dyfodol Energy Ltd. was low-risk positioning interpreted as short-term debt. This further confirms that the game matrix utilises past data and projects an optimal strategy concurrent with what the data suggests and, most importantly, easily and practically for everyone to use regardless of their investing sophistication and prowess.

Table 7 is designed as a summarised result presentation which could assist in evaluating the

game theory matrices' method by viewing the entities ex-post the relevant time frame.

As mentioned before, a disadvantage of using these game matrices is that they are backwards looking for guidance and rely on past decisions of the involved players. In that sense, the size of the time-frame providing the necessary data is crucial and any future predictability needs to be considered with a caveat. However, it is necessary to state that in situations involving R&D, the process is lengthy, thus providing an adequate number of annual data for the construction of matrix.

Table 7 summarises the results in contrast to the most recent figures and information, meaning the most recent financial statements for every entity plus additional documentation available in the UK. Companies House and WIPO. Hudol Thermal Ltd. seems to be in the best financial position or situation compared to the other two affiliated entities. Although it is not what one might describe as a financially sound and healthy entity, it owns the most assets, and the debt-to-assets ratio is probably the lowest. Moreover, it has the most patent publications

Table 7. Summarised results.

CASE NUMBER	ENTITY DETAILS	GAME MATRIX RESULT	PRESENT-DAY FIGURES & INFORMATION		
			CORPORATE STATUS	ASSETS (2021), £	DEBT/ ASSETS (2021), %
1	HUDOL LIMITED Private limited Company SIC 72190 - Other research and experimental development on natural sciences and engineering	Medium risk (LT-debt)	ACTIVE- NO P.S.C., HIGHEST VOTING POWER R.P.-S.W.	102.456,00	231,81
2	HUDOL THERMAL LIMITED (Former Celtus Ltd.) Private Ltd. Company SIC 72190 - Other research and experimental development on natural sciences and engineering	Low risk (St-debt)	ACTIVE-COMPULSORY STRIKE-OFF NOTICE 2018 (DISCONTINUED-DORMANT ACCOUNTS 2021-P.S.C. R.J.L.-ENTITY SHARES TRANSFERRED-LINKS TO THE OTHER CASE STUDY ENTITIES SEVERED	1500,00	0,00
3	DYFODOL ENERGY LIMITED (Former Alurec Ltd.) Private Ltd. Company SIC 72190 - Other research and experimental development on natural sciences and engineering	Low risk (St-debt)	ACTIVE – P.S.C. R.P. CONFIRMED IN 2017	16.513,00	1412,32

Note: Conclusions are drawn based on the most recent data provided by the UK Companies House.

in different jurisdictions and actual patent grants. The lowest debt-to-assets ratio belongs to Hudol Thermal Ltd.; however, this entity has undergone an ownership change and, second of

all, a debt haircut, probably due to the acquisition and restructuring. This scenario is not speculation, and it can be easily deducted by looking at the most recent financial statements combined with the additional documentation available at the UK Companies House [17]. The accounts of 2021 are dormant, and the persons with significant control have changed due to share transfers; however, the relevant documents of 2021 show a decrease in assets combined with a significant debt write-off. All these events occurred after an initial warning of a compulsory strike-off of the entity, which was discontinued. All these facts, paired with the transfer of ownership, justify the assumption that a debt restructuring has occurred; thus, the assets-to-debt ratio is not representative of the entity's situation. The creditors, most likely, were only partially and not fully compensated for their risk, at best. Also, this is the only entity out of the three with no intellectual property rights on intangible assets. Under these circumstances, the debt-to-assets ratio of Hudol Thermal Ltd. is probably the most decent out of the three, although quite high at 231,81 %. Considering that the game theory matrix's investment strategy indication for Hudol Thermal Ltd. was the riskiest of the three entities, it is not irrational to claim that the guidance was correct within the broader context of all the cases. The best investment strategy for the other two entities was short-term debt. As was already mentioned previously, if Hudol Thermal Ltd. underwent a debt restructuring, then those exposed to short-term debt had the best chances to sustain minimum damages; it should be noted that this entity was the one with no patent publication or grant; in comparison with the other two entities, Hudol Thermal Ltd was the least productive in terms of intellectual property.

On the other hand, the most productive in terms of patent publications and grants is Hudol Thermal Ltd., the only one where medium risk is indicated as the optimal strategy. In the case of Dyfodol Energy Ltd., the assets are relatively insignificant, just £16 513,00. Additionally, the debt to assets ratio at 1412,32 % indicates an unsustainable situation unless nothing short of a miracle occurs, such as a new investor stepping in or a major scientific breakthrough is achieved, or the patent status changes from publication to grant, boosting capital inflows. Taking into account all of the previous ex-post, the game matrices' were successful in indicating the most appropriate risk strategy in all three cases, and most importantly, no equity investment was suggested, which would have meant a catastrophic failure not only for investors but also for the presented methodology and related case study. A further application is necessary to reconfirm the advisory capabilities of the game theory matrices; however, this case study has concluded in an initial positive resolution.

CONCLUSIONS AND POTENTIAL CONTRIBUTIONS

The main contribution of this case study is that by outlining a dominant strategy in situations where investment is characterised by a combination of high-risk R&D intensity, data scarcity and information asymmetry, the sincerity of the managerial decision of capitalisation or expense, can be identified. These matrices can be used as a compass to navigate through a project's "liminal" stage between research and development, which hinges on the signalling properties of development cost capitalisation. What the matrices try to accomplish is filtering the information in the financial statements following a simple procedure and transforming it into a game theory table which provides an optimal investment strategy without having to analyse the financial statements in a sophisticated manner.

From a theoretical perspective, just as past performance does not guarantee future returns, past decisions are not necessarily correct under every circumstance; thus, they do not warrant predictive accuracy. In these case studies, the matrices relied on the previous investment decisions of investors to project the average investor reaction to development cost capitalisation. Prudent investing necessitates using multiple data analysis instruments such as various indexes and moving averages, a meticulous study of white articles, and even market

sentiment. Such a rigorous investigation is challenging to inexperienced investors, especially when data are scarce, as presented in this article and when dealing with private entities in general.

Additionally, investments in R&D-intensive internally generated intangible assets are, by definition, risky. The uncertainty around these kinds of projects is associated with technical feasibility issues and legal framework concerns, namely intellectual property rights protection. Since capitalisation of development costs is perceived as an indication of potential success, the game theory matrix presented attempts to capture the investors' reaction to the underlying signal of scientific breakthrough.

The significance of capitalisation in this case study arises from the nature of the entities' SIC (Standard Industrial Classification) code, which indicates their primary focus on research and experimental development in natural sciences and engineering. As R&D is the core driver of value creation for these entities, capitalisation becomes crucial in signalling their commitment and potential for successful innovation.

As a result, the development costs' capitalisation or the absence of it should reasonably affect how much risk investors are willing to assume. Indeed, the suggested game theory instrument presented here could not generically hold water for every industry type, nor is it intended to. Its purpose is to provide consultation and assistance in formulating investment strategies regarding private micro-entities operating in high-intangible-intensity industries.

The strategies focus on development cost capitalisation while disregarding other factors. This does not mean that other factors do not exist. However, they are not as important; the only exception could be earnings. Although earnings are important, most startups rarely post earnings in their financial statements before a major breakthrough in the projects under development. In the case of the presented entities, the earnings are from non-existent to trivial; this is an anticipated fact that contributes even more to the significance of development cost capitalisation. The absence of earnings during the early stages is not an isolated event, and it is common for startups in high-intangible intensity sectors which rely on extensive R&D spending.

A significant amount of information asymmetry is involved that 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 better-informed decisions 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 estimating tool when it comes to investing in R&D intensive private entities.

In practice, constructing the game theory matrix does not require significant effort, complex calculations, or extremely time-consuming data extraction. Most importantly, as demonstrated here, even abbreviated financial statements are adequate for the task. Ideally, an AI-generated pre-trained transformer in the future could use the matrices to form an opinion regarding investment strategies after "reading" the financial statements.

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 matrices presented in this case study could be one of the tools used to define the optimal investment strategy, given that such a strategy exists. By

considering all the parameters affecting the investment strategy, potential investors could customise the matrix's suggested strategy according to their risk profile and available funds, making it more prudent or aggressive.

The results of the game theory matrices in the case study presented in this article rely on the game's preset parameters explained in the methodology section. Specifically, the rule set mentioned in the methodology section describes the assumptions about the game matrix. Equity seems to be the best option where development costs are mostly treated as expenses and disclosures are limited [5]. This happens mainly 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, and it is considered a factor in the managerial decision regarding the capitalisation or expense of development costs. However, as mentioned in the fifth rule of the game, all three investment options are available to investors. The game matrix recognises the investor side as the predominant force in the fundraising process.

This is probably a main limitation for the investigated cases presented here. However, Table 1 shows 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 which 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 which probably have similar managerial principles.

The second limitation is that a significant number of years into research and development must pass before using the game matrix; unfortunately, during early stages where the uncertainty is highest, the matrix cannot be used until the initial year of capitalisation. In terms of efficiency, it is not an effective tool from the beginning of the research stage. However, there is no signalling during that stage, so interpreting signalling is unnecessary.

In summary, the capitalisation signalling impact on investors can be interpreted using the game matrices, which are simple and easy to construct with limited publicly available data. The results can indicate an optimal investment strategy in private R&D intensive entities based on risk. However, it is important to acknowledge the limitations, such as the necessary constraints and concessions for the matrices' functionality and the inability to construct them without entering a development cost capitalisation phase.

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