MANAGERIAL ECONOMICS

SEMIANNUAL

vol. 25 no. 2 ■ 2024

Wydział Zarządzania Akademii Górniczo-Hutniczej

EKONOMIA MENEDŻERSKA

PÓŁROCZNIK

tom 25 nr 2 ■ 2024

WYDAWNICTWA AGH

KRAKÓW 2024

Faculty of Management
AGH University of Krakow

MANAGERIAL ECONOMICS

SEMIANNUAL

vol. 25 no. 2 ■ 2024

AGH UNIVERSITY PRESS

KRAKOW 2024

Articles published in the semiannual Managerial Economics have been peer reviewed by reviewers appointed by the Editorial Board. The procedure for reviewing articles is described at the following web address: http://www.managerial.zarz.agh.edu.pl

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Cover and title page design: *Zofia Łucka*
DOI: https://doi.org/10.7494/manage

ISSN 1898-1143 (paper version), ISSN 2353-3617 (on-line version)

Number of copies 40. The printed version of the journal is the primary one.

Wydawnictwa AGH (AGH University Press)
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CONTENTS

Managerial Economics
2024, Vol. 25, No. 2, pp. 117–131
https://doi.org/10.7494/manage.2024.25.2.117

Fabian Beck*

Strategies for trading in money markets

1. Prologue

The financial industry accounts for a significant share of economic output, both in Switzerland and globally. The Federal Department of Foreign Affairs (2021) notes that the financial sector in Switzerland generates almost 10% of GDP, supplying over 200,000 full-time jobs in the country. A glance at the balance sheet items "Due from banks" and "Due to banks" gives a quantitative idea of the extent of money market trading among banks.

As shown Hertrich (2018), money market trading can be defined as trading between credit institutions and non-banks that trade their own liquidity or central bank balances. As part of my bachelor's thesis, three experts were interviewed about money market trading and various money market trading strategies were designed based on these interviews. Both the literature analysis and the expert interviews are the subject of this scientific abstract.

2. Expert interviews to conceptualize suitable strategies

The interviewees are experienced specialists and managers from Swiss banks, all of whom have an operational and/or strategic connection to money market trading as part of their professional career. The interviews were conducted between September and October 2023.

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Table 1
Results of the expert interviews

Questions	Rolf Hartmann	Franzpeter Strassmann	Expert 3[1]
How important is money market trading for banks?	Money trading is very important in Switzerland, as confidence in the interbank market is high. Money trading plays a lesser role in the USA	Treasury perspective: Trading of short-term, highly liquid assets with the aim of managing liquidity and risk	Money market trading is the lifeline of a bank. Money trading primarily in its function as a short-term liquidity management instrument
What inter-dependencies exist with other areas of the bank (Treasury, Investment Banking, Corpo-rate Banking)?	Closely related to corporate customer business, as money market products are easy for companies to process and easily accessible	The premise is that money market trading serves to manage liquidity. There are links to various business areas that generate relevant cash flows	Money market trading is influenced by sales units with high customer cash flows and is closely related to them. Treasury and the MB and BoD set strategic guidelines and limits for money market trading
In your opinion, what are the factors for suc-cessful money trading?	Risk management and limit systems, but also middle and back office are crucial for successful money trading Constant rating monitoring and anticipation of market developments are also important	Successful money trading is characterized by efficient funding. Funds management in the right currencies, maturities, etc. Furthermore, all regulatory and internal requirements must be met	Personal relationships and trust are essential. Accurate and conscientious traders and clerks. Downstream processes in the back office and accounting are also crucial (correct billing; daily interest calculations/ interest balances; interest rates, etc.)

[1] Anonymized

Table 1 cont.

What strategies are there for money trading?	Favourable fundraising on the liabilities side and investment in loans or financial assets. Another money trading strategy is to use borrowing and lending to manage regulatory ratios such as the LCR or the CET1 ratio	Positioning according to interest rate expectations: Long-term loans when interest rates fall. Exploit arbitrage effects in the event of a steep yield curve. Borrowing liabilities and investing in assets with the same maturity to exploit the interest rate differential	Utilization of the spread for asset/ liability transactions. Foreign currencies can also be integrated into these strategies. However, it should be noted that exploiting high spreads in illiquid currency markets is also associated with risks
Which money trading strategies do the different banks use and why?	Depending on the geographical focus and customer relationships of the banks, various currencies and instruments are offered and traded in money market trading	Since the financial crisis of 2007, banks have become more restrictive, anticipation of funding. The focus is on security and balance sheet management. Control of regulatory key figures (e.g., CET1)	Due to their high credit rating, state-guaranteed canonical banks can obtain liquidity at favourable terms, which in turn can be invested in the market. Otherwise, no general statements can be made
Which regulatory key figures play a role in money market trading?	LCR, NSFR, MIRE, CET1-ratio	LCR, Liquidity Buffer, Large Exposure, CET1-ratio	LCR as a key indicator. Capital ratios also very relevant
How should the required human capital be structured?	Money traders should have integrity, commitment, a team-oriented and extroverted character.	Employees should have expertise in trading, risk, accounting and controlling. Managers should also have	Requirements Treasury: Networked, model-based and strategic thinking. Money trading requirements: Trustworthy,

Table 1 cont.

Questions	Rolf Hartmann	Franzpeter Strassmann	Expert 3
	Knowledge of economics and business administration is a prerequisite	an academic background. Open-mindedness and integrity are required	outgoing, and acquisitive personalities
How should the corresponding infrastructure be designed?	Well-functioning core banking system as well as back and middle office tools. Operational processing via trading and information systems such as Bloomberg, Reuters and Instimatch	Trading and risk management systems are indispensable. Financial information and communication systems such as Reuters also represent an important infrastructure	Money market trading and treasury are still heavily Excel-based. FX and other trading systems are also important.
How important is it to maintain relationships with counterparties in money market trading?	Personal and professional exchange as well as participation in events and relationship management in general are essential	Personal development and maintaining relationships are essential	Relationship management and trust are very important
What significance does a bank's rating have in the money market?	This is very important, as the rating has a direct influence on the margin in money market trading and provides an orientation for the risk of a transaction	Essential for large and internationally oriented players to obtain corresponding limits from other players	Ratings correlate with a bank's refinancing costs. The better the rating, the more favourable the refinancing options
What role do brokers play in money trading?	Brokers serve as a kind of door opener for access to new customers and other banks. Brokers are important	Digitalization increases transparency and efficiency, which is why the importance of voice brokers tends to decrease.	Not specified

Table 1 cont.

	information brokers and orientation aids in a non-standardized and sometimes information-inefficient market	Comprehensive platform solutions will be in greater demand in the future, especially if an interface for banking systems can be built for them	
How can derivatives be used in money trading?	Reputational and credit risk are the most important risks in money market trading. Operational risks are also highly significant.	Direct risks are relevant due to external dependency. Correlation between the direct risks. (Reputation ↔ liquidity ↔ credit).	Reputational risk in the case of business relationships with foreign banks and other players. Operational risk if the LCR falls below
	Legal risks are to be classified as lower	Operational risks are also relevant, which can be mitigated by a functioning BCM	the regulatory limit due to inadequate management or coordination or a lack of understanding of the customer's business processes and business model. Credit risk for lending transactions. Repo transactions instead of unsecured money market transactions mitigate this risk
How can derivatives be used in money trading?	Interest rate derivatives are important for risk management in money market trading. Foreign exchange swaps are important money trading instruments due to the large number of foreign deposits at Swiss banks	Use of derivatives in connection with balance sheet hedging. Rather restrictive use for money trading activities	Currency and interest rate swaps as hedging instruments. Other derivatives, e.g. futures, are sometimes very illiquid

Table 1 cont.

Questions	Rolf Hartmann	Franzpeter Strassmann	Expert 3
How is it possible, despite the efficiency of the foreign exchange markets, that borrowing in USD or EUR can be more attractive than in CHF if information-efficient markets make arbitrage profits impossible?	Different risk assessments by the individual players lead to subjective price expectations in different currencies. As money trading is an over-the-counter transaction, arbitrage opportunities in different currencies are possible due to information inefficiencies	Arbitrage possible due to differing expectations and trading positions of the individual agents. Asymmetries in USD/CHF or EUR/CHF exchange rates due to the „safe haven" function of the CHF	The more attractive swap rates can be partly explained by a liquidity risk. For example, it is possible that borrowed currencies cannot be repurchased on the value date: This can cause a player to default despite being solvent. This risk must be adjusted for.

3. Interpretation of the results

Depending on the definition that the experts established at the beginning, different functionalities are assigned to money market trading and consequently different priorities are set. Based on this, the experts consider revenue generation to be either the main or secondary objective of money market trading. It should also be emphasized that there is no uniform definition of the requirements for the job profile of a money trader. According to one expert, for example, accounting and controlling skills are a primary requirement alongside trading expertise, whereas the other expert views economic and business knowledge such as the reliable application of discounting models and basic knowledge of financial modelling as important skills. There seems to be more of a consensus on the character traits required of a trader, as all experts consider integrity and extraversion to be indispensable personality traits. Furthermore, the experts agree in the regulatory area, as the CET1 ratio and the various liquidity ratios were classified by everyone as very relevant. According to experts, the LCR is particularly important. This is a regulatory indicator developed by the Basel Committee on Banking Supervision (n.d.) to ensure that a bank's short-term resilience to liquidity risks is high enough. This also applies to maintaining relationships with other stakeholders, the importance of which is also rated as high by the experts.

In summary, it can be said that, despite different perspectives, money market trading is seen by all experts as something very complex, has many interdependencies with other business areas, and is highly relevant in the banking sector.

4. Conception of the strategies

In the following, suitable money trading strategies are developed based on the expert interviews. These are all formally structured in the same way, in that the initial situation is first explained and then a corresponding strategy is designed. A brief list of the risks and an overview of the possible applications round off the strategy concepts.

4.1. FX-arbitrage strategy

Initial situation and assumptions

According to the findings from the expert interviews, relationship management in money market trading is of great importance. In addition to other banks, this network of relationships also includes other players in money market trading, such as institutional investors or multinational companies. The group of institutional clients defies a clear and generally recognized definition, as different criteria are used for classification depending on the perspective. In practice, however, non-banks only have a professional treasury department depending on the scale of the institution, which creates an information asymmetry for smaller players compared to that of banks.

As small and medium-sized companies or institutions are confronted with payment flows in EUR, USD, or other currencies, depending on their business focus, there are interesting arbitrage opportunities for banks. As published in Horsch & Kruse (2020), the term swap refers to a financial contract that provides for an exchange agreement between two parties in which future cash flows such as currency or interest payments are exchanged on predetermined terms. For example, a Swiss mechanical engineering company may obtain its receivables from an order in USD. As a rule, the company will sell the USD for CHF. However, if there is also an outgoing payment in USD in the foreseeable future (e.g., to a supplier), it makes sense to invest the USD in a fixed-term deposit for this period. The company's motives may be to minimize costs by avoiding the payment of the spread for buying and selling USD, and the company does not have to hedge against any currency rise because of a "natural hedge".

Strategy

Currency swaps are an important instrument of money trading in which a fixed deposit is taken out in one currency for a certain period and the resulting incoming payments are exchanged for another, e.g., the local currency.

If information asymmetry is also assumed, banks can exploit their knowledge advantage and obtain favourable liquidity in another currency by offering the borrower an interest rate which (converted into the local currency by the currency swap) would be lower than the interest rate for the same transaction in the local currency.

Risks

As explained in the expert interview, risk-free profits are generally not possible. The main risk for the banks is that the counterparty with which the currency swap was concluded may default on payment. In this case, it depends on the legal structure of the individual contractual relationships. Often there are exclusions of liability in the general terms and conditions if the correspondent banks do not deliver the foreign currencies on time.

Regardless of who is ultimately liable for the delay, the receiving bank will have to explain the situation to its customer, which can ultimately cause lasting damage to its credibility and reputation and jeopardize the overall relationship.

Possible applications

In principle, borrowing in foreign currencies, combined with a corresponding currency swap, is suitable for all banks. The motive is primarily to obtain favourable liquidity, whereby the liquidity can be used either for refinancing the credit and mortgage business or for lending to other banks or non-banks. However, it should be noted that risk-free (or low risk) arbitrage transactions are mainly made possible by the information asymmetry described above. If this information asymmetry no longer exists, or only to a limited extent, borrowing in foreign currencies will no longer be much more attractive than in the local currency. The borrowers can then use financial information systems to calculate and compare which conditions are customary on the market and adjust their interest rate expectations accordingly.

4.2. Asset/liability strategy for professional funds

Initial situation and assumptions

Risk is a core component of the banking industry. In an economy, banks perform the function of capital transformation, which in turn can be divided into

lot size, maturity, and risk transformation. A money market trading strategy can be derived from risk transformation in that banks attempt to generate a margin between professional deposits and assets. In this context, professional money refers to money that is not transferred to the liabilities side via a bank's retail business. This exclusive definition is chosen because non-professional deposits are not classified as money market transactions.

Strategy

As mentioned at the beginning, the spread between lending and borrowing is the banks' gross income. To generate the highest possible interest rate difference between borrowing and lending, banks can either try to refinance themselves as cheaply as possible or obtain a high interest rate for lending. In practice, it will be much more difficult to achieve favourable refinancing, as this correlates with the rating, the refinancing network of the banks and other factors. Nevertheless, banks should strive to obtain the most favourable refinancing possible, as there is no credit risk on the liabilities side – in contrast to the assets side. If a bank tries to generate a reasonable spread despite high refinancing costs, it will only succeed by charging a higher interest rate on the assets side. Lending money is always associated with risk. Therefore, an excessively high, non-market interest rate offer for a money market loan should always be viewed critically, as this can be seen as an early indicator of refinancing or liquidity problems on the other side. For this reason, money market loans that are not secured by securities (e.g., repo transactions) should only be concluded with first-class and trustworthy banks and non-banks.

Risks

The greatest risk of this strategy is the credit risk, as the bank must always be prepared for a default by the counterpart to which it has lent money. If asset transactions are secured by securities, the credit risk is minimized as the collateral received by the lending party serves as security in the event of default.

Furthermore, the reputational risk must also be considered, as loans to other players, which are themselves subject to public criticism, could be viewed critically by stakeholders. Even if Swiss bank-client confidentiality is intended to ensure that these transactions are not made public, it can never be fully guaranteed that this will be the case in practice. This is particularly true if a party is a non-bank, as it is not subject to bank-client confidentiality and is therefore not bound by any confidentiality obligations.

Possible applications

The asset/liability strategy is generally suitable for all banks that have an appropriate risk tolerance and qualified trading and risk management staff. In this

context, the risk department of a bank should constantly monitor the bank's asset positions and set appropriate limits. It should also be noted that asset transactions must be backed by own funds. This should always be considered when calculating margins. If a bank has a low equity ratio, the liquidity costs should also be considered, as it may not be possible to issue corporate loans or mortgages with a higher margin due to the use of one's own funds in connection with money trading activities. Money market transactions also lead to an extension of the balance sheet, which should also be considered about regulatory requirements and shareholder interests.

4.3. Scaling strategy

Initial situation and assumptions

Banks have many customer relationships with other banks and non-banks. In addition to relationships with large players, which in turn also have large networks, this network also includes relationships with smaller or medium-sized banks and non-banks.

Strategy

Banks have the option of borrowing money from smaller players such as pension funds, regional banks or non-listed companies and placing this liquidity in a bundle with another player. The money market traders will try to progressively scale the interest rates they offer according to the amounts involved.

This strategy represents a further development of the concept mentioned in section 4.2. In contrast to the asset/liability strategy, however, the aim is to use the bank's wholesale position to realize scaling effects on the market. The bank's focus with this strategy is therefore less on taking risks. The primary aim of this strategy is to profitably exploit the difference between interest rates for smaller and larger amounts.

For this reason, an attempt can also be made to raise liquidity from smaller players and invest it (with matching maturities) in secure assets such as repo transactions or SNB Bills. The Six Repo AG (2023) describes a repo transaction as a securities-backed financial transaction in which there is a lender and a borrower, and which consists of two transactions. In the first transaction, the borrower sells a basket of securities (also known as collateral) to the lender and in return receives the market value of the collateral in the form of liquidity. At the same time, the repurchase of this collateral is agreed in the same type, quantity, and quality, so that repo transactions can be described as collateralized money market transactions between two professional players.

Risks

In the context of this strategy, a distinction must be made between risks on the assets and liabilities side. The risks on the assets side are already described in detail in section 4.2, which is why we will not list them further. However, it should be noted that the risks can be reduced in the case of value creation via scaling effects by investing the money raised in secure assets and still achieving a worthwhile return via the scaling effect.

The risks on the liabilities side lie primarily in market transparency. Wherever possible, banks should try to process transactions by contacting the respective parties directly, as platforms and intermediaries could create unwanted transparency (from the bank's point of view), which in turn would have a negative impact on margins.

The following example illustrates this from the perspective of Bank A. Bank A borrows CHF 5 million each from company B and pension fund C and lends CHF 10 million to bank B. In this example, it is assumed that both banks have the same risk profile/rating and a comparable market position. The difference between the lending and deposit rates from Bank A's perspective is 40 bps. If Company B and Pension Fund C now had the information that Bank A generates a margin of 40 bps by pooling liquidity and placing it further, Company B and Pension Fund C could demand higher interest rates from Bank A or contact Bank B directly.

Finally, it should be noted that further risks may arise if the maturity match between assets and liabilities is not maintained.

Possible applications

All banks that are of a certain size and have a corresponding network can use this strategy. This strategy is more suitable for larger banks with correspondingly higher balance sheets and larger networks than for smaller and less well-connected banks.

4.4. CET1 opportunity cost strategy

Initial situation and assumptions

In principle, banks have the task of generating an annual surplus and thus promoting the welfare of their shareholders, cooperative members, or other owners. This also includes establishing an appropriate ratio between equity and debt capital. An equity ratio that is too high could lead to the market interpreting this as a negative signal, particularly in the case of listed companies, which in turn

would have a negative impact on the share price. CET1 ratios are an extremely relevant key figure in terms of corporate policy, the range of which is determined in practice by the Board of Directors in cooperation with the Executive Board. According to Art. 21 para. 1 ERV of the Schweizerische Eidgenossenschaft (2012), common equity tier 1 capital (also referred to as common equity tier 1 capital or CET1) includes the paid-in share capital, the disclosed and general reserves for banking risks and the profit carried forward. Furthermore, the profit for the current financial year less an approximate profit distribution to the equity providers is added. Banks will manage these ratios primarily through the lending and mortgage business as well as the trading business. As corporate loans and mortgages cannot be increased or reduced on a short-term basis, these types of asset transactions are not suitable for fine-tuning the CET1 ratio, or only to a limited extent.

Example: A listed bank is given the strategic target by the Board of Directors of achieving a CET1 ratio of between 15% and 18%. Shortly before the end of the year, the bank's finance department reports that the CET1 ratio currently stands at 20%.

Strategy

If the CET1 ratio is too high, the company management can instruct the relevant trading department to actively lend on the money market. The bank's money traders will use their network or brokers to ask other players at what interest rate they would be prepared to borrow money. The bank's traders will then risk-adjust the various offers and conclude corresponding transactions. The strategy can be summarized by the fact that the traders help to steer the relevant key figure back into the desired range within the shortest possible time.

Risks

In addition to the existing credit risk which unsecured loans entail, a possible liquidity risk must also be mentioned, as the lending transactions must first be refinanced before a corresponding loan can be made. The Austrian Financial Market Authority (n.d.) describes Liquidity risk as the risk that banks will not be able to meet their payment obligations or not at market conditions. A distinction is made between various liquidity risks, such as structural liquidity risk, maturity risk or call risk. Money trading can both mitigate and increase this risk, as large amounts are borrowed and lent in money trading. Internal and external requirements counteract the liquidity risk in the form of an early warning system. The management of the CET ratio must therefore never result in the bank falling below liquidity ratios such as the LCR to make a correction to the CET1 ratio.

Possible applications

In principle, this strategy can be used by all banks that have qualified staff in their trading departments. It is also suitable for banks that reach the lower limit of the bandwidth at short notice and need to increase their CET1 ratio within a very short space of time. To this end, traders can terminate existing call money or liquidate sight deposits at other banks and move them to their current account at the National Bank, which has a risk weighting of 0%.

However, it should be noted that not all banks are interested in optimizing their CET1 ratio. One expert stated that his employer, an internationally active private bank, traditionally reports a high CET1 ratio to signal security to existing and potential customers.

4.5. Interest rate expectation and maturity strategy

Initial situation and assumptions

If a bank's decision-makers expect a change in the key interest rate to be announced at the next National Bank meeting, they can try to manage fixed-term deposits and loans in line with their interest rate expectations.

Strategy

The strategies are different if an interest rate increase or decrease is expected. If the decision-makers expect interest rates to fall, they may try to make longer-term loans and refinance them in the short term. The reverse is true if the opposite is expected.

Risks

Decision-makers can never predict the National Bank's decisions with certainty. This gives rise to interest rate risks with the above-mentioned strategy, which can have a negative impact on the bank's earnings if expectations are incorrect. If a bank wishes to limit its risks, it has the option of hedging or limiting interest rate risks by means of interest rate derivatives. Conditional and unconditional interest rate derivatives are available for this purpose. One instrument would be the interest rate swap. Schäfer (2018) defines an interest rate swap as an instrument which has always two sides, for example party A receives a fixed interest rate (e.g. the 5-year CHF SARON swap) as an interest payment from party B and pays a variable interest rate (e.g. the SARON Overnight Compounded) to party B in return. From Party A's perspective, this swap is referred to as a receiver swap. For party B, the interest payments are exactly the opposite, whereby party B recognizes a payer swap.

Possible applications

As this strategy requires interest rate opinions, it is only suitable for banks that have the relevant economic expertise. Risk systems for limiting interest rate risks and qualified traders for trading interest rate derivatives are also required.

5. Outlook and recommendation

Money market trading is undoubtedly experiencing a renaissance in times dominated by higher interest rates and margins. At the same time, bank failures and ever-increasing regulatory requirements mean that money market trading is also being increasingly regulated and the primary trading intention of generating income is being pushed into the background.

In conclusion, it can be recommended to decision-makers in the trading departments of banks that the opportunities offered by money market trading are very diverse, both in terms of earnings and management, and should always be considered in trading and treasury strategies. It is also advisable to train and educate traders about regulatory and accounting aspects. In addition, retailers and relationship managers should be given the necessary freedom and resources to maintain and expand relationships with other players. In the future, these will be indispensable prerequisites and success factors for a functioning and profitable money market which should ultimately also be reflected in the overall results of a bank.

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Summary

Money market trading is a part of Investment Banking and highly business relevant to the Swiss Banking sector. It is astonishing, therefore, that there are very few scientific studies or papers available on this subject. The goal of this article is to clarify and analyse the relevance, chances, and risks of money market trading within the Swiss banking sector and provides comprehensive information not only to professionals such as employees of banks but also for other clients interested in this specific topic. Various aspects of the money market were analysed, taking in a mix of interviews with experienced banking professionals as well as literary analysis. These aspects include products of and participants in the money market and combine it with the politics of the Swiss National Bank over the last few years. Furthermore, the implications of Basel III on cash trading were explored and explained by way of an example. From the interviews with banking experts, some basic requirements for the job profile of money market traders were defined, 5 strategies for money trading designed and related risks identified.

JEL codes: G21, G23, G24

Keywords: *money market trading strategy and trading instruments, banking institutions, regulatory authorities*

Managerial Economics
2024, Vol. 25, No. 2, pp. 133–140
https://doi.org/10.7494/manage.2024.25.2.133

Somdeb Lahiri

The St. Petersburg paradox with state dependent linear utility functions for monetary returns. A note

1. Introduction

The conventional statement of the St. Petersburg paradox (see for instance Biswas 1997) goes something like the following:

In an experiment consisting of independent tosses of an unbiased coin, a participant receives 2^n units of money if the first head occurs on the n^{th} toss. How much should one be willing to pay for participating in the experiment?

"The problem was invented by Nicolas Bernoulli (1687–1759) who stated it in a letter to Pierre Raymond de Montmort (1678–1719) on September 9, 1713. However, the paradox takes its name from its analysis by Nicolas' cousin Daniel Bernoulli (1700–1782), one-time resident of Saint Petersburg, who in 1738 published his thoughts about the problem in the *Commentaries of the Imperial Academy of Science of Saint Petersburg*" (Wikipedia (n.d.)). It is important to note that the genesis of the paradox, suggests that none of the three mathematicians mentioned above were familiar with the work of the statistician and philosopher Thomas Bayes (1701–1761) at the time of their correspondence.

The standard conclusion based on the above experiment is that if the utility function for monetary returns was strictly increasing and linear, then since $\sum_{n=1} 2^n \left(\frac{1}{2}\right)^n = +\infty$, there should be no upper bound on what a participant would be willing to pay to participate in the experiment, contrary to what would be

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expected in reality. In reality, no one would be willing to pay more than some finite amount of money to participate in the experiment. Hence, this could be construed as an argument against strictly increasing and linear utility function for money (i.e., individuals being risk neutral) and therefore an argument in favour of a utility function for money which is non-linear, such as the natural logarithm of money. In 1728, a mathematician from Geneva – Gabriel Cramer (1704–1752) – in a private communication suggested that there is a saturation level for the utility money, beyond which its utility or use value remains constant. This could be the idea that motivated the use of utility functions for wealth that are strictly concave, strictly increasing but bounded above (e.g. $u(x) = a - ae^{-x}$ for some positive real number "a"). Much work and discussion has taken place on this topic and a comprehensive survey of the same may be found in the work by Gasparian et al. (2018), Peterson (2023) and references therein. Feller (1968) suggested a solution based on sampling and argued that the "worth" of the experiment be based on the total amount that the participants in the sample would be willing to pay. The fallacy in this suggestion is similar to the one we address in section 4 of this paper. Feller (1968) allows for the sample size to be infinite. Samuelson (1960) offers a "clever" explanation of the paradox, i.e., in reality no one would offer such an experiment since it requires an expected payment of an infinite amount of money. Of particular relevance to our approach in this note is the survey by Gasparian et al. (2018), as we will see towards the end of this note. Another attempt at resolving the paradox, that is not considered in the survey, is available in Vivian (2013), wherein it is argued that a different perspective on the paradox would lead to a different expected value and further that an alternative methodology would show that there is no paradox arising out of the experiment.

In Lahiri (2023), we suggest a critique of the way participants would calculate probabilities when faced with such a problem. We argued that it is unrealistic to assume that the subjective probability assigned by a participant to the occurrence of a head on the n^{th} toss conditional on all preceding tosses resulting in tails is $\frac{1}{2}$, regardless of how large n is. For instance, it is not unreasonable to assume that the probability assigned by a participant to the occurrence of a head on the n^{th} toss conditional on all preceding tosses resulting in tails is $\frac{1}{2}$ for n = 1,2, $\frac{1}{4}$ for n = 3, $\frac{1}{8}$ for n = 4 and 0 for $n \geq 5$. In this case the expected value from participating in the experiment is $1+1+\frac{1}{2}+\frac{1}{8}=2\frac{5}{8}$ and not $+\infty$.

In this note, we take a different route that reconciles probabilities that were initially proposed for the experiment with linear utility functions for money – albeit state dependent ones.

2. The St. Petersburg experiment with a set of countably infinite states of nature and state dependent linear utility of monetary gains

Let $\mathbb{N}$ – the set of natural numbers – denote the countably infinite set of states of nature (sons), where state of nature (son) n denotes the event that in independent tosses of an unbiased coin, the first head occurs on the n^{th} toss, the probability of which is $\left(\frac{1}{2}\right)^n$. For son n, the constant average utility of money $u_n > 0$ is defined as follows: there exists a subjective discount factor $\delta \in (0, 1)$ and positive integers r, s such that for $n = 1, \ldots, r$, $u_n = 1$ and for all non-negative integers t, if $n = r + ts + 1, \ldots, r + (t + 1)s$, $u_n = \delta^{t+1}$. Clearly, this defines for us a profile of (state-dependent) linear utility functions for money given by the infinite sequence $\langle u_n \mid n \in \mathbb{N} \rangle$.

It is worth noting that since a "state of nature" is an "event" – and hence a subset of a sample space, it is relevant and meaningful along with all other concepts related to it, only in the context of the experiment for which it is defined. Thus, if $n \in \mathbb{N}$ is a son in the context of a performance of the experiment being discussed here, then $u_n > 0$ is the constant average utility money in son 'n' only in the context of the performance of the experiment being discussed here, and not universally. For instance, if son n occurs simultaneously with the totally unrelated event that a free lottery ticket wins a large sum of money, then for a participant in the experiment who also owns a free lottery ticket of this type, it is quite possible that u_n is "different" from the same participant's constant average utility of money if the "free lottery ticket wins a large sum of money". The two events occur in two different experiments, and decision making for the two by the participant may be totally unrelated in time, space and with regard to other relevant qualifiers.

The expected utility of participating in the experiment to a participant with the linear utility profile defined above is $r + \cdot \sum_{t=0}^{\infty} \delta^{t+1} s = r + \frac{s\delta}{1-\delta}$.

Thus, $\sum_{n=1}^{\infty} \left(\frac{1}{2}\right)^n u_n 2^n = \sum_{n=1}^{\infty} u_n = r + \frac{s\delta}{1-\delta}$ which is a strictly positive scalar.

If CE denotes the "certainty equivalent" of the expected utility $\sum_{n=1}^{\infty} u_n$ to a participant in the experiment with the linear utility profile $\langle u_n \mid n \in \mathbb{N} \rangle$ then CE satisfies the equation: CE $\sum_{n=1}^{\infty} \left(\frac{1}{2}\right)^n u_n = \sum_{n=1}^{\infty} \left(\frac{1}{2}\right)^n u_n 2^n = \sum_{n=1}^{\infty} u_n$.

Now

$$\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n = \sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n + \sum_{t=0}^{\infty}\delta^{t+1}u_n \sum_{n=r+ts+1}^{r+(t+1)s}\left(\frac{1}{2}\right)^n =$$

$$= \frac{1}{2}\times 2\times\left(1-\left(\frac{1}{2}\right)^r\right)+\sum_{t=0}^{\infty}\delta^{t+1}\left(\frac{1}{2}\right)^{r+ts+1}\sum_{j=0}^{s-1}\left(\frac{1}{2}\right)^j =$$

$$= 1-\left(\frac{1}{2}\right)^r+\sum_{t=0}^{\infty}\delta^{t+1}\left(\frac{1}{2}\right)^{r+ts+1} 2\left(1-\frac{1}{2}^s\right)=$$

$$= 1-\left(\frac{1}{2}\right)^r+2\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^{r+1}\delta\sum_{t=0}^{\infty}\delta^t\left(\frac{1}{2}\right)^{ts} =$$

$$= 1-\left(\frac{1}{2}\right)^r+\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^r\delta\sum_{t=0}^{\infty}\delta^t\left(\frac{1}{2^s}\right)^t = 1-\left(\frac{1}{2}\right)^r+\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^r\frac{\delta}{1-\frac{\delta}{2^s}}.$$

Since $\delta\in(0, 1)$, $\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n = 1-\left(\frac{1}{2}\right)^r+\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^r\frac{\delta}{1-\frac{\delta}{2^s}}$ is a strictly positive scalar.

Hence, CE = $\frac{\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n 2^n}{\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n} = \frac{r+\frac{s\delta}{1-\delta}}{1-\left(\frac{1}{2}\right)^r+\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^r\frac{\delta}{1-\frac{\delta}{2^s}}}$, which is a strictly positive scalar.

Thus, an individual with a linear utility profile given by $<u_n \mid n\in \mathbb{N}>$ will be willing to pay no more than $\frac{r+\frac{s\delta}{1-\delta}}{1-\left(\frac{1}{2}\right)^r+\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^r\frac{\delta}{1-\frac{\delta}{2^s}}}$ to participate in the experiment.

To give a numerical example for the suggested formulas, let $r = s = 1$ and $\delta = \frac{1}{2}$.

Then, the expected utility of participating in the experiment to a participant with the above values of the relevant parameters $\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n 2^n = r+\frac{s\delta}{1-\delta} = 2.$

Further,

$$\mathrm{CE} = \frac{\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n 2^n}{\sum_{n=1}^{\infty}\left(\frac{1}{2}\right)^n u_n} = \frac{r+\frac{s\delta}{1-\delta}}{1-\left(\frac{1}{2}\right)^r+\left(1-\frac{1}{2}^s\right)\left(\frac{1}{2}\right)^r\frac{\delta}{1-\frac{\delta}{2^s}}} =$$

$$= \frac{2}{1-\frac{1}{2}+\left(1-\frac{1}{2}\right)\left(\frac{1}{2}\right)\frac{\frac{1}{2}}{1-\frac{1}{2}}} = \frac{2}{\frac{1}{2}+\frac{1}{6}} = 3\,.$$

Hence, a participant with the values of the parameters being $r = s = 1$ and $\delta = \frac{1}{2}$, will be willing to pay no more than 3 units of money.

3. A more realistic resolution of the paradox

The above analysis was in the context of an unrestricted "thought experiment" without any constraints that reality may impose. Hence, let us recall the immortal words in the poem entitled *Garden of Prosperine* by Algernon Charles Swinburne (n.d.):

"… no life lives for ever;
That dead men rise up never …"

For this reason, and also because no potential participant would want to commit his/her entire future to such an experiment, for any state-dependent linear utility profile $<u_n | n \in \mathbb{N}>$, there is a positive integer N, such that $u_n > 0$ for all $n \in N$ and $u_n = 0$ for all $n > N$. This is true for any participant with any state-dependent linear utility profile, regardless of how it is defined or what the experiment under consideration is. This is analogous to the point raised by Carl Menger as briefly summarized in two paragraphs of the second column in page 188 of Gasparian et al. (2018) which is reproduced below:

"The next type of practical restrictions that Menger notes is limited playing time, interrupting too long chains of the coin flips.

The limited time allowed D. Brito to interpret the St. Petersburg paradox in terms of G. Becker's theory of time allocation, linking the time and capital constraints at the optimal point of the mathematical problem of the consumer's behavior".

Vivian (2013) is related to issues discussed in the paragraph that immediately follows the two above.

Hence the expected utility of the participant from participating in the St. Petersburg experiment is $\sum_{n=1}^{N}\left(\frac{1}{2}\right)^n u_n 2^n = \sum_{n=1}^{N} u_n$, which is a positive scalar.

Since $\sum_{n=1}^{N}\left(\frac{1}{2}\right)^n u_n$ is a positive scalar, the "certainty equivalent" corresponding to the expected utility $\sum_{n=1}^{N} u_n$ is the positive scalar $\frac{\sum_{n=1}^{N} u_n}{\sum_{n=1}^{N}\left(\frac{1}{2}\right)^n u_n}$, which, is also a positive scalar.

Thus, an individual with a linear utility profile given by $<u_n \mid n \in \mathbb{N}>$ such that for some positive integer N, it is the case that $u_n > 0$ for all $n \in N$ and $u_n = 0$ for all $n > N$ will be willing to pay no more than $\frac{\sum_{n=1}^{N} u_n}{\sum_{n=1}^{N}\left(\frac{1}{2}\right)^n u_n}$ and certainly not an unbounded sum of money, to participate in the experiment underlying the St. Petersburg paradox.

To give a simple numerical example illustrating what the formulas yield, suppose $N = 6$, $u_n = 1$, for $n = 1, \ldots, 6$ and $u_n = 0$ for $n > 6$. The numbers seem to be quite reasonable.

Then, any participant in the experiment with these values of the parameters for the formula determining the certainty equivalent would be willing to pay no more than $\frac{6}{\sum_{n=1}^{6}\left(\frac{1}{2}\right)^n} = \frac{6}{\frac{63}{64}} \cong$ (approximately) 6 units of money.

4. Conclusion

Whether this is simply the conclusion of the St. Petersburg paradox or the beginning of expected utility (decision) analysis with constant state-dependent linear utility of money as initiated in Lahiri (2024), only time can tell. At the very least, what our discussion above should have conveyed is that the St. Petersburg

paradox is crucially dependent on the choice of perspective for it to be recognized as a paradox, and by no means can the perspective that justifies its paradoxical nature be considered robust.

Acknowledgment: I would like to thank Subhadip Chakrabarty and Loyimee Gogoi for carefully verifying the calculations in section 3. I would also like to thank an anonymous referee of this journal for suggesting the inclusion of numerical examples for the solutions proposed in the paper and for drawing my attention to the contribution of Gabriel Cramer on utility functions for monetary wealth.

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Summary

In the experiment underlying the St. Petersburg paradox, we use state-dependent linear utility functions for money with a countably infinite set of states of nature to show that a potential participant will be willing to pay no more than a finite sum of money to participate in the experiment.

Keywords: *St. Petersburg paradox, countably infinite states of nature, state-dependent linear utility function of money*

Managerial Economics
2024, Vol. 25, No. 2, pp. 141–158
https://doi.org/10.7494/manage.2024.25.2.141

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The interdisciplinarity of the publications of the Medical University of Silesia in Katowice based on the analysis of the co-occurrence of issues specific to medicine and computer science

1. Introduction

1.1. Interdisciplinarity

The development of civilization causes an increase in the complexity of analyzed problems, which often exceed the competence of one discipline. Studied phenomena and processes are influenced by many factors and it is very difficult to isolate them from the environment, hence the idea of interdisciplinarity. In addition, technological and IT progress through the development of electronic databases as well as the increase of the speed and span of collected, processed and transmitted information enabled easier access to knowledge, and thus gave the opportunity to take a holistic look at many research problems (Gorynia 2013).

Interdisciplinarity has become an indispensable element of multidimensional science, and interdisciplinary research has begun to be perceived as more innovative, enabling the achievement of breakthrough solutions both on economic and social grounds (Yegros et al. 2015).

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There are many definitions of interdisciplinarity in the literature, but they are often diverse and ambiguous. (e.g. Klein 1990; Morillo et al. 2001; Wang et al. 2015; Rodríguez 2017). One of them, proposed on the basis of interviews and literature research, presents interdisciplinarity as: "any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process" (Aboelela et al. 2007). However, as noted by Porter and Rafols (2009), or Wagner et al. (2011), the key issue in interdisciplinary research is the integration of knowledge, not people. For this reason, one of the most commonly used definitions of interdisciplinarity in the literature, presented in the Report of the National Academies (2005), emphasizes integration, which may concern concepts, theories, tools, techniques, information or data from various areas of knowledge. The degree of this integration can be determined by such concepts as: transdisciplinarity, multidisciplinarity or plurdisciplinarity. Multidisciplinarity presupposes joint participation in research of many different fields that are not closely related, and each uses its own language and methods to describe the problem (Gara 2014). Transdisciplinarity refers to a higher degree of domain integration, also assuming a combination of theory and practice. Finally, plurdisciplinarity refers to the relationship between correlated sciences on the level of using common data, theories or methods (Grabowski 2011).

The source of research to measure interdisciplinarity are scientific publications, which were and are of great importance for the dissemination of knowledge and its exchange on the national and international arena, as well as in relation to the assessment of a scientific unit, the development of individual scientific disciplines, and the authors themselves (Kwiek 2015). The methods that have been proposed in the literature for measuring interdisciplinarity can be divided into two basic groups: field research and desk research (Fig.1) (Abramo et al. 2012).

Field research consists of conducting surveys, focusing largely on the study of team processes, social dynamics, or the motives of researchers (Wagner 2011).

Desk research can be described as quantitative research, distinguishing among them those that are based on co-authorship, citations and text (Evans 2016). The analysis of co-authorship is carried out on the basis of information on the disciplines represented by the authors of the publication, and diversity in this area means integration in research (Schummer 2004). This type of approach, however, does not focus on the most important assumption of interdisciplinarity – the integration of knowledge, but only on the presence of co-authors from various disciplines.

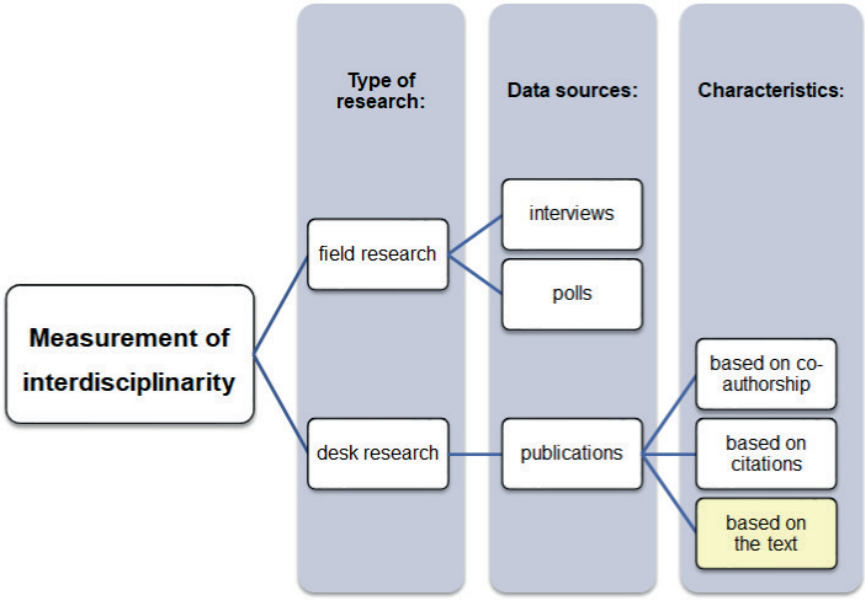


Figure 1. Methods of measuring interdisciplinarity

Bibliometric measures of interdisciplinarity based on citations allow to assess both the impact and contribution of research, as well as to determine the distances between disciplines (Adams et al. 2007; Chavarro et al. 2014; Zhang et al. 2016). The disadvantage of this approach, however, is the lack of focus on the product itself, which is the publication, and the difficulty in actually quantifying the integration.

The text-based method, although it is the youngest, is characterized by great potential, as language seems to be the key in assessing integration (Evans 2016). The authors decide which terms, ideas, methods, and specific vocabulary best describes their research. The use or omission of discipline-specific language situates scientific research in particular areas (Vilhena et al. 2014). Text is a rich source of data that allows you to analyze interdisciplinarity in publications at various levels, taking into account publication titles, keywords, summaries or even entire articles. In the conducted research on the importance of IT issues in publications in the field of medicine, the text-based method was used, because it gives the opportunity to conduct analyzes at the level of a single publication. One of the disadvantages of this type of approach, however, is time and computing power, because the data from abstracts alone can contain hundreds of words for one publication.

1.2. Interdisciplinarity in the field of medicine

Today's era is the era of computerization. Over the past years, computer science applications have been reported in many fields of study including customer services, accounting, financial services and human resources, its applications also have great impact on healthcare. Medical informatics is the study and application of methods to improve the management of patient data, clinical knowledge, population data, and other information relevant to patient care and community health. In recent years, various branches of the discipline have appeared, including public health informatics, consumer health informatics, and clinical informatics (Wyatt, Liu 2002).

The scope of public health informatics includes the conceptualization, design, development, deployment, refinement, maintenance, and evaluation of communication, surveillance, information, and learning systems relevant to public health (Magnuson, Fu 2014). There are various concepts associated with public health informatics, such as learning health systems, smart health systems, and adaptive complex health systems. Learning health systems were defined as systems where "science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience" (Institute of Medicine 2011). A learning health-care system routinely enables pursuit of better and safer care at lower cost, enhancement of public health and consumer empowerment (Lee, Yoon 2017). Example of learning health-care system implementation are electronic health records (EHRs) in clinical settings aimed at integrating clinical, financial, and administrative data (Etheredge 2007), usage of learning health system is also crucial for detection of novel communicable diseases such as COVID-19 (Romanelli et al. 2021). Smart healthcare is a health service system that uses technology such as wearable devices, IoT, and mobile internet to dynamically access information, connect people, materials and institutions related to healthcare, and then actively manages and responds to medical ecosystem needs in an intelligent manner and facilitate the rational allocation of resources. From the perspective of patients, they can use wearable devices to monitor their health at all times, seek medical assistance through virtual assistants, and use remote homes to implement remote services; from the perspective of doctors, a variety of intelligent clinical decision support systems are used to assist and improve diagnosis (Tian et al. 2019) Complex Adaptive Systems (CAS) are focusing on the relations and interconnections of the system components, rather than on the individual components themselves (Pype et al. 2018). Using complexity science to study healthcare has provided insights

that could not have been reached when only using the traditional explanatory model in medicine based on scientific positivism that describes the linear cause-effect relationship between two isolated events (Sweeney, Griffiths 2002). As such, many healthcare concepts (e.g. diseases) and systems (e.g. hospitals) have subsequently been described as CAS (Sweeney, Griffiths 2002; Thompson et al. 2016; McDaniel et al. 2009).

Consumer health informatics is the branch of medical informatics that analyses consumers' needs for information; studies and implements methods of making information accessible to consumers; and models and integrates consumers preferences into medical information systems (Eysenbach 2000). Over the years, medical informatics has focused mostly on developing applications for health professionals, implementation of applications for consumers was rarely the case. The increasing availability of interactive information that is accessible to consumers, most notably through the internet and related technologies coincides with the desire of most consumers to assume more responsibility for their health (Eysenbach et al. 1999; Jadad 1999). Home telehealth, personal health records, mHealth and The Quantified Self (QS) are examples of consumer health informatics. Thanks to the implementation of home telehealth patients and their families can use technology to monitor vital signs and symptoms of chronic diseases, transmit the data to a clinical site, and access tailored educational resources or communicate via video with home care providers. For patients with chronic conditions, the use of home telehealth is meant to reduce hospitalizations and allow for early detection and intervention (Demiris 2016). Personal health records are defined as "an electronic application through which individuals can access, manage, and share their health information in a private, secure, and confidential environment" (Foundation: Connecting for Health Personal Health Working Group 2003). Personal health records include tools to help individuals take a more active role in their own health (Tang et al. 2006). Mobile health (mHealth) refers to the use of mobile communication devices to facilitate health communication and access to health information, enable delivery of care services, and support clinical decision making (Demiris 2016). It is estimated that in 2015, approximately 500 million of the 1.4 billion worldwide smartphone users used some type of a mobile health care application (Research2Guidance, 2013). The Quantified Self (QS) movement which aims to improve various aspects of life and health through recording and reviewing daily activities and biometrics (Appelboom et al. 2014). As technology advances, the range of physiological parameters and environmental variables that can be measured keeps growing (including vital signs, steps, overall activity, caloric intake, sleep quality, time spent sitting, air quality, humidity, luminosity) (Demiris 2016).

Clinical Informatics is an interprofessional practice that combines medical practice with information technologies and behavioral management principles. Rather than a rigid academic or technical pursuit, clinical informatics is a practical discipline that improves patient outcomes, advances medical research, and increases the value of healthcare delivery (Jen et al. 2021). Clinical informatics has far-reaching applications including: Electronic Health Record, Predictive Medicine, Clinical Decision Support Systems. Aim of the Electornic Health Record (EHR) is to record every patient encounter, medication ordered, and laboratory test performed, the EHR impacts every aspect of a healthcare institution's operations (Foundation: Connecting for Health Personal Health Working Group 2003). One of the most promising applications of clinical informatics is predictive medicine. Predictive medicine is the science of accurately risk-stratifying an individual for developing the disease within a specified time-frame. Predictive tools based on big data has the potential to help clinicians better predict who will get sick when and how best to intervene before the patient becomes sick (Jen at al. 2021). Clinical DSS are used in medicine to aid clinicians in making diagnostic and therapeutic decisions in patient care. They can simplify access to data needed to make decisions, provide reminders and prompts at the time of a patient encounter and alert clinicians when new patterns in patient data are recognized (Payne 2000).

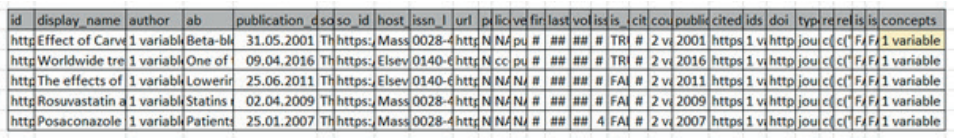
2. Methods

OpenAlex (named after the ancient Library of Alexandria) is an open catalog, which includes various entities and connections between them (OpenAlex 2023). Entities include works (journal articles, books, datasets, theses), authors, sources (journals, conferences, preprint repositories, institutional repositories), institutions, concepts and publishers. OpenAlex is a bibliographic database supported by data mainly from Scopus, WoS and Google Scholar. OpenAlex uses concepts that make up the Wikidata knowledge base to describe the content of publications.

The concepts on the basis of which the following studies were carried out are classified in OpenAlex on 6 levels, starting with 19 concepts at the main level, which branch into layers of descendants, forming a collection of about 65,000 concepts. Classification of concepts generally has hierarchical structure. But some concepts have interdisciplinary character and have two or more ancestors. Concepts are assigned to individual publications based on the title, abstract and title of its host place. Furthermore, for each concept assigned to the publication, its importance measured by the real *score* coefficient) is determined.

3. Results and discussion

The research was aimed at analyzing publications affiliated with the Medical University of Silesia in Katowice in terms of their connection with issues included in the area of Computer Science. First, a list of 14,136 publications from the Medical University of Silesia in Katowice was downloaded from the OpenAlex bibliographic database, including such data as: publication id, title, author, abstract, journal, date of publication, ISSN number or concepts (Fig. 2).



id	display_name	author	ab	publication_d	so	so_id	host_	issn_l	url	pd	lic	ve	fir	last	vol	iss	is_	cit	cou	public	cited	ids	doi	typ	re	rel	is	is	concepts
http	Effect of Carve	1 variable	Beta-blo	31.05.2001	Th	https:/	Mass	0028-4	http	N	NA	pu	#	##	##	#	TR	#	2 v	2001	https	1 v	http	jou	c(	c(	("	FA	FA	1 variable
http	Worldwide tre	1 variable	One of	09.04.2016	Th	https:/	Elsev	0140-6	http	N	cc	pu	#	##	##	#	TR	#	2 v	2016	https	1 v	http	jou	c(	c(	("	FA	FA	1 variable
http	The effects of	1 variable	Lowerir	25.06.2011	Th	https:/	Elsev	0140-6	http	N	NA	NA	#	##	##	#	FA	#	2 v	2011	https	1 v	http	jou	c(	c(	("	FA	FA	1 variable
http	Rosuvastatin a	1 variable	Statins	02.04.2009	Th	https:/	Mass	0028-4	http	N	NA	NA	#	##	##	#	FA	#	2 v	2009	https	1 v	http	jou	c(	c(	("	FA	FA	1 variable
http	Posaconazole	1 variable	Patients	25.01.2007	Th	https:/	Mass	0028-4	http	N	NA	NA	#	##	##	4	FA	#	2 v	2007	https	1 v	http	jou	c(	c(	("	FA	FA	1 variable

Figure. 2. Description of sample publications from the Medical University of Silesia in Katowice

Concepts are assigned to each publication based on the words contained in their title, abstract, and the title of its host place (Tab. 1) and each of them has parameters such as: OpenAlex concept id, wikidata concept id, display name, concept level and score. Level means successive descendant layers, starting from 0 indicating the main level, up to the level 5. Score, on the other hand, determines the certainty of the classifier in the choice of a given concept.

Table 1

Concepts for a single publication

No	Id	Wikidata	Display_ name	Level	Score
1	https://openalex.org/C2780591200	https://www.wikidata.org/wiki/Q412534	Carvedilol	3	0.9544748
2	https://openalex.org/C71924100	https://www.wikidata.org/wiki/Q11190	Medicine	0	0.9481240
3	https://openalex.org/C2778198053	https://www.wikidata.org/wiki/Q181754	Heart failure	2	0.6986554
4	https://openalex.org/C27081682	https://www.wikidata.org/wiki/Q269829	Placebo	3	0.6943185
5	https://openalex.org/C78085059	https://www.wikidata.org/wiki/Q641303	Ejection fraction	3	0.6266149

Table 1 cont.

No	Id	Wikidata	Display_ name	Level	Score
6	https://openalex.org/C44249647	https://www.wikidata.org/wiki/Q208498	Confidence interval	2	0.5679432
7	https://openalex.org/C2778721985	https://www.wikidata.org/wiki/Q1183680	Decompensation	2	0.5641719
8	https://openalex.org/C82789193	https://www.wikidata.org/wiki/Q2142611	Relative risk	3	0.5082704
9	https://openalex.org/C126322002	https://www.wikidata.org/wiki/Q11180	Internal medicine	1	0.5031356
10	https://openalex.org/C164705383	https://www.wikidata.org/wiki/Q10379	Cardiology	1	0.4306402
11	https://openalex.org/C197934379	https://www.wikidata.org/wiki/Q2047938	Adverse effect	2	0.4105666
12	https://openalex.org/C42219234	https://www.wikidata.org/wiki/Q131130	Anesthesia	1	0.3409184

For further analysis, concepts with a score greater than 0 were taken into account. These concepts are grouped, then the score values for individual concepts are summed up, and then sorted by the total score value. In this way, we obtain a list of the most important concepts in the analyzed works (Tab. 2).

Table 2

Part of the table showing total_score results for each medical concept

No	Id	Display_name	Total_score
1	https://openalex.org/C71924100	Medicine	8019.58543
2	https://openalex.org/C126322002	Internal medicine	3859.26797
3	https://openalex.org/C164705383	Cardiology	1181.61756
4	https://openalex.org/C185592680	Chemistry	1115.01945
5	https://openalex.org/C134018914	Endocrinology	988.75308
6	https://openalex.org/C86803240	Biology	888.79391
7	https://openalex.org/C141071460	Surgery	874.35678
8	https://openalex.org/C2908647359	Population	533.85639
9	https://openalex.org/C90924648	Gastroenterology	532.88443
10	https://openalex.org/C203014093	Immunology	516.98749

Table 2 cont.

11	https://openalex.org/C2779134260	Disease	484.08618
12	https://openalex.org/C500558357	Myocardial infarction	391.10553
13	https://openalex.org/C142724271	Pathology	390.53460
14	https://openalex.org/C555293320	Diabetes mellitus	372.73302
15	https://openalex.org/C15744967	Psychology	352.92913
16	https://openalex.org/C98274493	Pharmacology	342.41419
17	https://openalex.org/C187212893	Pediatrics	323.92426
18	https://openalex org/C121608353	Cancer	320.65181
19	https://openalex.org/C177713679	Intensive care medicine	319.06229
20	https://openalex.org/C2911091166	Transplantation	314.26488

Overall, the most prevalent concepts in the publications were concepts regarding the field of the medicine such as: medicine, internal medicine, cardiology, chemistry, endocrinology, biology, surgery, population, gastroenterology and immunology.

In order to determine the most important concepts in the field of computer science, from the obtained list of 11,803 concepts, we filter out those that are in the area of computer science, according to the openalex concept graph (Tab. 3). The most prevalent concepts concerning computer science in the publications were: computer science, logistic regression, artificial intelligence, schizophrenia (object-oriented programming), multivariate analysis, receiver operating characteristic, univariate analysis, algorithm, computer vision and process.

Table 3

Part of the table showing total score results for each computer science concept

No	Id	Display name	Total score	Type
1	https://openalex.org/C41008148	Computer science	154.050922	Computer science
2	https://openalex.org/C151956035	Logistic regression	71.035605	Computer science
3	https://openalex.org/C154945302	Artificial intelligence	65.859091	Computer science
4	https://openalex.org/C2776412080	Schizophrenia (object-oriented programming)	49.295028	Computer science
5	https://openalex.org/C38180746	Mutivariate analysis	44.368518	Computer science

Table 3 cont.

No	Id	Display name	Total score	Type
6	https://openalex.org/C58471807	Receiver operating characteristic	38.006075	Computer science
7	https://openalex.org/C46762472	Peripheral	31.413913	Computer science
8	https://openalex.org/C11413529	Algorithm	30.288503	Computer science
9	https://openalex.org/C144301174	Univariate analysis	30.231545	Computer science
10	https://openalex.org/C31972630	Computer vision	23.454699	Computer science
11	https://openalex.org/C98045186	Process (computing)	17.016801	Computer science
12	https://openalex.org/C2778715743	Prosthesis	15.578284	Computer science
13	https://openalex.org/C153180895	Pattern recognition (psychology)	14.683867	Computer science
14	https://openalex.org/C2779679103	Degradation (telecommunications)	14.325376	Computer science
15	https://openaiex.org/C2775841894	Sleep (system call)	13.130052	Computer science
16	https://openalex.org/C12713177	Perspective (graphical)	11.939481	Computer science
17	https://openalex.org/C12174686	Risk assessment	11.337850	Computer science
18	https://openalex.org/C104779481	Composite number	10.699288	Computer science
19	https://openalex.org/C99476002	Analysis of variance	10.107022	Computer science
20	https://openalex.org/C161191863	Library science	10.085594	Computer science

Once we have concepts from both groups at our disposal, we calculate the strength of their connections by calculating the arithmetic mean of the score value for each pair of IT and medical concepts contained in a single publication. For example, to calculate the strength of the links between The Internet and Nursing in a specific publication, we add the score values of both concepts and then divide by 2. The resulting averages are summed up with each other within the

same pairs of concepts. The obtained data were visualized using a heat map based on a square matrix, and the relationships between 25 concepts from both groups with the highest degree of association were presented (Fig. 3).

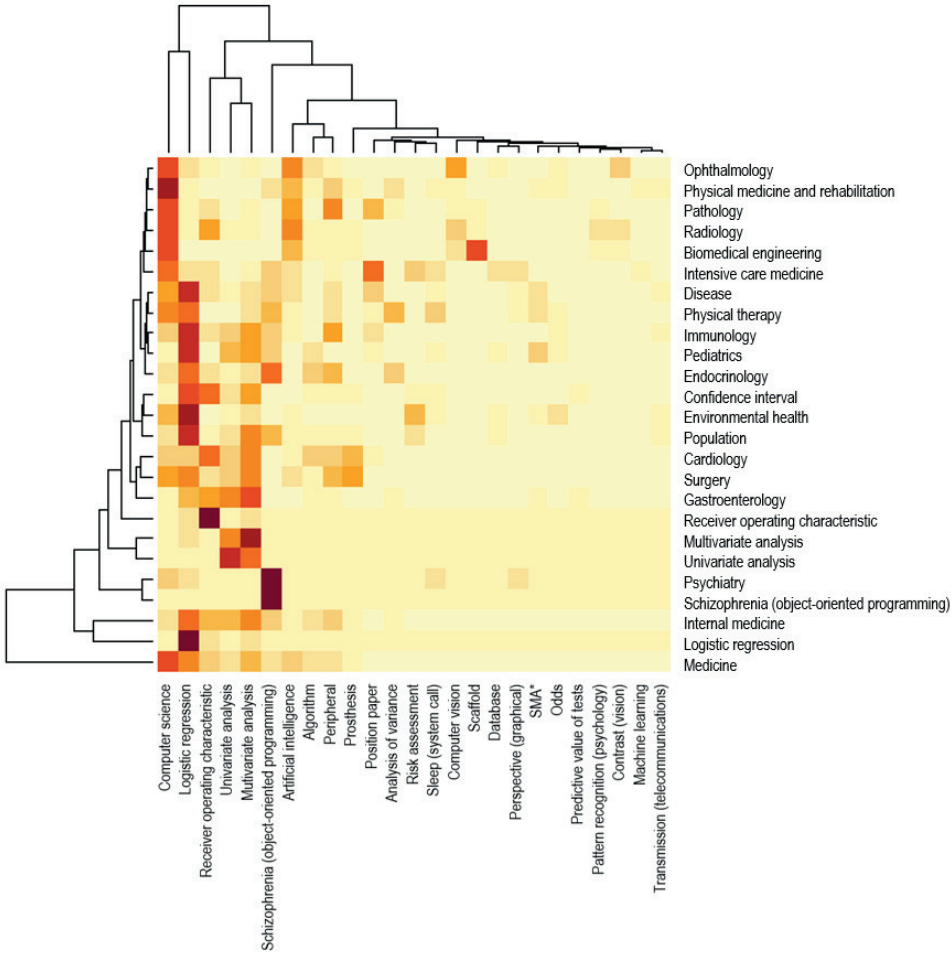


Figure 3. Heat map showing the coexistence of the 25 most common medical and IT concepts

For further analysis, we take into account concepts belonging to only one of the analyzed medical or computer science groups, for this purpose we remove those that appear simultaneously in both groups. After selecting data on key

concepts for the Medical University of Silesia and concepts represented by scientific knowledge in the field of computer science, research was carried out on the links between them (Tab. 4).

Table 4

Fragment of the table with data showing the score of links between concepts in individual publications

Concept name	Computer science	Artificial intelligence	Human computer interaction
Medicine	120.14946871	48.6163478	1.6221291
Endocrinology	2.50972404	0.5952675	0.0000000
Internal medicine	21.42572445	7.2793859	0.1038922
Anatomy	3.83453393	1.7476726	0.0000000
Surgery	12.60463382	4.9168730	0.2712516
Radiology	9.72081481	7.2888692	0.0000000
Environmental health	5.00787376	0.3396549	0.0000000
Pathology	9.24241992	5.2239793	0.0000000
Nuclear medicine	4.10885481	2.6392507	0.0000000
Psychiatry	8.56483308	1.6106183	0.2380379
Anesthesia	2.11922226	1.3306540	0.0000000
Cardiology	7.41956755	3.1499599	0.1141980
Audiology	3.45798585	1.2490722	0.0000000
Physical medicine and rehabilitation	7.80857815	2.9953318	0.2467440
Physical therapy	6.14922054	1.6860576	0.3718766
Physiology	0.00000000	0.0000000	0.0000000
Intensive care medicine	5.69107251	1.9829336	0.1437431
Pharmacology	4.91574598	0.7197974	0.0000000

Due to the structure of the ontology used and the fact that the same concepts occur in both groups of concepts, and thus the existence of connections between identical concepts, a decision was made to conduct another experiment. For this purpose, concepts belonging to only one of the analyzed medical or computer science groups were taken into account for further analysis, while those concepts that appeared simultaneously in both groups were removed.

The results were also visualized using a heatmap, presenting the relationships between 25 concepts from both groups with the most common associations (Fig. 4). In the rows there are concepts from the field of medicine, and in the columns the most frequently related IT concepts.

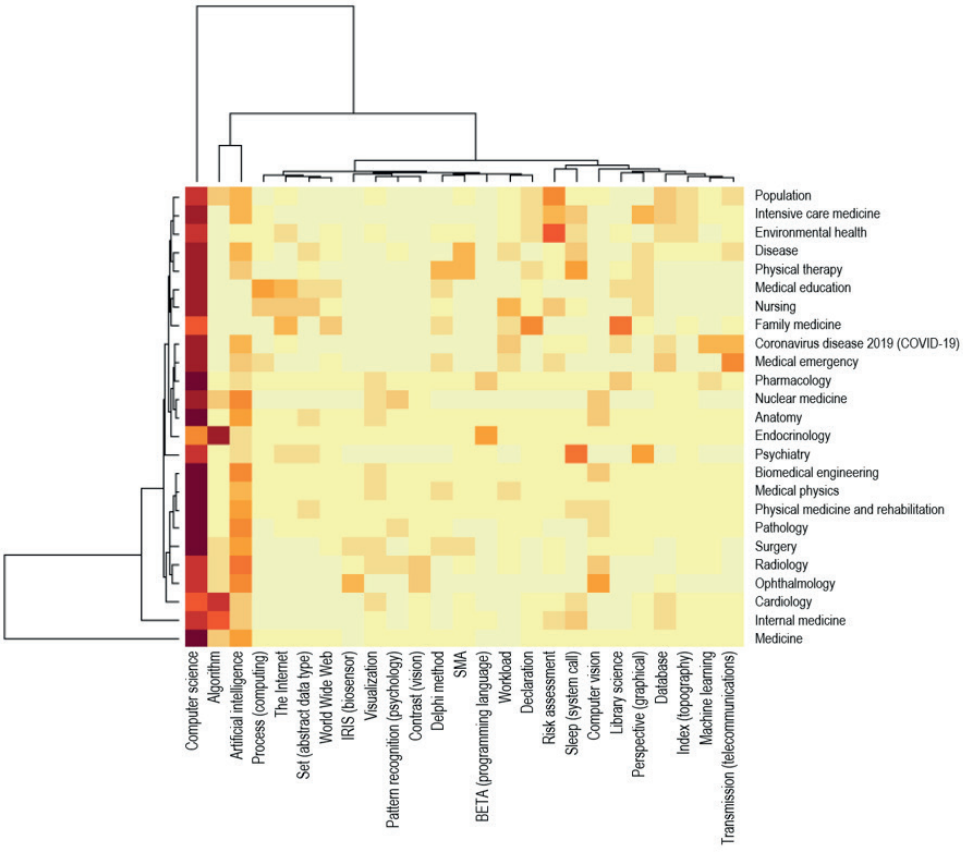


Figure 4. Heat map showing the coexistence of the 25 most common medical and IT concepts in the relationship, excluding concepts that recur in both groups

A spectrum of colors from light yellow to brown was used to present the results, where the darker ("warmer") the color indicates greater integration between concepts. As can be read from the above heatmap, the concept of Computer Science is most often used, with 25 medical concepts selected, this is largely due to the fact that it is located in the concept tree, it is the root of the tree. Another IT concept

that often coexists in medical publications is artificial intelligence, with its greatest integration observed in issues such as Radiology, Nuclear Medicine, Biomedical engineering, Pathology, or Ophthalmology. As expected artificial intelligence was highly integrated with Radiology, Nuclear Medicine, Biomedical engineering Pathology and Ophthalmology, since artificial intelligence is widely used in these fields (artificial intelligence algorithms- deep learning used in image recognition tasks in the field of radiology, diagnosis and treatment monitoring in the field of nuclear medicine, drug discovery and development of personalized medicine in the field of biomedical engineering, error reduction and expert communication in the field of pathology and medical imaging identification in the field of ophthalmology.

We can also highlight the important links between Algorithms and Endocrinology, Cardiology and Internal Medicine. We can also pay attention to the connection of Process (computing) with Medical Education and Nursing, or The Internet with Medical Education, Nursing and Family Medicine.

During the conducted research, certain aspects were encountered that may disturb the proper interpretation of the results. Firstly, polysemous concepts were present, which pertain to different entities despite sharing the same name. Examples of such include "Declaration", "Contrast (visio)", "Sleep (system call)" or "Schizophrenia (object-oriented programming)". Consequently, their integration with medical concepts may raise certain doubts. Another issue is the fact that within the OpenAlex database, there are instances where assigning concepts to publications may be disputable. Additionally, it should be noted that the data structure is not typically tree-like; it rather assumes the form of a graph which is not a hierarchical structure. As a result, the same concepts may be assigned to different areas; an example of this could be the concept of logistic regression.

4. Conclusions

The conducted research confirms the importance of IT issues in publications in the field of medicine, especially in the context of artificial intelligence applications in medicine. Such collaboration enables the creation of innovative solutions that have the potential to significantly enhance healthcare.

The study of interdisciplinarity in publications on the basis of text analysis of both titles and abstracts gives great opportunities and encourages further research in this area. The methodology used in the research, based precisely on content analysis, allows for a deeper analysis of the interdisciplinarity of publications, by delving into the subject matter in detail, employing research methods, or using discipline-specific terminology. Such an approach enables the assessment of the degree of integration between disciplines as well as in the context of specific

studies. In the broader perspective, it may facilitate the identification of new, not always obvious connections between disciplines or contribute to the discovery of new research areas.

Ewelina Paluch's participation in the publication presents the results of research carried out as part of the project no. 54/SD/2021/PRO financed from the funds of a subsidy granted to the Krakow University of Economics.

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Summary

Over the years, the study of the interdisciplinarity of publications has taken various forms, from its identification based on the disciplines represented by the authors, through the examination of citations used when writing the article, to the analysis of the publication text itself. The last of these approaches seems to be the most reliable in the context of verifying the real integration between disciplines in a specific text. The approach utilized in the conducted research facilitates a deeper analysis of integration not only between disciplines in general but also between specific issues within their domains, aiding the examination of the intensity of such connections. The research was aimed at analyzing publications affiliated with the Medical University of Silesia in Katowice in terms of their connection with issues included in the area of Computer Science. OpenAlex, a bibliographic database supported by data mainly from Scopus, WoS and Google Scholar, which uses concepts that make up the Wikidata knowledge base to describe the content of publications was used. A list of 14,136 publications from the Medical University of Silesia in Katowice was downloaded from the OpenAlex bibliographic database including such data as: publication id, title, author, abstract, journal, date of publication, ISSN number or concepts. Overall, the most prevalent concepts in the publications were concepts regarding the field of the medicine (medicine, internal medicine, cardiology). The most prevalent concepts concerning computer science in the publications were: computer science, logistic regression and artificial intelligence. The strenght of the connections between concepts regarding medicine and computer science was calculated by calculating the arithmetic mean of the score value for each pair of IT and medical concepts contained in a single publication. The study showed the importance of computer Science issues in the medical publications and highligted the growing importance of AI in the field of medicine.

JEL codes: I29, I19, Y80

Keywords: *interdisciplinarity, scientific publication, medicine, computer science, artificial intelligence*

Managerial Economics
2024, Vol. 25, No. 2, pp. 159–172
https://doi.org/10.7494/manage.2024.25.2.159

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Functional business valuation – purpose is king!

1. Functional business valuation in the tension field between objective and subjective valuation theory

Determining the value of a company is one of the main tasks to be done in preparation for negotiations about an intended transfer of ownership (Hering 2021, pp. 5 f.). Both the prospective seller and the presumptive buyer, who are henceforth called **valuation subjects**, are interested in finding the value of the company in question (**valuation object**) in order to judge the economic adequacy of a given price in an emerging negotiation (Matschke, Brösel 2021, pp. 55 f.; Matschke et al. 2024, p. 141). Hereby, the purchase/sale promotes the interest of the potential buyer/seller as long as the price paid/received for the acquired/sold company does not exceed/is not less than the value associated with it (Hering et al. 2006, p. 407; Matschke et al. 2010, pp. 9 f.; Brösel et al. 2012a, p. 243). Then, the transaction causes no economic loss (Olbrich et al. 2015, p. 5; Herbener, Rapp 2016, p. 20; Follert et al. 2018, p. 319; Toll, Kintzel 2019, p. 1081).

While **objective business valuation theory** (Moral 1920; Mellerowicz 1952) pursues the futile quest for the one true value that must be generally valid for all parties, **subjective business valuation theory** (Käfer 1946; Busse von Colbe 1957; Münstermann 1966) focuses on the specific valuation subject, taking into account its personal intentions and expectations. Even further goes the **functional business valuation theory** (Matschke 1975; Sieben 1976; Moxter 1983; Hering

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2021; Matschke, Brösel 2021; Matschke et al. 2024), as being addressed in the present contribution, which stresses the significance of purpose orientation, by which means not only distinct, individual values with regard to distinct valuation subjects are presumed, but even diverging values for the same valuation subject depending on diverging purposes of valuation.

Subjective as well as functional business valuation theory are based on the principles of **subjectivity, future orientation and entity valuation** (Münstermann 1966, pp. 18–28; Hering et al. 2006, p. 408; Matschke et al. 2010, p. 3; Brösel et al. 2012a, p. 244; Olbrich et al. 2015, pp. 18–20; Herbener, Rapp 2016, pp. 14 f.; Matschke, Brösel 2021, pp. 11 f.; Brösel et al. 2023, p. 11), whereby the latter is supplemented by the principle of **purpose dependency** (Moxter 1983, pp. 5–8; Matschke et al. 2010, pp. 4 f.; Brösel et al. 2011, p. 31; Brösel et al. 2012b, p. 93; Olbrich et al. 2015, pp. 29 f.; Matschke, Brösel 2021, p. 11):

- Since business valuations are made from a specific decision-maker's point of view, for example, a presumptive buyer or seller, his target system – which discloses the will or ends – and decision field – which indicates the means and limitations – must enter into the valuation process, thus satisfying the presumption of **subjectivity** and allowing the determination of subjective marginal prices.
- According to the principle of **future orientation**, all expected future cash flows are attributed to a valuation object for a going-concern alternative. Past company earnings serve as nothing more than mere indicators for a prognosis of the projected future trend of earnings.
- Following the principle of **entity valuation**, a company as a whole business unit is viewed as an entity since synergy effects (positive as well as negative) may lead to a situation in which the sum of the values of all of its single assets may not mirror the entire value of the company.
- The principle of **purpose dependency** introduces a specific purpose as the basis for a determination of business values. Depending on a single task resp. intended function of business valuation, there can result "purpose-related" values, which are bound to specific intentions belonging to specific valuation tasks.

If the company valuation to be done aims at a transfer of ownership rights of a valuation object (i.e., a company), a distinction into main functions of functional company valuation is of the utmost importance. Three relevant main functions to be mentioned are the **decision function**, the **mediation function** and the **argumentation function**. Valuations that have no influence on existing

ownership rights fall into the realm of secondary functions (e.g., information function, taxation function, contract arrangement function), which are not discussed herein (Matschke, Brösel 2021, pp. 14 f.). Of chief interest are those three main functions and their assigned value concepts, which are characteristic for functional company valuations. Hence, in the present contribution, we would like to give a comprehensive overview to interested economists as well as practitioners concerning the basic concepts of functional company valuation theory as a viable alternative to mainstream valuation theory and practice, which is dominated by market-oriented procedures that belong to the so-called "younger objective valuation theory" due to their "neo-classical", finance-theoretical origin. However, the fact that a "unique" equilibrated and "objective market" value cannot exist in real valuation situations, even though persistently propagated by "finance theoreticians", is an immediate consequence of a functionally graded problem perception. To anchor those alternative valuation procedures, as offered by "functionalists", not only in valuation-theoretical literature but also in business practice, there is certainly a demand for an easily "digestible" overview. This is the motivation from which the relevance of the present contribution stems, whereby not only the ruling principles of functional company valuation are worked out in concise form, but also insights into useable valuation models, which are specific to each main function, are briefly discussed. All of this lies at the center of the following three sections. The contribution ends in Section 5 with a brief summary of the lessons learned.

2. The decision function in functional business valuation theory

The **decision function** is the most important main function, by which means a **decision value** – to be understood as a subjective marginal price for a company and, thus, the outermost limit of willingness of concession for a respective valuation party – is determined (Matschke 1975, pp. 26 f.; Matschke, Brösel 2021, pp. 13 f.). Since finance-theoretical valuation procedures disregard the individual target and decision field of a certain valuation subject, investment-theoretical and therefore individually suited procedures have to be applied for the determination of decision values, by which means individual conditions, as given for a certain valuation subject, are taken into consideration. In contrast to valuation methods based on finance theory, which abstract from the point of view of valuation subjects and presume an idealized, complete and perfect capital market, investment-theoretical

valuation methods have the advantage that decision-supporting assessments of cash flows are made possible, which are applicable under more realistic capital market conditions (Hering, Toll 2015, p. 15; Hering 2021, pp. 201–203, 306, 311; Matschke, Brösel 2021, pp. 13 f.).

To exemplify the valuation process for determining marginal prices in advance of an acquisition of a company under the condition of an imperfect capital market under quasi-certainty, the investment-theoretically well-founded state marginal price model (SMPM) is considered here (Hering et al. 2015, pp. 3 f.; Hering 2021, pp. 45–52). The procedure can be broken down into two main steps (see Fig. 1), namely the determination of the base and the valuation approach (Matschke, Brösel 2021, p. 65).

In the approach for the **base program** (step 1) it is assumed that there are no changes of ownership rights of the valuation object (Hax 1964; Franke, Laux 1968, p. 755; Matschke et al. 2010, pp. 13 f.; Lerm et al. 2012, p. 265; Hering et al. 2013, p. 42). Here, only the level of utilities is of interest which can be reached by a valuation subject if the intended purchase of the company is just not realized. Under this assumption, the very investment and financing program is to be calculated which **maximizes** the target function value (income *EN* or wealth *GW*) consistent with the target system of a given valuation subject. We can differentiate between the target of maximization of income and wealth, whereby income maximization is assumed in the valuation scenario presented below, i.e., the withdrawals at certain points in time *t* are governed by individual consumption preferences of the valuation subject. As additional constraints, we demand the satisfaction of liquidity conditions to ensure a continuous solvency of the valuation object. Thereby, we guarantee that at any time *t* the sum of the cash flows from the realized investment and financing objects as well as the balance of predisposed, decision-independent payments is not less than the desired withdrawals within each period.

Illustrated by the example of a company purchase, the valuation object (company) is now to be integrated into the previously established investment program of the presumptive buyer by formulating a corresponding **valuation approach** (step 2), in which the **maximum affordable price** is sought (Hering et al. 2015, p. 4; Hering 2021, p. 52). The presumptive buyer must determine the price he can afford to pay without the acquisition proving disadvantageous. In other words, the buyer has to know which price would not create a worse economic position than if he had refrained from the transaction. Hence, the valuation approach contains the additional constraint which demands that the maximal width of the income stream (EN^*), as has been determined in the base approach, is at least reached in the valuation program as well: $EN \geq EN^*$.

base approach	valuation approach	quantity constructs
max. Entn; Entn := EN	max. U; $U := p$	
$-\sum_{j=1}^{m} g_{j0} \cdot x_j \leq b_0$	$-\sum_{j=1}^{m} g_{j0} \cdot x_j + p \leq b_0$	
$-\sum_{j=1}^{m} g_{jt} \cdot x_j + \overline{w}_t \cdot EN \leq b_t$	$-\sum_{j=1}^{m} g_{jt} \cdot x_j + \overline{w}_t \cdot EN \leq b_t + g_{Kt}$	$\forall\, t \in \{1, 2, \dots, n\}$
	$-EN \leq -EN^*$	
$x_j \leq x_j^{\max}$	$x_j \leq x_j^{\max}$	$\forall\, j \in \{1, 2, \dots, m\}$
$x_j, EN \geq 0$	$x_j, EN, p \geq 0$	$\forall\, j \in \{1, 2, \dots, m\}$

Symbols: Entn := EN = width of the income stream; EN^* = maximum target function value of the base program; g_{jt} = cash flow of object j at point in time t; x_j = number of realizations of object j; $x_j^{\max}$ = maximally allowed number of realizations of object j; $\overline{w}_t$ = weighting factor for the width of the income stream at point in time t; b_t = fixed given autonomous payment at point in time t; $U := p$ = price of the valuation object; g_{Kt} = cash flow of the purchase object K at point in time t; n = planning horizon (number of planning periods); m = number of objects j

Figure 1. Base and valuation approaches of the SMPM

To determine the maximum affordable price p^* in a partial-analytical way, we can, under the presumption of known endogenous discount factors ρ_t resp. endogenous marginal interest rates i_t, apply a so-called **complex valuation formula** derived by means of the duality theory of linear optimization (Laux, Franke 1969, pp. 214–218; Hering et al. 2015, pp. 5; Toll, Kintzel 2019, p. 1088; Hering 2021, pp. 53 f.; Matschke, Brösel 2021, p. 130; Kintzel, Toll 2022, p. 1290). The following notation particularly emphasizes the relation to the future earnings value:

$$p^* = \underbrace{\sum_{t=1}^{n} g_{Kt} \cdot \rho_t}_{\substack{\text{future earnings} \\ \text{value of the} \\ \text{valuation object}}} + \underbrace{\sum_{t=0}^{n} b_t \cdot \rho_t + \sum_{C_j > 0} x_j^{\max} \cdot C_j - \sum_{t=1}^{n} \overline{w}_t \cdot EN^* \cdot \rho_t}_{\substack{\text{net present value difference due to restructuring} \\ \text{from base to valuation program}}}$$

with $\rho_t = \prod_{\tau=1}^{t} \left(1 + i_\tau\right)^{-1}$ = endogenous discount factors

and $C_j = \sum_{t=0}^{n} g_{jt} \cdot \rho_t$ = net present value of object j.

It is obvious that the **marginal price** p^* and the **future earnings value** don't necessarily match in imperfect capital markets unless the change in net present value by means of restructurings between the base and valuation programs vanishes. In this case, due to the identity of the marginal price p^* and the future earnings value E_K, the "complex" valuation formula can be transferred into a **simplified valuation formula**, which can be recast as follows (Laux, Franke 1969, pp. 210–214; Brösel et al. 2012a, pp. 245–249; Hering et al. 2015, pp. 5 f.; Olbrich et al. 2015, pp. 21 f.; Rapp et al. 2018, pp. 565–573; Hering 2021, pp. 55–57; Matschke, Brösel 2021, p. 131):

$$p^* = \sum_{t=1}^{n} g_{Kt} \cdot \rho_t = E_K = \text{future earnings value from the viewpoint of the buyer.}$$

3. The mediation function in functional business valuation theory

The second main function of functional valuation theory is the **mediation function**, by which means an arbitration value is determined that lies between the marginal values of both the prospective buyer and the seller. This value, e.g., introduced by an impartial arbitrator as an arithmetic mean of both marginal prices, should achieve a certain balance of interests for both conflict parties involved in a company transaction (Matschke 1979; Brösel et al. 2012a, p. 243; Olbrich et al. 2015, p. 31; Matschke, Brösel 2021, pp. 213–256). The anonymous market can also function as such an arbiter (Hering 2021, p. 6.).

If the conflict situation is **non-dominated** – which means no conflict party (buyer resp. seller) has the ultimate power to enforce the transfer of ownership rights against the will of the counterparty – the arbitration value serves different roles: It can be seen as a non-binding recommendation of an impartial arbitrator, as a possible starting point for further negotiations or as an actual accepted exchange value after a common initial cross-party agreement with regard to the validity of a valuation made by the arbiter. The higher the relevance of the imposed arbitration value for the conflict parties is, which means the stronger both parties are bound by the propositions of an independent authority, the more careful their related interests have to be considered, which are, so to speak, ultimately channeled into an arbitration value being put forward. Even though the governing decision values remain confidential, the arbitrator should do all he can to serve the interests of both parties in the best-possible way and should devote himself fully to the determination of an intersubjectively verifiable and justifiable, in the best case "fair", but in any case for all sides **acceptable** arbitration value.

If the arbitration value has merely a recommendatory character, the requirements for its determination are mitigated: The proposition of a basically acceptable potential interval of agreement, which may serve as a measuring metric or a starting point for further negotiations, is a non-binding recommendation and can, in the most extreme case, also lead to a cancelation of negotiations, which should be introduced by an arbiter as a possible outcome at the outset of negotiations.

As a particularly interesting application area of the mediation function, therefore remains the determination of an arbitration value as a certain kind of exchange value being subjected to stricter requirements. If the proposition for a compromise introduced by the arbitrator is stated as binding, the limits of willingness to concession of both parties must not be violated to fulfill the **postulate of rationality of actions** to lead to an acceptable resolution to a conflict solution for both sides. Hence, the existence of an arbitration area, which is spanned by the decision values of both parties, representing the presumptive area of agreement (see Fig. 2), is a basic prerequisite for non-dominated conflict situations (Matschke, Brösel 2021, pp. 215 f.).

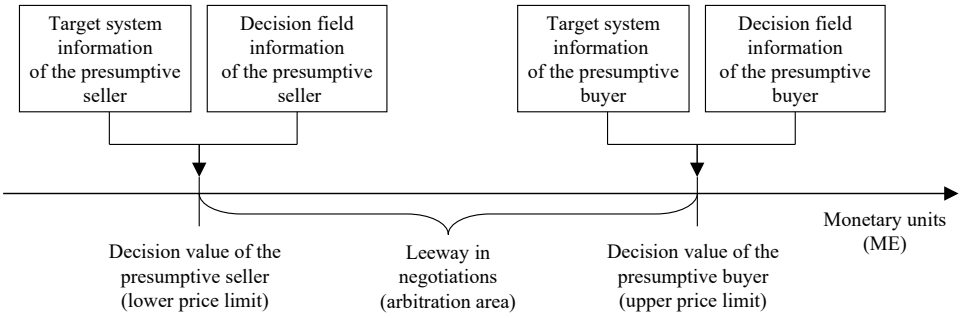

Figure 2. The area of agreement for the arbitration value

The starting point for the determination of an arbitration value to be proposed should be the decision values of both parties, which, however, are normally unknown to an impartial arbiter and could be estimated at best. For this purpose, the impartial arbiter puts himself in the position of both the buyer and the seller in the framework of a non-dominated acquisition-sale conflict situation to estimate their presumable target systems and decision fields as well as the respective subject-related future earnings associated with the valuation object as thoroughly as possible by applying a well-posed investment-oriented valuation procedure – like the state marginal price model (SMPM) as presented in Section 2, for instance. If an area of agreement and, thus, a possible arbitration value exists

that does not violate the limits of concession of both parties, the basic postulate of the rationality of actions is served justice.

In a second step, the arbiter has to turn his attention to the **postulate of party-related adequacy**. The conflict solution concerning the proposal of an arbitration value has to be based on a fairness postulate, which should lead to an acceptable and balanced agreement for both parties. As a possible distribution rule, **the rule of absolutely equal division** could be justified for which the difference between the buyer's upper price limit and the seller's lower price limit as the total distributable benefit is granted in exactly equal parts to both parties.

A thoroughly performed weighing of interests, which has to be done by an arbiter in the framework of a determination of arbitration values, is of the utmost importance in particular in those conflict situations in which changes of ownership rights can be enforced on the opposite party even against their will. Such a **dominated conflict situation** is further aggravated if there is no area of agreement, but the arbiter still has to assign an arbitration value. In the following, we present a special **model for the determination of an adequate cash compensation** to be chosen in the context of a "squeeze out" (Toll, Benda 2014, pp. 365 f.; Hering et al. 2019, p. 40), which illustrates the objective of the protection of minorities (here: the minority shareholder), when determining an arbitration value (here: in the form of a compensation). According to the regulation of Germany's Federal Court of Justice (BGH), only the maximum of both the stock market price and the future earnings value per share is eligible for compensation, which means, it should be considered as adequate to define an arbitration value.

The main parameters of the model are the cash compensation (CC) offered by the majority shareholder as well as the maximum minimal claim of the minority shareholders to be compensated ($\max\{MP; SV_j^{\min}\}$), which consists of the maximum of the **stock market price** (MP) and the corresponding share value as computed according to the future **earnings value method** ($SV_j^{\min}$). Thereby, $SV_j^{\min}$ is determined by the maximum of minimal claims of the individual minority shareholders j. For the party to be compensated, the following acceptable conflict solution results under the consideration of the fundamental assumption of the best alternative strategy: $\{CC \mid CC \geq \max\{MP; SV_j^{\min}\}\ \forall j\}$. The **decision value** of the minority shareholders in the case of a long-term holding strategy results as follows: Starting from the maximum width of the payout stream $EN^{\max}$ of the company in question in the initial situation (without squeeze out), it is determined which proportion of dividend payouts is attributable to each share: $D = (\beta \cdot EN^{\max})/N$. Thereby, $\beta \cdot EN^{\max}$ is the proportion of dividend payouts to be distributed to the minority shareholders, and N is the number of shares entitled to compensation. Furthermore, an unlimited time horizon for the going-concern

is assumed. To determine SV_j^{min} the annual proportion of dividend payouts for each share (D) is to be divided by the very interest rate (r_j), which is seen as the best alternative use from the minority shareholders' point of view to compute an individual present value according to the future earnings value method using the well-known capitalization formula for each share: $SV_j^{min} = D/r_j$. Since each minority shareholder has its own individual best alternative use, and since the maximum of all minimal claims is always relevant, the lowest alternative interest rate is assumed for each minority shareholder ($\min\{r_j\}$), which gives the highest share value. Hence, the following holds: $\max\{SV_j^{min}\} = D/\min\{r_j\}$.

The **adequate cash compensation** in the case of a non-existing area of agreement is then to be determined as follows (Toll, Benda 2014, p. 366; Hering et al. 2019, p. 40; Matschke et al. 2024, p. 652):

$$CC_{adequate} = \{CC \mid CC = \max_j\{MP; SV_j^{min}\}\} = \max\{MP; D/\min\{r_j\}\}.$$

4. The argumentation function in functional business valuation theory

The value concept that is most prevalent in business practice is the **argumentation value**, which is introduced in negotiations to enforce one's own negotiation position or to influence the opposite party (Matschke 1976; Brösel et al. 2012a, pp. 243 f.; Olbrich et al. 2015, pp. 32 f.; Matschke et al. 2020; Matschke, Brösel 2021, pp. 259 ff.). Since the cross-party objective for a negotiation aimed at a presumptive change in ownership rights is to reach a negotiation result that is as far away as possible from one's own limit of concession, a full position-strengthening rationale is channeled and cast into an argumentation value, disguised as an alleged decision value or purported impartial arbitration value.

Concerning the argumentation function, it is not only necessary to know one's own decision value, but also to have a perception of the decision value of the opposite party. Argumentation values can aim at occupying a more favorable position within the estimated area of agreement with **manipulative intent** or – following a more **cooperatively minted intent** – at a change or widening of an existing area of agreement, which enlarges the benefits for both parties in the case of an agreement. A widening of the area of agreement might come about by providing or underpinning information, which could lead the opposite party to adapt its decision value (Matschke, Brösel 2021, p. 266). Thereby, it is inevitable to convince the negotiation partner about the validity of the propagated information and the proposed value. In particular, methods used for valuation should be basically accepted by the recipient.

Currently, **valuation reports** made by auditors based on Anglo-Saxon valuation theory boast a high degree of credibility among practitioners. Even though they do not allow one to compute real decision values, they can certainly be used to introduce some kind of argumentation values during negotiations. Popular – besides the theoretically unfounded valuation by comparables – are the various **discounted cash flow** (DCF) **methods**, which are in fact based on unfirm foundations, but are held as almost sacrosanct by the majority of valuation addressees. The "text book formula", which predominates in Anglo-Saxon publications, is presented pars pro toto below, by which means so-called free cash flows (FCF^e) are discounted using a weighted average cost of capital (k = WACC) (for a comprehensive discussion see Olbrich et al. 2015, pp. 6–17; Hering 2021, pp. 266 ff.):

$$V = \frac{FCF^e}{k} = \frac{FCF + (1-s)\cdot i \cdot FK}{i_{EK}\cdot\frac{EK}{V} + (1-s)\cdot i \cdot \frac{FK}{V}}.$$

Symbols: FCF^e = expected free (gross = net) cash flow at the hypothesis of pure equity financing; k = weighted average cost of capital; FCF = expected free (net) cash flow; s = corporate tax rate; i = discount rate in a perfect market; FK = market value of debt capital ($FK = V - EK$); i_{EK} = expected rate of return of equity capital; EK = market value of equity capital ($EK = V - FK$); V = total company value in equilibrium ($V = EK + FK$).

5. Insight benefits of functional business valuation theory

The Anglo-Saxon capital market-oriented school of valuation, which pursues the futile quest for the one true value, has been confronted in the present contribution by the German school of functional business valuation. In view of the three previously addressed main functions, the purpose-dependency of valuation as well as their corresponding task-specific values clearly emerge in the previous sections. Beyond idealized model worlds, it should be stated that the "one and only" company value simply cannot exist. To try to find a solution to realistic valuation problems under the assumption of a perfect, complete capital market with perfect competition can confidently be classified as an aberration. The recent financial market crisis may serve as an indication for this statement. Since the capital market-oriented DCF methods propagated by Anglo-Saxon and internationally operating "investment banks" as having no alternative are associated with a welter of new problems (Hering 2021, pp. 273–290) due to a coupling

of incompatible finance-theoretical equilibrium models (capital structure models of Modigliani/Miller, capital asset pricing model and option pricing models), it is not surprising that many serious company crises were inflicted in the course of erroneous strategic company decisions caused by unrealistic company valuations. Although the North American investment banks were not the sole trigger of the financial market crisis that spread across the globe, they can at least be seen as a kind of "fire accelerant" (Brösel, Toll 2011; Brösel, Toll 2016, pp. 37; Hering 2021, pp. 341–343). To avoid such misdevelopments happening again, researchers are called upon to stand up firmly as a critical corrective instead of being hired out as pure "henchmen" of North American consulting firms (Brösel, Toll 2016, p. 43). Thus, valuation theory and practice must be made more aware of the fact that functional company valuation theory allows one to deliver valuation approaches that can bridge the gap between the diversities of individual valuation situations and is more narrowly oriented toward the reality of everyday business practice, particularly due to its core principle of purpose dependency being operationalized by the main functions, as explained in the present contribution. The supporting pillars of the school of functional company valuation theory emerge clearly through its main functions, which reflect the inherent complexities within valuation situations, by which means they can be appropriately resolved and analyzed at all in the first place (Hering 2021, pp. 7 f., 14, 201–203, 327–347).

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Summary

In the present contribution, we discuss the basic principles of functional business valuation. In addition to a distinction between objective and subjective valuation theory, the differences between finance-theoretical and investment-theoretical valuation approaches are worked out. The core of our discussion is devoted to an overview of the three main functions and value concepts of functional business valuation theory.

JEL codes: C78, D46, G31, G34

Keywords: *functional business valuation, decision function, mediation function, argumentation function*

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Book with an editor

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All the items cited in the main text, and no other items, must be placed in the list of references.

Authors should include 2–3 JEL codes with manuscript during submission. For more details on the JEL classification system CLICK HERE.

Information about the journal and the deadlines for submitting articles for next issues are presented at

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Double blind peer review procedure

1. In order to assess a quality of submitted publication the Editorial Board consults at least two outside referees (not affiliated to any of the authors' institutions) which are recognized experts in the specific field.

2. At least one of the referees must represent a foreign institution (i.e. an institution located in other country than the home institution of each author).

3. The journal uses double blind peer review policy, i.e. neither the author nor the referee knows the identity of the other. In addition, each referee signs a declaration of no conflict of interests, whereby the conflict of interest is defined as a direct personal relationship (kinship to the second degree, legal relationships, marriage) or a professional scientific cooperation between the referee and the author which took place at least once in the past two years preceding the year of accepting the invitation to review.

4. Only written referee reports are considered (journal does not accept face-to-face or phone-call- based reports). Each report should clearly express the referee's final recommendation (i.e. whether the article should be accepted for publication, revised or rejected). The referees are kindly requested to fill the review form which can be found in "For reviewers" section. In general, the referees are asked to:

– assess:

- the scientific importance of the submission's topic,
- the quality of research;

– verity whether:

  - the Abstract is concise and informative,
  - the facts and interpretations are satisfactorily separated in the text,
  - the interpretations and conclusions follow from the data,
  - the length and structure of the paper is appropriate,
  - the paper can be shortened without loss of quality,

- all the tables and figures are necessary,
- the diagrams and photographs are of good quality,
- there are all essential figures that should be prepared,
- all the references are exact,
- the manuscript requires proof reading by native speaker,
- there is sufficient attention given to previous research.

5. The names of the referees of particular articles are classified.

6. Once a year the journal publishes the complete list of referees.