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Modelling the impact of innovation-related risks on firm value

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1. Relevance of the study

Creation and efficient utilization of innovations[1] are key factors determining the prospects for economic growth (e.g., Gokhberg, Kuznetsova, 2012). Innovations make a crucial contribution to strengthening businesses' competitiveness. To step up their innovation activity, companies need to attract significant financial resources, in particular in capital markets. Along with the growth of innovation funding, also grow the risks associated with increasingly complex management processes, uncertain results of innovation activities, high competition in the international and domestic innovative products and services markets, and the shortcomings of state innovation policies. For Russian enterprises, these risks are exacerbated by the growing sanctions pressure, and reduced access to foreign technologies and markets. To support decision-making on investing in innovative companies in global and domestic capital markets in the situation of growing uncertainty, there is an increasing need to develop applied techniques for assessing the risks associated with the creation and application of innovations.

In economics, companies' innovation activities are usually discussed in the context of risk and the uncertainty of their results (Schumpeter, 1911; Knight, 1921). The basic theoretical approach implies that since innovation and associated with it opportunities and risks make a critical impact on companies' long-term financial position (Greenhalgh, Rogers, 2010), investors' current perception of innovation becomes a key factor affecting the firm's strategic goals, including its value (Hirshleifer et al., 2013). Empirical evidence of such impact has been presented in (Griliches, 1981; L. K. Chan et al., 2001; S. H. Chan et al., 1990; Hall, 1993; etc.).

In this study the emphasis will be on companies' innovation development, which is defined as innovation aimed at accomplishing the company's strategic goals. Risks[2] of innovation development (ID risks) are understood as the impact of uncertainty associated with the company's innovation activities on the accomplishment of its goals. Value creation as a key strategic company

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[1] Key concepts related to innovation are defined in line with the Oslo Manual (OECD, 2018).

[2] Key concepts related to risk management are defined in line with international risk management standards (ISO 31000, 2018)

goal is analysed in the context of the company's innovation development, taking into account ID risks. According to the Oslo manual (2018), a firm's innovative activity consists of several components: research and development (R&D), including engineering, design and other creative activities; marketing and brand promotion; protection of intellectual property; employee training; acquisition or formation of fixed assets, including development of software and databases; innovation management. The main internal sources of ID risks include: R&D costs; patenting; capital costs associated with innovation activities; strategic management decisions aimed at implementation and usage of innovations. The main external sources of ID risks include changes in government science technology and innovation policy (STI policy), as well as competition from other innovation-active firms. Other external risk factors (financial, operational, environmental, etc.) that affect the value of the company are studied within the framework of this study in the context of their relationship with ID risks.

The impact of innovation-related risks on company value can be modelled using methods commonly applied to assess its value (see, e.g., Damodaran, 2012): cash flow discounting; market comparison (or the multiplier method); considering managerial flexibility using the real options method. When a company is evaluated using the discounted cash flow method, risks (including innovation-related ones) are taken into account in the discount rate (coefficient or factor), which is determined on the basis of the *cost of equity estimates*. If the multiplier method is used for evaluation purposes, it is difficult to separate the impact of ID risks on the company value from that of other risks, so this approach will not be considered in this study. When the *real options method* is applied for company evaluation, risks (including ID risks) are assessed in real option values. Implementing strategic decisions related to innovation development can significantly affect company value. To analyse the consequences of such decisions, in addition to traditional approaches to company evaluation a methodology can be developed to take into account various types of effects such as synergies, substitutes, effects associated with diversification, etc. Therefore, to model the impact of innovation-related risks on company value, a separate investigation of the *consequences of strategic decisions* on innovation development, and of the key factors which determine their consequences must be conducted.

Thus, three key approaches for modelling the impact of innovation-related risks on company value can be identified:

1. Cost of equity models;
2. Real options method;
3. Analysing the consequences of strategic decisions related to innovation development.

For each of these approaches, main research topics can be identified.

The first approach involves taking into account innovation-related risks in asset pricing (see, e.g., Lev, Sougiannis, 1996). On the one hand, investors view innovation expenditures as high-risk investments, with information about their results not always available, so they expect a premium on innovative firms' return rates (Lev et al., 2005). On the other hand, innovation ensures the firm's long-term competitiveness and opens opportunities for its sustainable development, which should reduce the risks of investing in its shares (Branch, Chichirau, 2010). Modelling various investor behaviour patterns involves assessing their attitude towards innovation-related risks and determining their preferences. Some investors do not see short-term losses associated with innovation as crucial; they expect innovation to lead to the growth of long-term value (Kung, Schmid, 2015). On the contrary, for investors with a short investment horizon the impact of innovation costs on the current financial performance is important. Modelling the impact of the ID risk factor on company value, one must not only take into account investors' preferences and set the utility function, but also construct the innovation-related risk factor for inclusion in the cost of equity model (Hirshleifer et al., 2013). The specifics of innovation statistics, its reflection in financial and non-financial reports, and the time lag between innovation expenditures and returns create additional problems with modelling the impact of innovation-related risks on company value. When assessing pricing model parameters, the effect of other risk sources (including those associated with changing macroeconomic parameters) on investors' attitude to risk, and therefore on their exposure to the ID risk factor must be estimated (Petkova, 2006). Finally, developing a cost of equity model one must take into account the specifics of the capital market in which it is applied. For example, in knowledge-intensive economies innovation activity is widespread and supported by advanced infrastructure, and thus may be perceived by investors more positively than in countries with low R&D funding where innovation-related risks may be significantly higher.

Thus, for the first approach – taking into account innovation-related risks in cost of equity models – one can identify the following relevant research topics:

- Modelling investor preferences;

- Modelling risk factors affecting company value and assessing the exposure to these factors taking into account capital market specifics.

Though cost of equity models estimate the expected returns on assets reflecting the key risks, they do not take into account management flexibility, or ability to make use of the situation after the implementation of risks to create additional value. The second approach involves ***modelling changes in the company's cash flows*** due to the implementation of risks, including innovation-related ones, ***considering managerial flexibility***, or future decisions made to cope with challenges (Trigeorgis, Reuer, 2017). Accounting for managerial flexibility in company evaluation is possible using the real options method originally proposed in (Myers, 1977). The real options method is applied to evaluate assets with highly uncertain future cash flows (Dixit, Pindyck, 1994). Since innovation results tend to be highly uncertain, the real options method is often used to evaluate companies and projects in which innovation plays a significant role. Practical application of this method involves a number of difficulties. Using it in continuous time, one should distinguish between pricing real and financial options: traditional pricing theory hypotheses on no-arbitrage and complete markets become more controversial in a situation when the underlying asset of the option is not a traded one (as is the case with financial options), but firms' future discounted cash flows. To apply real options in discrete time, scenarios describing changes in cash flows must be built. Scenario planning becomes particularly difficult if one tries to consider not only innovation-related risks, but also their relationship with other risk factors, including macroeconomic ones. Problems may also arise when macro-level scenarios are projected to the industry or specific firm level (He et al., 2022). Modelling cash flows using the real options method, various industries' innovation development specifics must be taken into account (Christofi et al., 2021).

Thus, in the second approach – taking into account innovation-related risk factor in company evaluation using the real options method – the following research topics can be identified:

- Evaluation using the real options method in continuous time;
- Evaluation using the real options method in discrete time (including scenario building and taking into account industry specifics).

Managerial decisions company management makes in response to the implementation of innovation-related risks may be part of the firm's adaptive strategy. The real options method assumes that management makes optimal decisions with predictable results, which in theory will allow a transition to risk-neutral cash flow evolution. However, the practical implementation of strategic decisions may be ineffective. In particular, mergers and acquisitions involve innovation-related risks associated with the specifics of the acquired technologies, and organisational difficulties in adapting them (Lichtenthaler, 2010). Therefore, the ***third approach is the modelling of the impact of innovation-related risks on company value while implementing strategic decisions***.

Key strategic decisions related to firms' innovation development include the following (Greenhalgh, Rogers, 2010):

- Determining the amount of R&D expenses;
- Patenting (or other forms of intellectual property protection);
- Determining the launch time for innovative products production or innovative processes implementation;
- Deciding when to sell the developed technology to third parties;
- Choosing between developing the core business and innovation-related diversification;
- Acquiring of other firms to get access to their technology and knowledge.

As already noted, the effects of the first two decision types (on R&D expenditures and patenting) on firm value is studied in the literature in the scope of the first approach – modelling cost of equity (Hirshleifer et al., 2013; Lev, Sougiannis, 1996). The impact of innovation-related risks on company value associated with timing the application of innovations can be estimated in the scope of the second area: using a real option to delay, and with timing technology sales, a real option to exit (Dixit, Pindyck, 1994; Trigeorgis, Reuer, 2017). The consequences of the latter two decision types (business diversification and mergers and acquisitions) involve effects and risks which are analysed in the academic literature using other approaches, including the event study method and data envelopment analysis (Rahman et al., 2016; Renneboog, Vansteenkiste, 2019). Thus, in the third approach – taking into account innovation-related risk factor to analyse the consequences of strategic decisions on company value – the following relevant research topics can be identified:

- Assessing the consequences of business diversification;
- Assessing the consequences of mergers and acquisitions.

2. Literature review

A number of theoretical and empirical problems must be solved for the described three approaches to modelling the impact of innovation-related risks on company value. The following unsolved problems outlined in the academic literature can be identified for each approach.

Approach 1. Cost of equity models

Modelling investor preferences

Asset pricing models are commonly used to estimate the cost of equity, the best known of which is the Capital Asset Pricing Model (CAPM) proposed by Sharpe and Lintner (Lintner, 1965; Sharpe, 1964). The CAPM logic is based on the neoclassical approach to modelling investor behaviour, which, in its turn, is based on economic rationality understood as maximising the utility function. In the context of describing investor preferences, individual attitudes to risk play an important role (Arrow, 1965; Pratt, 1965). Solving the investor's utility optimisation problem allows one to determine a stochastic discount factor, and thus estimate the expected return rate taking into account the risks (Cochrane, 2009).

According to Cochrane (2009), the Sharpe-Lintner CAPM can be seen as a special case of the classical consumption capital asset pricing models family which identify investors' preferences on the basis of their consumption (Breden, 1979; Hansen, Singleton, 1983; Rubinstein, 1976). In consumption asset pricing models the stochastic discount factor depends solely on the level of consumption.

Consumption asset pricing models have been criticised in the literature (Mehra, Prescott, 1985), as they cannot explain the high risk premium in stock markets. Initially, problems with such models included the inability to describe investors' attitudes to risk using quadratic or exponential utility functions. Later, researchers (Constantinides, 1990; Epstein, Zin, 1991) proposed utility functions which could explain investor behaviour in equity markets more accurately. Despite the significant progress achieved in this field, and the development of the recursive utility function by Epstein and Zin (Epstein, Zin, 1991), relevant research continues (Giglio et al., 2021). In particular, efforts are taken to move away from the representative investor hypothesis towards more comprehensive heterogeneous investor behavioural models (Ameriks et al., 2020).

Given the high uncertainty of innovation development, the behaviour of investors who face it has a number of specific features. In particular, such investors may have an asymmetrical attitude towards the implementation of market risks, perceiving negative dynamics of their market portfolio more dramatically than positive ones. Therefore the following problem can be formulated in this research area:

Problem 1. *Drawbacks of consumption based utility functions, including those related to the impact of innovation risks on investor behaviour*.

In recent decades, attempts have been made in the framework of the behavioural finance theory to abandon the hypothesis of economic agents' rational behaviour: making informed decisions aimed at finding the optimal risk/return balance for their portfolios (Barberis et al., 1998; Daniel et al., 1998; Kahneman, Tversky, 2013). In particular, Milovidov proposed the concept of "symmetry of misconceptions" of investors (Milovidov, 2019), a number of researchers have studied "herding investor behaviour" (Chiang, Zheng, 2010); given the growing popularity of the responsible investment agenda, arises the need to take into account "non-financial" investor goals when describing their behaviour, which significantly affect asset pricing (Izgarova et al., 2023; Rubtsov, Annenskaya, 2019; Karminsky et al., 2022).

Companies' innovation activities are aimed at strengthening their competitiveness, and creating long-term value. "Irrational" (in terms of the expected utility theory) investor behaviour can significantly increase the exposure of such companies' shares to market risks and hinder the achievement of their strategic goals, including innovation-related ones. Therefore the following problem can be formulated in this research area:

Problem 2. *The existence of irrational investor motives, which affect the exposure to the ID risks.*

Modelling asset pricing risk factors and assessing risk factors exposure

Consumption-based models belong to the broader intertemporal models class (ICAPMs) developed by Nobel laureate Robert Merton (Merton, 1973a). In ICAPM models, the investor solves an intertemporal problem by choosing between consumption and investment in a situation defined by a single (as in the Sharpe-Lintner CAPM model), or multiple financial market variables (Harvey, Liu, 2021). E.g. Ross's (1976) arbitrage-free pricing model and intertemporal multifactor models use multiple risk factors to explain the expected return on an asset.

One example is the foreign exchange risk factor included in arbitrage-free pricing models by Solnik (1974), and later by other researchers (Adler, Dumas, 1983; Sercu, 1980). Such models (taking into account the foreign exchange risk factor) are called international asset pricing models, as they can be applied to capital markets where assets are traded in local currencies. Modelling investor attitude to innovation-related risks in such markets, one must take into account the currency risk factor and the market specifics. In particular, in emerging markets large firms are more exposed to currency risks since they are involved in international trade, while in developed markets it's smaller firms that are more exposed to foreign exchange risk, and face additional hedging costs (Jeon et al., 2017). Given the significant changes in foreign exchange markets in recent years, the impact of currency risks on company value remains a relevant research topic (Karolyi, Wu, 2021). Thus the following problem can be formulated in this research area:

Problem 3. *Specifics of emerging capital markets, and international asset pricing model testing.*

The efficient market hypothesis (the foundation of the CAPM) was not supported by the testing in the US market (Fama, French, 1989). "Anomalies" not accounted for by the traditional pricing models, capable of predicting long-term stock performance (Banz, 1981; Basu, 1983; Bernard, Thomas, 1989; Rosenberg et al., 1985), prompted researchers to develop multifactor models. Such anomalies represent unexplained differences between the actual returns of assets (asset portfolios) with certain properties, and the returns predicted by existing pricing models. What seems to be an anomaly for one model, for another may be just a risk factor affecting the stochastic discount factor and the expected returns. In particular, the size effect (Banz, 1981) is an anomaly for the CAPM, but for the now classic three-factor model suggested by Fama and French (1992), the size factor is one of the risk sources incorporated into the model. After the Fama and French publication, the search for anomalies, and the identification of associated risk factors continues to this day (S. Gu et al., 2021; Harvey, Liu, 2021).

In 2008, Fama and French (2008) proposed a version of the multifactor model with a risk factor associated with investing in stocks of companies with a high rate of R&D expenditures. The authors called the additional risk premium “R&D anomaly.” This work was preceded by the publications by Lev and Sougiannis (1996) and Chan, Lakonishok, and Sougiannis (L. K. Chan et al., 2001) who noted the significant impact of R&D expenditure on company share price. Incorporating the risks associated with R&D costs into pricing models poses a number of problems for researchers due to the complexity of accounting for such costs, the time lag between making R&D expenditures and obtaining results, and capital markets’ specifics (Branch, Chichirau, 2010; Eberhart et al., 2004; Hirshleifer et al., 2013; Lev et al., 2005). Thus the following problem can be formulated in this research area:

Problem 4. *Constructing an innovation-related asset pricing risk factor.*

An important feature of taking into account innovation-related risks in assessing company value is their relationship with other risk sources (L. Gu, 2016). In particular, risk is created by changes in the parameters which determine the state of the financial system in intertemporal value models (Pástor, Stambaugh, 2009; Petkova, Zhang, 2005). That’s why such models are sometimes called “conditional,” meaning that their parameters, in particular exposures to risk factors affecting company value, depend on changing conditions (Jagannathan, Wang, 1996). Considering the relationship between risk factors remains a challenge in asset pricing (see, e.g., Dong et al., 2022). In particular, companies’ innovation development and the associated risks may depend on internal factors and institutional conditions (see, e.g., Baranov, Dolgopyatova, 2013). Therefore the following problem can be formulated in this research area:

Problem 5. *Relationship between innovation-related and other risk factors in cost of equity models.*

Approach 2. Real options method

Real options method in continuous time

Innovation development creates high uncertainty for companies, and inextricably depends on the decisions the management makes in response to the implementation of risks associated with this uncertainty. Asset evaluation using the real options method involves making optimal managerial decisions in the future depending on the implementation of risks, which, in turn, ensures risk neutrality or, in other words, equality of expected cash flows discounted at a risk-free rate, the current asset value (Trigeorgis, 1996).

Achieving risk neutrality when pricing options in continuous time is similar to using a stochastic discount factor in asset pricing models (Cochrane, 2009). Consumption capital asset pricing models are general equilibrium models which solve the problem of maximising investor utility function. To find general equilibrium in financial markets, a number of conditions must be met; in particular, the market must be complete and arbitrage-free. Market completeness was defined by Arrow and Debreu (1954) as the existence of an equilibrium price for any asset in such a market. The completeness and arbitrage-free prerequisites have often been criticised for not matching the actual operating conditions in financial markets (Bansal, Viswanathan, 1993).

Similar problems arise when real options are evaluated using the classic model proposed by Black, Scholes, and Merton (Black, Scholes, 1973; Merton, 1973b). The prerequisites of market being complete and arbitrage-free, which ensure the existence of a single portfolio copy for an option (and therefore a single discount factor) do not always make sense (Fernández, 2019). It is especially difficult to find an asset with similar cash flows when modelling options for innovation-related risks. In particular, the market may become incomplete if a "jump" component is added to the random process describing asset value dynamics (Øksendal, Sulem, 2019). In this case the jump-diffusion process may reflect the implementation of competitive innovation projects and their impact on the firm's or project's cash flows (Trigeorgis, Reuer, 2017). Therefore the following problem can be formulated in this research area:

Problem 6. *Possible jumps in asset value due to the realization of innovation-related risks, leading to an incomplete market and preventing the use of the Black, Scholes, Merton formula.*

Real options method in discrete time

Applying the real options method in discrete time, one must model an event tree describing the changes in the project's discounted cash flows taking into account the uncertainty (Dixit, Pindyck, 1994). The traditional approach involves the use of a binomial cash flow evolution model, which aggregates all risks in standard deviation. However, to assess the specific impact of innovation-related risks more complex scenarios must be built, considering innovation development paths on the national or industry level (He et al., 2022). Thus the following problem can be formulated in this research area:

Problem 7. *Separating the impact of innovation-related risks when building scenarios and event trees.*

Another problem with using the real options method in discrete time is taking into account the numerous compound and/or simultaneous managerial decisions, and the associated real options that can be implemented. In many cases the complexity of managerial decisions is due to industry specifics. Many studies are devoted to the particulars of applying the real options method in various industries and situations (Harikae et al., 2021; Ioulianou et al., 2021; Wreford et al., 2020). Real options are particularly actively used in, e.g., the electric power industry. Its low margins, along with a high dependence on tariff policy and the high volatility in energy markets lead to highly uncertain cash flows of electric power companies. In this case real options may be associated with switching to alternative energy sources and introducing energy-saving technologies. Standard real options models proposed in (Myers, 1977) are not always suitable for modelling industry-specific situations. Therefore, the following problem can be formulated in this research area:

Problem 8. *Complex real options related to the industry specifics of companies' innovation activities.*

Approach 3. Analysing the consequences of strategic decisions related to innovation development

Assessing the consequences of business diversification

One of the key approaches of studying business diversification effects is based on the organisational ambidexterity concept. Organisational ambidexterity (OA), or finding the optimal balance between applying innovations to improve the efficiency of the core business, and to launch alternative business lines new for the company (sometimes even competing with its core business), creates risks for accomplishing strategic company goals. OA effects on firms have been examined in a number of studies (March, 1991; Gupta et al., 2006; Junni et al., 2013; Maletič et al., 2016). Assessing the consequences of OA, and its impact on company value is closely linked to the implementation of innovation-related risks (Junni et al., 2013). Analysing OA involves a number of difficulties, one of which is measuring the level of company's OA. Thus the following problem can be formulated in this research area:

Problem 9. *Difficulties with measuring organisational ambidexterity to estimate its impact on the company value.*

Assessing the consequences of mergers and acquisitions

Strategic decisions related to mergers and acquisitions significantly affect company value (Avdasheva, Tsytsulina, 2015; Ivashkovskaya et al., 2020). Assessing the impact of innovation-related risks on the success of a merger can be critically important (Bena, Li, 2014; L. Gu, 2016; Ruefli et al., 1999). However, the specifics (including industry-related ones) of this impact determined by the characteristics of the acquirer and target companies, by capital markets, and the parameters of deals continue to spur researchers' interest (Larchenko, Ruzhanskaya, 2023; Rogova, Pakhardymova, 2022). In particular, it remains unclear how successfully the company will be able to adapt the acquired technologies if it's actively involved in research and development itself (Bena, Li, 2014). Thus, the following problem can be formulated in this research area:

Problem 10. *Uncertain outcomes of applying technology and knowledge acquired through mergers and acquisitions.*

3. Goals and objectives of the study

The goal of the study is to develop theoretical and methodological tools for modelling the impact of innovation development risks on company value.

To achieve this goal, the following objectives must be accomplished (objectives are grouped according to three approaches discussed in the previous sections):

Approach 1. Cost of equity models

Objective 1. Develop a utility function model describing asymmetrical investor's reaction to market risk.

Objective 2. Analyse examples of irrational investor behaviour, and identify its consequences for companies' innovation development.

Objective 3. Develop an international pricing model for emerging capital markets.

Objective 4. Develop a methodology for taking into account the innovation-related risk factor in the cost of equity model.

Objective 5. Develop a methodology for assessing the relationship between innovation-related and other risk factors' impact on company value.

Approach 2. Real options method

Objective 6. Develop a model for assessing real options in incomplete markets in continuous time, taking into account the possibility of jumps in asset value.

Objective 7. Develop a methodology for building scenarios describing the implementation of innovation-related risks, to model real options in discrete time.

Objective 8. Analyse the industry specifics of using the real options method to model the impact of innovation-related risks on company value, using the example of the electric power companies

Approach 3. Analysing the consequences of strategic decisions

Objective 9. Develop a methodology for assessing organisational ambidexterity and its impact on company value.

Objective 10. Develop a methodology for assessing the consequences of acquiring technologies, and their impact on the value of the merged company.

Accomplishing the objectives to develop a methodology for modelling the impact of innovation-related risks on company value often involves testing the methodology in various capital markets and economic sectors where the companies operate.

Table 1 shows the connection between the problems identified above on the basis of literature analysis and objectives, which must be accomplished to achieve the goal of the study. The problems and objectives are structured into three key approaches. Relevant publications by the author are presented for each objective.

Table 1. Links between the study objectives and problems identified in the literature

Problems identified in the literature	Objectives of the study	Relevant publications
Approach 1. Cost of equity models		
1. Drawbacks of consumption-based utility functions, including those related to the impact of innovation risks on investor behaviour.	1. Develop a utility function model describing asymmetrical investor's reaction to market risk.	• Dranev Y. CAPM-Like Model and the Special Form of the Utility Function // Корпоративные финансы. 2012. № 1. С. 33-36.
2. The existence of irrational investor motives, which affect the exposure to ID risks.	2. Analyse examples of irrational investor behaviour and identify its consequences for companies' innovation development.	• Дранев Ю. Я., Ананьев Н. С. Влияние изменения индикаторов фондового рынка на привлечение средств в российские паевые фонды акций // Корпоративные финансы. 2010. № 2. С. 5-15. • Dranev Y. Impact of ESG Activities on the Innovation Development and Financial Performance of Firms // Journal of Corporate Finance Research. 2023. Vol. 17. No. 3. P. 152-159
3. Specifics of emerging capital markets, and international asset pricing model testing.	3. Develop an international pricing model for emerging capital markets.	• Дранев Ю. Я. Валютный риск и теория ценообразования активов // Корпоративные финансы. 2013. Т. 28. № 4. С. 114-124. • Дранев Ю. Я., Нурдинова Я. С., Редькин В. А., Фомкина С. А. Модели оценки затрат на собственный капитал компаний на развивающихся рынках капитала // Корпоративные финансы. 2012. № 2. С. 107-117. • Kuchin I., Elkina M., Dranev Y. The Impact of Currency Risk on the Value of Firms in Emerging Countries // Journal of Corporate Finance Research. 2019. Vol. 13. No. 1. P. 7-27. doi

Problems identified in the literature	Objectives of the study	Relevant publications
4. Constructing an innovation-related asset pricing risk factor.	4. Develop a methodology for taking into account the innovation-related risk factor in the cost of equity model.	• Dranev Y., Levin A., Kuchin I. R&D Effects, Risks and Strategic Decisions: Evidence from Listed Firms in R&D-intensive Countries // Foresight. 2017. Vol. 19. No. 6. P. 615-627. doi
5. Relationship between innovation-related and other risk factors in cost of equity models.	5. Develop a methodology for assessing the relationship between innovation-related and other risk factors' impact on company value.	• Dranev Y., Levin A., Kuchin I. R&D Effects, Risks and Strategic Decisions: Evidence from Listed Firms in R&D-intensive Countries // Foresight. 2017. Vol. 19. No. 6. P. 615-627. Doi • Dranev Y., Kotsemir M. N., Syomin B. Diversity of research publications: relation to agricultural productivity and possible implications for STI policy // Scientometrics. 2018. Vol. 116. No. 3. P. 1565-1587. Doi • Dranev Y., Chulok A. Assessing interactions of technologies and markets for technology road mapping // Technological Forecasting and Social Change. 2015. Vol. 101. P. 320-327. Doi • Dranev Y. Impact of ESG Activities on the Innovation Development and Financial Performance of Firms // Journal of Corporate Finance Research. 2023. Vol. 17. No. 3. P. 152-159
Approach 2. Real options method		
6. Possible jumps in asset value due to the implementation of innovation-related risks, leading to an incomplete market and preventing the use of the Black, Scholes, Merton formula.	6. Develop a model for assessing real options in incomplete markets in continuous time, taking into account the possibility of jumps in asset value.	• Дранев Ю. Я. О риск-нейтральном подходе ценообразования реальных опционов // Корпоративные финансы. 2010. № 1. С. 62-73.
7. Separating the impact of innovation-related risks when building scenarios and event trees.	7. Develop a methodology for building scenarios describing the implementation of innovation-related risks, to model real options in discrete time.	• Saritas O., Dranev Y., Chulok A.A. A Dynamic and Adaptive Scenario Approach for Formulating Science and Technology Policy // Foresight. 2017. Vol. 19. No. 5. P. 473-490. doi • Dranev Y., Chulok A. Assessing interactions of technologies and

Problems identified in the literature	Objectives of the study	Relevant publications
		markets for technology road mapping // Technological Forecasting and Social Change. 2015. Vol. 101. P. 320-327. doi
8. Complex real options related to the industry specifics of companies' innovation activities.	8. Analyse the industry specifics of using the real options method to model the impact of innovation-related risks on company value, using the example of the electric power companies.	• Дранев Ю. Я. Об использовании метода реальных опционов в электроэнергетике // Корпоративные финансы. 2011. № 1. С. 129-135.
Approach 3. Analysing the consequences of strategic decisions		
9. Difficulties with measuring organisational ambidexterity to take into account its impact on the company value.	9. Develop a methodology for assessing OA and its impact on company value.	• Dranev Y., Izosimova A., Meissner D. Organizational Ambidexterity and Performance: Assessment Approaches and Empirical Evidence // Journal of the Knowledge Economy. 2020. No. 11. P. 676-691. doi
10. Uncertain outcomes of applying technology and knowledge acquired through mergers and acquisitions.	10. Develop a methodology for assessing the consequences of acquiring technologies, and their impact on the value of the merged company.	• Dranev Y., Ochirova E., Harms R., Miriakov M. Assessment of Interorganizational Technology Transfer Efficiency // Foresight and STI Governance. 2023. Vol. 17. No. 3. P. 20-31. doi • Ochirova E., Dranev Y. The Impact of R&D Expenditure upon the Efficiency of M&A Deals with Hi-Tech Companies // Foresight and STI Governance. 2021. Vol. 15. No. 1. P. 31-38. doi • Dranev Y., Frolova K., Ochirova E. The impact of fintech M&A on stock returns // Research in International Business and Finance. 2019. Vol. 48. P. 353-364. doi

4. Methodology of the study

This section provides a description of the methodology and identifies the author's contribution to the development and modification of the considered approaches.

Approach 1. Cost of equity models

Taking into account asymmetrical investor preferences in cost of equity models

In pricing theories investor preferences are described using a utility function, which in turn can be based on measuring risk. Therefore, researchers aim to solve a dual problem: maximising investor's utility, and minimising risk (Rachev et al., 2011). The literature suggests that risk measures used in pricing models should reflect investors' asymmetrical attitudes toward market risk and take into account their strong aversion to losses (Bawa, Lindenberg, 1977; Hogan, Warren, 1974). Particularly important is to model this attitude for investors who consider investing in assets exposed to innovation-related risks.

Various risk measures which more accurately reflect investor behaviour have been described in the literature, including coherent (Artzner et al., 1999), distortion (De Giorgi, Post, 2008), and deviation measures (Rockafellar et al., 2006). A broader class of dispersion measures includes variance, semivariance, and colog measures (Rachev et al., 2011). The colog risk measure is calculated for the random variable X as follows:

$$Colog(X, X) = E(X\log X) - E(X)E(\log X) \tag{4.1.1}$$

Due to the logarithm properties, the use of colog measure for asset valuation allows to asymmetrically take into account positive and negative changes in asset prices (Dranev, 2012), which is especially important for investing in assets exposed to innovation-related risks. A methodology for using a colog risk measure to develop an appropriate cost of equity model is briefly described below.

Let w_t denote the total wealth at moment t, and c_t, c_{t+1} – investors' consumption at moments t and $t+1$. Savings $k_t = w_t - c_t$ will be invested at the rate of $r_{w,t+1}$ and consumed during the period $t+1$. I.e.:

$$(w_t - c_t)(1 + r_{w,t+1}) = c_{t+1} \tag{4.1.2}$$

Following Cochrane's methodology (Cochrane, 2009), investor preferences are determined through the following intertemporal utility function:

$$U(c_t, c_{t+1}) = u(c_t) + \beta E_t\big(u(c_{t+1})\big), \tag{4.1.3}$$

where E_t is conditional expected value, given information for period t is available and consumption preference coefficient $\beta < 1$ in period t. The investor chooses between consuming today or in the next period, maximising (4.1.3) taking into account (4.1.2).

We assume that investor's utility function has the following colog form:

$$u(c) = (c - c_0) - a(c - c_0)\log(c - c_0), \tag{4.1.4}$$

where consumption c bounded from below is $c_0 > 0$, and $a > 0$ is an analogue of the risk aversion coefficient.

If the investor is limited to a finite set of N risky assets with returns of $r_{i,t+1}$, $i = 1, \dots, N$ and a risk-free rate of $r_{0,t+1}$, then the investor's optimal choice will be defined by the following system of equations:

$$u_c(c_t) = E_t\left(\beta u_c(c_{t+1})\big(1 + r_{i,t+1}\big)\right), i = 0, \dots, N, \tag{4.1.5}$$

where $u_c(\cdot)$ is marginal utility, or the first derivative of the utility function with respect to consumption.

Then the stochastic discount factor will be equal to:

$$M_{t+1} = \beta \frac{u_c(c_{t+1})}{u_c(c_t)} = a_0 - a_1\, log\big(\theta_t r_{w,t+1} + 1\big), \tag{4.1.6}$$

where a_0, a_1 are certain positive non-random coefficients which depend on a,$c_0\beta$, marginal utility $u_c(c_t)$ and k_t at time t;

$\theta_t = \frac{w_t - c_t}{w_t - c_t - c_0} > 1$ is a coefficient showing how much the savings exceed a certain minimum level. θ_t; it becomes greater when consumption growth exceeds wealth growth (e.g., with a loose monetary policy introduced during a crisis).

Using the formula for stochastic discount factor M_{t+1}, an expression for estimating the expected return on the i_{th} asset is obtained:

$$E_t\left(r_{i,t+1} - r_{0,t+1}\right) = \frac{COV_t\left(r_{i,t+1}, log\left(1+\theta_t r_{w,t+1}\right)\right)}{COV_t\left(r_{w,t+1}, log\left(1+\theta_t r_{w,t+1}\right)\right)} E_t\left(r_{w,t+1} - r_{0,t+1}\right) \quad (4.1.7)$$

Equation (4.1.7) is similar to the traditional CAPM pricing model, but takes into account the greater weight of negative market dynamics for investors. The greater the coefficient θ_t the more $log\left(\theta_t r_{w,t+1} + 1\right)$ differs from $r_{w,t+1}$, and the stronger investors' aversion to the risk of asset value reduction.

The model (4.1.7) proposed by the author of the dissertation has not only theoretical advantages. Preliminary testing in emerging capital markets revealed that the pricing model based on a colog risk measure more accurately described stock price dynamics (Dranev, Chupin, 2022). Also, the colog risk measure better predicted irrational investor behaviour when investing in mutual funds (Dranev, 2010).

Constructing a pricing factor associated with innovation development using asset portfolios

To model a pricing factor associated with innovation-related risk, a measuring parameter for it must be determined. Measuring innovation is a separate problem, the solution to which depends on the application area (Gokhberg et al., 2023). Based on literature about pricing (L. K. Chan et al., 2001; Lev et al., 2005; Lev, Sougiannis, 1996), it is proposed to use as a proxy parameter the rate of company's R&D expenditures to its revenue:

$$RDI_{FY_t} = \frac{RD_{FY_t}}{RMC_{FY_t}} \quad (4.1.8)$$

where RMC is revenue, and FY_t is financial year.

To estimate the cumulative effect of R&D expenditures, two- and three-year moving averages are used in addition to R&D expenditures rate (Dranev et al, 2017):

$$\begin{cases} MA(RDI,3)_{FY_t} = \frac{1}{3}\sum_{i=0}^{2}\frac{RD_{FY_{t-i}}}{RMC_{FY_{t-i}}} & (4.1.9) \\ MA(RDI,2)_{FY_t} = \frac{1}{2}\sum_{i=1}^{2}\frac{RD_{FY_{t-i}}}{RMC_{FY_{t-i}}} & (4.1.10) \end{cases}$$

Another measure is the growth of the R&D expenditures rate, calculated in two ways:

$$\begin{cases} RDI\ Growth_{FY_t} = \dfrac{\left(\dfrac{RD_{FY_t}}{RMC_{FY_t}}\right)}{\left(\dfrac{RD_{FY_{t-1}}}{RMC_{FY_{t-1}}}\right)} & (4.1.11) \\ RDI\ Growth_{FY_t} = \dfrac{\left(\dfrac{RD_{FY_t}}{RMC_{FY_t}}\right)}{\left(\frac{1}{2}\sum_{i=1}^{2} \dfrac{RD_{FY_{t-i}}}{RMC_{FY_{t-i}}}\right)} & (4.1.12) \end{cases}$$

Indicators (4.1.9)-(4.1.12) are then used to build portfolios. Portfolios weighted by price and capitalisation are considered:

$$\begin{cases} R_{ik}^{equal-weighted} = \dfrac{1}{N}\sum_{j=1}^{N} r_{jk} \\ R_{ik}^{value-weighted} = \dfrac{\sum_{j=1}^{N} r_{jk} * Market\ Cap_j}{\sum_{j=1}^{N} Market\ Cap_j} \end{cases}, \quad (4.1.13)$$

where R_{ik} is the return on portfolio *i* for month *k*, and r_{jk} is the logarithmic return on asset *j* in this portfolio in the same month.

With the help of portfolios, pricing factors are constructed, and added to the three-factor model (Dranev et al., 2017):

$$R_{ik} - r_{fk} = \beta_{im} * \left(E(R_{mk}) - r_{fk}\right) + \beta_{iSMB} * SMB_k + \beta_{iHMLRD} * HMLRD_k \quad (4.1.14)$$

where r_{fk} is the risk-free rate for month *k*, $E(R_{mk})$, SMB_k $HMLRD_k$ are the returns on risk factors associated with market risk, size effect, and R&D expenditures.

The three-factor model for assessing the importance of the risk factor associated with R&D expenditures is tested in line with the Fama-MacBeth procedure (Fama, MacBeth, 1973) with Newey-West adjustments (Newey, West, 1987). The process described above allows to construct a risk factor associated with R&D expenditures; an approach is proposed for testing the cost of equity model taking into account R&D-related risks (Dranev et al., 2017). The advantage of the approach to constructing a risk factor associated with R&D expenditures proposed by the author of the dissertation is that this method takes into account not only expenditures over several years, but also the changes in their rate, which may be negatively perceived by investors.

Modelling the relationship between innovation-related risks and other pricing factors

Asset price volatility can be explained by two components: one arising from individual (idiosyncratic or diversification) risk, and the other from systemic risk. Ang et al. (2006) showed that idiosyncratic volatility negatively affected expected returns of the US stock market. Switzer and Picard (2015) found that in emerging markets diversification risks can positively affect expected returns. Risks associated with R&D expenditures by their nature are closer to diversification risks, since they reflect organisations' specifics, and the effectiveness of their innovation activities. Increasing R&D expenditures can strengthen companies' competitiveness and ensure their sustainability in the long term. Therefore, R&D expenditure rate can reduce firms' systemic risks, which in turn are closely related to foreign exchange risk (Cho et al., 2016). To test this hypothesis, a model has been developed to estimate the relationship between R&D expenditures rate and exposure to currency risk (which can be considered an important component of market or systemic risk, especially in emerging markets).

Exposure to foreign exchange risk is assessed through the impact of exchange rate fluctuations on stock returns (Kuchin, Elkina, Dranev, 2019). Dranev et al. (2017) use a two-step procedure to estimate the relationship between R&D expenditure rate and exposure to foreign exchange risk. Determination coefficient is used as an indicator of exposure to exchange rate fluctuations. At the first stage the simplest model for calculating the R-squared regression determinant for the company is applied:

$$\widehat{R_{i,t}} = \widehat{\alpha_{i,t}} + \widehat{\beta_{ExR_t}} * ExR_t + \epsilon_{i,t}, \quad (4.1.15)$$

where ExR_t is the national currency exchange rate, and $R_{i,t}$ is the return on asset *i* in period *t*.

At the second stage the impact of R&D expenditures rate on exposure to currency risk is assessed:

$$Z_i = \widehat{\alpha_i} + \widehat{\beta_i} * \widehat{\overline{RDIl_i}} + \epsilon_i, \tag{4.1.16}$$

where Z_i is the value of 1 minus R-squared for the i_{th} asset, and $\widehat{\overline{RDIl_i}}$ R&D expenditures rate calculated in several ways (to revenue, assets, capitalisation, two-year moving average).

Thus, a model is proposed to test the relationship between two risk factors, one of which reflects the firm's innovation development, and the other – the exposure of its value to exchange rate fluctuations. Assessing the relationship between these risk factors allows to develop advanced intertemporal pricing models which assess risk exposure dynamically, and taking into account other factors as well (Campbell et al., 2018). Moreover, the proposed methodology allows to assess the impact of innovation-related risks in international pricing model not via an individual pricing factor, but through the relationship with the exposure to currency risk.

The relationship between innovation and market risk factors can be addressed at the industry or whole economy level. In particular, a paper by Dranev (Dranev, Chulok, 2017) proposes a methodology for taking such a relationship into account using a production function model. Testing this methodology allowed to evaluate output forecasts for the manufacturing industry. The results can be used to model future cash flows of companies operating in different industries.

Another example of studying the impact of innovation-related risks on industry parameters is presented in (Dranev et al., 2018). It's the analysis of the impact of science, technology, and innovation (STI) policy (concerning research diversification) on the growth of industry productivity. An original approach to measuring the effects of research diversification is proposed, which allowed to assess STI policy-related risks on the example of agriculture sector in different countries. The results can also be used to model the impact of innovation-related risks (associated with STI policy) on agricultural firms' cash flows.

Theoretical analysis shows that the risks of implementing ESG practices can reduce innovation processes' efficiency, and increase innovation-related risks for companies (Dranev, 2023). Despite the decline in socially responsible companies' costs of equity observed in the years before the pandemic, synergy between R&D expenditures and the implementation of ESG practices was not discovered in a number of cases. Different ESG standards, inconsistent rating systems, and associated information asymmetries lead to a negative impact of additional ESG-related costs on innovation performance.

Approach 2. Real options method

Cochrane (2009) noted that cost of equity models are based on the same principles as option pricing. According to the literature on option pricing (Delbaen, Schachermayer, 1998; Harrison, Pliska, 1981; Lin, Huang, 2010), the price of an option C with underlying asset S, strike price K, and expiration date T can be expressed as follows:

$$C=E\big(Z(\max(S(T)\text{-K}),0)\big) \tag{4.2.1}$$

where $Z = \frac{dP*}{dP}$ is the Radon-Nikodym derivative which allows for a transition to a risk-neutral probability space with an absolutely continuous (relative to the original measure P) measure $P*$. Multiplying the max(S(T)-K) option payment by Z is similar to using a stochastic discount factor in cost of equity models.

An approach to pricing real options is described (Dranev, 2010). When modelling the changes in the value of the option's underlying asset in continuous time, market risk factors must be taken into account, in particular those associated with fluctuations in commodity prices or currency rates. Multidimensional Brownian motion $W = (W_1, \dots, W_d)$ is used for this purpose. However, to assess innovative companies' value using the real options method, one must take into account uncertainties which can cause "jumps' in cash flows. Such uncertainties may arise from the entry of competitors or new products into the market (Trigeorgis, Reuer, 2017). Abrupt changes in cash flows due to the influence of such uncertainties can be set by $k - d$ processes N_i, each of which is a sequence of pairs $(t_n, z_n, n \geq 1)_j$ where t_n is the time of the n_{th} jump, and z_n is a random value with jump size distribution density of $\phi_j\ (t, z)$, and jump intensity $\lambda_j(t)$.

The impact of the j_{th} risk factor associated with the Brownian motion component W or the "jump" process component N on the i_{th} asset is modelled via predictable integrated variation processes $\sigma_{ij}^W(t)$ и $\sigma_{ij}^N(t, z)$, the latter acts as a monotone function differentiable with respect to z. To predict the growth rate of the asset value S_i (reduced cash flows in the case of a real option), predictable process $b_i(t)$ will be used. Then the logarithm of the asset value change can be written as follows:

$$log(S_i(t)) = R_i(t)$$
$$= \int_0^t b_i(s)ds + \sum_{j=1}^{d} \int_0^t \sigma_{ij}^W(s)dW_j(s) + \sum_{j=1}^{k-d} \int_0^t \int_R \sigma_{ij}^N(s,z)\, dN_j(s,z) \qquad (4.2.2)$$

The stochastic discount factor (or the density of risk-neutral measure) for such an asset will be calculated using the following formula:

$$Z = \varepsilon\left(-\sum_{j=1}^{d} \int_0^t \upsilon_j(s)dW_j(s) - \sum_{j=1}^{k-d} \int_0^t \int_R \eta_j\,(s,z)dq_j(s,z) \right), \qquad (4.2.3)$$

where $\upsilon_j(s)$ and $\eta_j(s,z)$ are predictable integrable variation processes which can be described by the following systems of linear equations for each fixed t:

$$\hat{b}_i(t) - \sum_{j=1}^{d} \sigma_{ij}^W(t)\upsilon_j(t) - \sum_{j=1}^{k-d} \lambda_j(t) \int_R \hat{\sigma}_{ij}^N(t,z)\eta_j(t,z)\ \ \varphi_j(t,z)dz = 0,\ \ i = 1, \dots, m.$$

$$\hat{\sigma}_{ij}^N(t,z) = e^{\sigma_{ij}^N(t,z)} - 1, \quad dq_j(t,z) = dN(t,z) - \lambda_j(t)\varphi_j(t,z)dtdz \qquad (4.2.4)$$

$$\eta_j(s,z) = 1 - r_j(t)\psi_j(t,z),$$

where $r_j(t)$ and $\psi_j(t,z)$ define the marked point process N_j for the new measure P^*. N_j will have intensity $\lambda_j^*(t) = r_j(t)\lambda_j(t)$ and distribution density $\phi_j^*(t,z) = \psi_j(t,z)\phi_j(t,z)$ which match the new measure P^*.

In the general case, the hypothesis about market completeness (just a single portfolio copy exists) may not be valid, so there's an infinite number of the system solutions $\upsilon_j(s)$, $r_j(t)$, $\psi_j(t,z)$, which means there are infinitely many equivalent martingale measures and option price values . Therefore an optimal in a sense measure is selected, which maximises, over infinitesimal intervals, the utility u of increased asset value (or reduced cash flows). The problem of finding such a measure is solved using the optimal portfolio copy $\pi(t)$, which in turn is a solution of the following system of equations (Dranev, 2010):

$$\hat{b}_i(t) + u''(0)\sum_{j=1}^{d}\sigma_{ij}^{W}(t)\sum_{l=1}^{m}\pi_l(t)\,\sigma_{lj}^{W}(t) -$$
$$-\sum_{j=1}^{k-d}\lambda_j(t)\int_R \hat{\sigma}_{ij}^{N}(t,z)\left(u'\left(\sum_{i=1}^{m}\pi_i(t)\hat{\sigma}_{ij}^{N}(t,z)\right)-1\right)\varphi_j(t,z)dz \;=0. \quad (4.4.5)$$

If strategy $\pi(t)$exists, the parameters of the optimal martingale measure $P*$ will be set by the following formulas (Dranev, 2010):

$$v_j(t) = u''(0)\sum_{l=1}^{m}\pi_l(t)\,\sigma_{lj}^{W}(t)$$

$$r_j(t) = \int_R u'\left(\sum_{i=1}^{m}\pi_i(t)\hat{\sigma}_{ij}^{N}(t,z)\right)\varphi_j(t,z)dz \qquad (4.2.6)$$

$$\psi_j(t,z) = \frac{u'\left(\sum_{i=1}^{m}\pi_i(t)\hat{\sigma}_{ij}^{N}(t,z)\right)}{\int_R u'\left(\sum_{i=1}^{m}\pi_i(t)\hat{\sigma}_{ij}^{N}(t,z)\right)\varphi_j(t,z)dz}$$

As a utility function, one can choose a quadratic function, colog measure, etc. The above calculations allow to estimate real option values using the Monte Carlo method or, in simpler cases, an explicit formula (Dranev, 2010). Thus with the real options method one can assess the value of companies whose cash flows may jump due to the implementation of innovation-related risks. It should be noted that the suggested approach can be applied in incomplete markets, which is particularly important for evaluating innovative companies (finding market analogues for whose cash flows is difficult). Moreover, this approach can be used not just to evaluate real options, but also to directly estimate the expected stock returns of innovative firms using a stochastic discount factor (4.2.3).

Firm's value can be more accurately assessed using the real options method if the relevant industry specifics are taken into account. In particular, electric power companies face significant uncertainty, which leads to active use of the real options method for valuation purposes. For example, power generation companies are viewed in the literature as options with strike prices dependent on energy prices (Nadarajah, Secomandi, 2023). The specifics of using the real options method to assess the value of electric power companies are described in (Dranev, 2012).

Another approach to taking into account cash flow jumps associated with innovation-related risks is the real options method in discrete time. This implies building an event tree using scenario analysis. In particular, ways to take into account the impact of science and technology development in scenario building are described in the publication by the author of the dissertation (Saritas, Dranev, Chulok, 2017). The original scenario building methodology proposed by the authors combines several approaches to scenario analysis: direct and reverse path extrapolation, the orthogonal risk factors method, projection of external scenario factors onto internal ones. Another work by Dranev (Dranev, Chulok, 2015) proposes a method for building scenarios which take into account the impact of innovation-related risks using a production function model. The developed approaches allow to build company cash flows scenarios taking into account innovation-related risks. It can serve as a basis for decision about the implementation of real options at event tree nodes.

Approach 3. Analysing the consequences of strategic decisions

Using the event study method to analyse investors' reactions to innovation-related risks

The hypothesis about markets reaction to news about companies' innovation can be examined using the event study method. It's a classic tool designed to study market behaviour after new information is received. This method was first introduced in the well-known work of Fama, Fischer, Jensen, and Roll (Fama et al., 1969). In the following decades, the original idea of analysing data on US stock market returns in relation to corporate events became a popular approach to observing security prices' dynamics (Binder, 1998). Comparing the actual stock returns with those predicted by broad market indices, the authors were expected to obtain abnormal or excess returns that reflected deviations in stock profit margins caused by corporate events (Khotari, Warner, 2006). In this dissertation research, the event method was applied to analyse the reaction to companies' obtaining financial technologies through the acquisition of fintech firms (Dranev et al., 2019), and to examine the consequences of acquiring technology and knowledge through mergers and acquisitions for high-tech companies (Ochirova , Dranev, 2021).

Using the event study method to analyse reactions to technology acquisition implies the application of the popular in academic literature market model (Dranev et al., 2019). A merger announcement typically serves as the event under study. The expected return for each firm in the sample is calculated based on the daily return over the model testing window. Different event windows are used, to compare the dynamics of the returns for various periods before and after the event. The global MSCI index or, if the analysis is carried out for each country separately, relevant national stock exchange indices can be used as reference market index. Thus taking into account all the specifics of applying the event study method for several countries, the expected return is calculated:

$$R_{it} = \alpha_i + \beta_i R_{wmt} + \varepsilon_{it}, \tag{4.3.1}$$

where R_{wmt} is the return on the global market index on day t, ε is the abnormal (excess) return component, and α_i and β_i are the model parameters. The model is estimated using the least squares method on the testing window. Next, the observed return is compared with the expected ones over different event windows, to calculate the excess return:

$$AR_{it} = R_{it} - (a_i + b_i R_{wmt}) \tag{4.3.2}$$

Cumulative abnormal return (CAR), or average abnormal return (AAR) are also calculated for different event windows:

$$CAR_i(t_j t_k) = \sum_{t_j}^{t_k} AR_{it}, \tag{4.3.3}$$

$$AAR_i(t_1 t_2) = \frac{1}{N} \sum_{t_1}^{t_2} AR_{it}, \tag{4.3.4}$$

Cumulative average abnormal return is the average of all CARs for the selected event window:

$$CAAR(t_1 t_2) = \frac{1}{N} \sum_{t_1}^{t_2} CAR_{(t_1, t_2)}, \tag{4.3.5}$$

The estimates obtained by the event study method allow to analyse the factors which have caused the excess returns in more detail. Using the event study method to analyse the results of obtaining technology through mergers and acquisitions allows to assess the efficiency of such deals in the short and medium term, and identify innovation-related risk factors which directly affected the deals' results (Dranev et al., 2019; Ochirova, Dranev, 2021). The author of the dissertation was the first to use the event study method to assess the impact of financial technology acquisition on company value (Dranev et al., 2019).

Using data envelopment analysis to assess the impact of innovation-related risks on the consequences of strategic decisions

Conducting data envelopment analysis (DEA) to assess the consequences of technology acquisition and identify its determinants involves a two-step procedure (Dranev et al., 2023). DEA allows to assess the efficiency of merger and acquisition deals on the basis of post-merger financial results in relation to the parameters of the acquired technologies. When the relative efficiency is assessed with the help of DEA, the relationship between efficiency and innovation-related risk indicators is examined.

DEA is a popular benchmarking method for assessing relative performance indicators in strategic decision making (Lafuente, Berbegal-Mirabent, 2019). The efficiency of acquiring technology and knowledge through mergers and acquisitions is assessed by comparing the financial results of the merged firm with the technological characteristics of the acquired company (Dranev et al., 2023). The performance of the most efficient merged firms serves as the efficiency threshold. Any merged firm with less successful post-merger performance falls below the efficiency threshold. The radial distance between the merged company's position and the relevant point on the efficiency threshold shows the degree of inefficiency. Finally, the performance measure ranges between 0 and 1, and allows to compare the results of M&A deals across the sample.

The DEA approach defines performance indicator as follows (Charnes et al., 1978):

$$Max\ \theta_j = \frac{\sum_{r=1}^{q} y_{rj} u_r}{\sum_{i=1}^{m} x_{ij} v_i} \tag{4.3.6}$$

provided that

$$\frac{\sum_{r=1}^{q} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \ \ (j = 1, \dots, n), \ \ u_r \geq 0 \ (r = 1, \dots, q), v_i \geq 0 \ (i = 1, \dots, m); \tag{4.3.7}$$

where θ_j is the calculated efficiency indicator of the j_{th} transaction; $y_{i,1}, \dots y_{i,N}$ are the acquirer's financial performance indicators after the merger; $x_{i,1}$, … $x_{i,M}$ are the characteristics of the target technological base; u_1, … u_q and v_1, … v_m are the output and input parameters' weights, respectively.

Post-merger financial performance can be measured using accounting and market indicators. If used separately, both types of measurements can produce fragmented performance estimates. To assess post-merger performance more accurately, it is recommended to use both accounting and market measures (King et al., 2021).

The first market indicator is post-merger cumulative abnormal return (CAR) on the company stock (Bettinazzi, Zollo, 2017). CAR is the most popular stock performance measure in empirical M&A research, reflecting the short-term effect of the deal, i.e. investors' immediate reaction to the M&A announcement (Renneboog, Vansteenkiste, 2019). CAR is estimated using the market model within three days of the acquisition announcements. A longer event window may produce inconsistent results as estimates are influenced by changes in the correlation of stock and market returns (MacKinlay, 1997). DEA's second market indicator, M/B (market to book value) for the year following the merger, reflects investors' long-term expectations. Return on equity (ROE) is used as a third (accounting) indicator because it is less sensitive to the relative size of the deal than return on assets (ROA) (King et al., 2021). Thus CAR, ROE, and M/B are used as DEA output variables. These measures cover various planning horizons, reflect multiple aspects of firms' performance, and provide a comprehensive assessment of their efficiency.

Input DEA parameters describe acquired technologies and knowledge. R&D expenditures are often used as a proxy for firms' technological depth, since they reflect their technological expertise (George et al., 2008). The number of patents can indicate technological breadth (number of potential knowledge applications) (Boh et al., 2014). Rate of capital expenditures can be used to estimate technology adoption. Finally, M/B ratio is a potential growth indicator related to investors' expectations regarding the success of technological development (L. Gu, 2016). Taken together, these indicators reflect the key stages of a linear innovation model, from research (R&D expenditures rate) to technology development (patenting activity), application (capital expenditures rate), and expected commercialisation results (M/B ratio). All of the above parameters are directly related to risks associated with innovation.

DEA estimates are obtained using an input-oriented model based on constant returns to scale and radial distance (CCR) (Korhonen et al., 2003). Typically, having acquired new technology, the firm will try to use it to create value for itself and improve its financial results. It is assumed that costs at all stages, from research to commercialisation, should vary in line with the increase or decrease in the acquired technological capabilities. The lowest input parameter values are considered to check whether the desired results of the merger have been obtained, which justifies the choice of the CCR model. To address the DEA bias problem, bootstrapping is used (Simar, Wilson, 2000). DEA values after bootstrapping adequately reflect the effects of acquiring technology and knowledge through the merger, since they compare the parameters of the technological base of the acquired company and the results of the merged one.

At the second stage, a regression is built to identify the determinants which most significantly affect the performance of acquired technologies. The model is estimated using beta regression, which is applied if the dependent variable ranges between 0 and 1 (Ferrari, Cribari-Neto, 2004). The advantage of using beta regression is that beta distribution is not necessarily symmetrical and heteroskedastic around the mean, and to a lesser extent around 0 and 1. Independent variables affecting technological efficiency include characteristics of acquirer firms exposed to innovation-related risks.

Although the DEA method has been used to analyse mergers and acquisitions previously (Wanke et al., 2017), the author of the dissertation is the first to propose an approach that allows to separate and analyse the component of a merger and acquisition deal's efficiency associated with innovation-related risks (Dranev et al., 2023, Ochirova, Dranev, 2021). Also, the DEA method can be used to analyse the consequences of other strategic decisions. E.g. in the scope of this dissertation study, DEA was applied to assess the impact of organisational ambidexterity on company value (Dranev et al., 2020). In particular, the authors considered the use of DEA to assess the effects of oil and gas companies' diversification through actively investing in renewable energy technologies which compete with their core business.

5. Results

The main result of this study is the developed theoretical and methodological tools, which allow to model the impact of various ID risks of on the value of a company using three key approaches: estimation of the cost of equity, the real options method and analysis of the consequences of strategic decisions.

In accordance with the study objectives, the following results were obtained in key approaches of modelling the impact of ID risks on company value:

Approach 1. Cost of equity models

Related to Objective 1

1) Obtained a solution to the optimization problem of investors, whose preferences are modeled using the colog-measure (Дранев, 2012). A new formula for estimating the cost of equity has been derived.

Related to Objective 2

2) Using a vector autoregression model it was shown that Russian investors perceive the increase of market risks extremely negatively, and (unlike US investors) limit their investments in mutual funds for several months (Dranev, Ananyev, 2010). Risks were measured using, among others, the colog measure. This result can be useful for assessing investor preferences and developing cost of equity models for Russian companies whose activities are exposed to innovation-related risks.

Related to Objective 3

3) The features of currency risk pricing factor are analyzed (Дранев, 2013). Approaches to developing models for estimating the cost of equity in emerging markets are explored (Дранев и др., 2012). Based on the analysis, an international pricing model is proposed (Dranev и др., 2019).

Related to Objective 4

4) Using a sample of companies from knowledge-intensive economies it was shown that a risk premium associated with R&D expenditures exists when cost of equity is assessed (Dranev et al. 2017). It was demonstrated that a sharp decrease in the rate of R&D expenditures should increase the premium on the company's innovation-related risks.

Related to Objective 5

5) A positive risk premium associated with the rate of R&D expenditures may be accompanied by reduced exposure to market risks, in particular currency risk (Dranev et al. 2017).

Approach 2. Real options method

Related to Objective 6

6) It has been shown that the real options method can be used to assess the value of innovative companies and projects whose cash flows are subject to abrupt changes caused by the emergence of competing innovative products, increased uncertainty associated with the introduction of innovations, or sharp fluctuations in market risk factors (Dranev, 2010).

Related to Objective 7

7.1) A methodology for assessing the impact of technological development on the growth of economic sectors using the production function model has been modified (Dranev, Chulok, 2015). This methodology can be applied to model cash flows and build scenarios using the real options method.

7.2) Based on scenario analysis an approach has been developed which makes it possible to generate an event tree reflecting macroeconomic risks and ID risks. An approach can be used to determine the value of real options in discrete time (Saritas, Dranev, Chulok 2017).

7.3) For the first time a non-linear relationship has been identified between diversifying agricultural research and agricultural productivity in various countries. Optimal diversification levels for countries were determined, which, other country-specific factors being equal, allow to maximise productivity. These results can be useful not only for assessing the effectiveness of science, technology, and innovation policies, but also for modelling the impact of relevant innovation-related risks on agricultural firms' cash flows (Dranev et al. 2018).

Related to Objective 8

8) The specifics of applying the real options method in the electric power industry have been demonstrated, related to decision-making on irreversible investments, including in innovation development, switching to alternative energy sources, and the introduction of energy-saving technologies given strong fluctuations in energy prices and supply disruptions (Dranev, 2012).

Approach 3. Analysis of the consequences of strategic decisions

Related to Objective 9

9) It has been determined that in the energy sector, investors assess the growth potential of more organisationally ambidextrous companies higher. It was demonstrated that energy companies which diversify their business into renewable energy can create additional value. The hypothesis about the positive impact of pharmaceutical companies' ambidexterity on their

potential to increase their value was not confirmed. In addition to the first-ever application of DEA to measure ambidexterity, other methods were used, based on assessing revenue diversification and R&D expenditures. The results of the analysis (Dranev et al., 2020) allowed to assess the effects of organisational ambidexterity on company value, and develop recommendations for making strategic decisions on business diversification.

Related to Objective 10

10.1) For the first time a negative relationship was revealed between the acquirer companies' R&D expenditures and the efficiency of procuring technologies and knowledge through mergers and acquisitions. This may indicate that companies which already have an advanced technological base and established technology development organisational processes may experience issues with adapting acquired technologies. Risks associated with new technology acquisition negatively affect merger results, among other things due to the technology substitution effect. These results can be useful for developing mergers and acquisitions strategy for the purpose of procuring technologies. Empirical testing was carried out on a sample of countries with developed capital markets, using data envelopment analysis (Dranev et al., 2023). Similar conclusions were drawn after testing the model on a narrower sample of high-tech companies, (Ochirova, Dranev, 2021).

10.2) For the first time, a significant positive short-term impact of acquiring fintech companies on the share price of the acquirer firm was discovered. In the long term this effect was not confirmed, which may indicate, on the one hand, an irrational investor reaction to acquiring fintech firms, and on the other, issues with adapting technologies obtained through a merger, especially for non-financial companies. A more significant effect was observed for companies in countries with developed capital markets, especially in the case of cross-border deals. The effect of acquiring financial technologies by companies with a history of acquisitions was less pronounced. Financial sector companies received the greatest benefits from financial technology acquisitions (Dranev et al. 2019).

6. Novelty

A comprehensive system of methods was developed for the first time to model the impact of internal and external ID risks on the value of a company using equity capital cost models, valuation of real options in discrete and continuous time, as well as analysis of strategic decisions related to business diversification and acquisition of technology and knowledge.

The original scholarly contribution of the key results is described, with references to relevant publications by the author.

1) A new version of the cost of equity model has been developed, where investor utility function is calculated using a colog risk measure (Dranev, 2012). The model takes into account investors' asymmetrical attitude to market risks, and can be used to estimate expected return on shares of companies exposed to innovation-related risks. For the first time it was demonstrated that colog risk measure allows to more accurately predict investor behaviour, using Russian mutual funds as an example (Dranev, 2010).
2) A new model for estimating real options value in continuous time has been developed, which allows to take into account cash flow jumps caused by the implementation of innovation-related risks (Dranev, 2010). The proposed methodology can be applied to estimate cost of equity for innovative companies whose stock returns are subject to abrupt changes.
3) An original approach has been proposed for assessing the impact of R&D expenditures on exposure to market risks (Dranev et al., 2017). The approach allows to view innovation-related risks not as a separate risk factor in the cost of equity model, but either take into account its impact on the exposure to market risk factors (including in international pricing models), or consider the innovation-related risk factor as a state variable in intertemporal pricing models.
4) A new methodology has been developed for assessing the effects of acquiring technology through mergers and acquisitions with the help of data envelopment analysis (Dranev et al., 2023). Using the DEA method with the proposed set of parameters (input parameters describe the innovation of the target company, and output ones - the financial results of the merged company) for the first time allowed to identify and analyse the effects of mergers and acquisitions associated with innovation-related risks.
5) A new methodology for assessing organisational ambidexterity using DEA has been proposed, which allows to assess the impact of companies' strategic choice between creating incremental and breakthrough innovations on firm value with the help of DEA (Dranev et al., 2020).
6) An original approach was proposed to identifying mergers and acquisitions aimed at obtaining financial technologies based on industry classification, which allows to study its effects (Dranev et al., 2019).
7) A new methodology has been developed to assess the impact of STI policy (regarding the diversification of scientific research) on productivity in agriculture (Dranev et al. 2018). This

methodology can be applied to assess the impact of ID risks associated with STI policies on cash flows in order to predict their dynamics and to determine the value of firms.

7. Theoretical and practical significance of the study

7.1.Theoretical significance

This dissertation contributes to the literature on corporate finance theory, risk management, financial economics, and economics of innovation. The studies present a theoretical and methodological apparatus which allowed to solve a number of methodological problems identified in the academic literature and provided a systemic foundation for assessing the degree and nature of the impact of innovation-related risks on company value. The author's research contributes to the development of: models describing investor behaviour, assessing cost of equity, the real options pricing theory, and approaches to assessing merger and acquisition effects associated with innovation-related risks.

At the same time, the author sees prospects for further research in each of the key approaches. In particular, regarding cost of equity models, the following studies can be considered: developing model modifications incorporating innovation-related risk factors in the pricing model based on investors' colog-preferences; modelling the switching of investor attitude modes to innovation-related and market risks depending on the dynamics of other risk factors. Separately, it is proposed to continue relevant research of the relationship between innovation-related risks and risks associated with the implementation of ESG practices. Another promising research approach is advancing a methodology for modelling the impact of STI policy approaches diversification on the dynamics of industry parameters, and the associated financial results of individual companies.

In the real options framework, using the already developed methodology, it is proposed to continue examine the impact of innovation-related risks on company value in industries where the real options method is most actively used, in particular the energy and pharmaceutical sectors (Nadarajah, Secomandi, 2023).

Regarding the analysis of strategic decisions, it is proposed to continue mergers and acquisitions research using data envelopment analysis and other methods, to assess the effects in various economic sectors. In particular, one of the most cited studies by the author of the dissertation on the effects of acquiring fintech firms (Dranev et al., 2019) has been addressed in modern academic literature: an updated methodology has been proposed on the basis of the emergence of previously unavailable information (Browne et al., 2023).

7.2.Practical importance

The author's works can be used: to support investment decisions related to the investment in shares of innovative companies in developed and developing capital markets; for proposing a strategy for innovative companies; making management decisions related to business diversification and the acquisition of technology and knowledge; development of state policy in the field of science, technology and innovation.

Most of the papers which provided the basis for this dissertation study were written in the scope of research projects implemented by the HSE ISSEK International Laboratory for Science and Technology Studies and the Corporate Finance Laboratory of the HSE Faculty of Economic Sciences, supported by the HSE Basic Research Programme. The materials presented in the papers were used to prepare the following educational courses for undergraduate and graduate students delivered at the National Research University Higher School of Economics in 2010-2024: “Corporate Risk Management”, “Value Assessment”, “Corporate Finance”, “Financing Innovations”, “Economics of Innovation”. The topics addressed in the study formed the basis of more than 90 Masters and Bachelors qualifying works successfully defended under the academic supervision of the applicant at the National Research University Higher School of Economics. Also, two PhD dissertations were defended at the National Research University Higher School of Economics under the applicant’s supervision.

8. Evaluation of research results

The results of the study were discussed at seminars of the Corporate Finance Laboratory of the HSE Faculty of Economic Sciences, the Financial Innovation and Risk Management Research and Educational Laboratory of the National Research University Higher School of Economics, and various Russian and international conferences:

1. V Russian Economic Congress (Ekaterinburg, 2023). Report: “The impact of ESG ratings on the attractiveness of exchange-traded foundations for investors”

2. X Annual International Scientific Conference “Economics and Management” (St. Petersburg, 2023). "Report: Impact of Corporate Social Responsibility on Research and Development returns: evidence for firms from high R&D intensive industries."

3. Workshop Effects of Enterprise Innovation Culture Openness (Moscow, 2021). Report: «M&A as a means of innovation».

4. 11th Annual International Academic Conference Foresight and STI Policy (Moscow, 2020). Report: «Efficiency of Technology M&A: Implications for Open Innovation».

5. GSOM Emerging Markets Conference (St. Petersburg, 2019). Report: «Mergers & Acquisitions and Technological Efficiency».

6. XVIII April International Academic Conference on Economic and Social Development (Moscow, 2017). Report: «R&D and performance in agricultural sector».

7. World Finance Conference (New York, 2016). Report: «COLOG Asset Pricing».

8. 12th EIASM interdisciplinary workshop on “intangibles, intellectual capital & extra-financial information” (St. Petersburg, 2016). Report: «R&D Expenditures and Cross Section of Stock Returns in R&D Intensive Markets».

9. V World Finance Conference (Venice, 2014) Report: «Asymmetric exchange-rate exposure in BRIC countries»

10. 13th EACES Biennial Conference (Budapest, 2014) Report: «Differences in Exchange Rate Exposures in BRIC Markets».

11. 9 th EBES Conference (Rome, 2013). Report: «Differences in Exchange Rate Exposures in BRIC Markets».

12. XIV April International Academic Conference (Moscow, 2013). Report: “Entropy risk measures and costs of equity: empirical evidence from Russia.”

9. Published papers

9.1. Main articles on the topic of the dissertation

1) Dranev Y., Ochirova E., Harms R., Miriakov M. Assessment of Interorganizational Technology Transfer Efficiency // Foresight and STI Governance. 2023. Vol. 17. No. 3. P. 20-31. doi
2) Ochirova E., Dranev Y. The Impact of R&D Expenditure upon the Efficiency of M&A Deals with Hi-Tech Companies // Foresight and STI Governance. 2021. Vol. 15. No. 1. P. 31-38. doi
3) Dranev Y., Izosimova A., Meissner D. Organizational Ambidexterity and Performance: Assessment Approaches and Empirical Evidence // Journal of the Knowledge Economy. 2020. No. 11. P. 676-691. doi
4) Kuchin I., Elkina M., Dranev Y. The Impact of Currency Risk on the Value of Firms in Emerging Countries // Journal of Corporate Finance Research. 2019. Vol. 13. No. 1. P. 7-27. doi
5) Dranev Y., Frolova K., Ochirova E. The impact of fintech M&A on stock returns // Research in International Business and Finance. 2019. Vol. 48. P. 353-364. doi
6) Dranev Y., Kotsemir M. N., Syomin B. Diversity of research publications: relation to agricultural productivity and possible implications for STI policy // Scientometrics. 2018. Vol. 116. No. 3. P. 1565-1587. doi
7) Saritas O., Dranev Y., Chulok A.A. A Dynamic and Adaptive Scenario Approach for Formulating Science and Technology Policy // Foresight. 2017. Vol. 19. No. 5. P. 473-490. doi
8) Dranev Y., Levin A., Kuchin I. R&D Effects, Risks and Strategic Decisions: Evidence from Listed Firms in R&D-intensive Countries // Foresight. 2017. Vol. 19. No. 6. P. 615-627. doi
9) Dranev Y., Chulok A. Assessing interactions of technologies and markets for technology road mapping // Technological Forecasting and Social Change. 2015. Vol. 101. P. 320-327. doi
10) Дранев Ю. Я., Нурдинова Я. С., Редькин В. А., Фомкина С. А. Модели оценки затрат на собственный капитал компаний на развивающихся рынках капитала // Корпоративные финансы. 2012. № 2. С. 107-117.
11) Дранев Ю. Я., Ананьев Н. С. Влияние изменения индикаторов фондового рынка на привлечение средств в российские паевые фонды акций // Корпоративные финансы. 2010. № 2. С. 5-15.
12) Dranev Y. Impact of ESG Activities on the Innovation Development and Financial Performance of Firms // Journal of Corporate Finance Research. 2023. Vol. 17. No. 3. P. 152-159

13) Дранев Ю. Я. Валютный риск и теория ценообразования активов // Корпоративные финансы. 2013. Т. 28. № 4. С. 114-124.
14) Дранев Ю. Я. CAPM-Like Model and the Special Form of the Utility Function // Корпоративные финансы. 2012. № 1. С. 33-36.
15) Дранев Ю. Я. Об использовании метода реальных опционов в электроэнергетике // Корпоративные финансы. 2011. № 1. С. 129-135.
16) Дранев Ю. Я. О риск-нейтральном подходе ценообразования реальных опционов // Корпоративные финансы. 2010. № 1. С. 62-73.

9.2.Preprints

1) Kuchin I., Baranovskii G., Dranev Y., Chulok A. Does green bonds placement create value for firms? / NRU Higher School of Economics. Series WP BRP "Science, Technology and Innovation". 2019. No. 101.
2) Gareeva Y., Dranev Y., Kucherov A. The Impact of Innovation Capital on Firm Values / National Research University Higher School of Economics. Series WP BRP "Basic research program". 2018. No. 79.
3) Dranev Y., Babuskin M. Asymmetric Exchange-Rate Exposure in BRIC Countries / NRU Higher School of Economics. Series FE "Financial Economics". 2014.
4) Dranev Y., Chupin D. Colog Asset Pricing, Evidence from Emerging Markets / NRU Higher School of Economics. Series FE "Financial Economics". 2022. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4198227
5) Dranev Y., Fomkina S. An asymmetric approach to the cost of equity estimation: empirical evidence from Russia / NRU Higher School of Economics. Series FE "Financial Economics". 2012. No. 12/FE/2012.
6) Dranev Y., Dabrowski A. R. Jump-diffusion markets: equivalent measures and optimality / Laboratory for Research in Statistics and Probability, Carleton University. Series "Technical report series". 2004. No. 405.

10. References

Баранов, А., & Долгопятова, Т. (2013). *Эмпирический анализ инновационного поведения фирм при различных институциональных условиях*. НИУ ВШЭ.

Гохберг, Л. М., & Кузнецова, Т. Е. (2012). Инновации как основа экономического роста и укрепления позиций России в глобальной экономике. *Вестник международных организаций: образование, наука, новая экономика*, *7*(2), 101–117.

Изгарова, А., Рогова, Е., & Бахарева, О. (2023). Взаимосвязь информации о ESG-инвестициях и доходности акций: Кейс крупных российских компаний. *Управленец*, *14*(3), 17–29.

Ларченко, Н., & Ружанская, Л. (2023). Determinants of Mergers and Acquisitions in Emerging Asian Countries: Effects of Confucianism and Technological Development. *Journal of Corporate Finance Research/Корпоративные Финансы| ISSN: 2073-0438*, *17*(3), 28–42.

Миловидов В.Д. (2019) *Симметрия заблуждений: Факторы неопределенности финансового рынка в условиях технологической революции.* М.: Магистр

Рогова, Е. М., & Пахардымова, А. С. (2022). Взаимосвязь цифровой трансформации и успешности сделок слияний и поглощений.

Рубцов, Б., & Анненская, Н. (2019). « Зеленые» облигации-особый инструмент в создании дорожной карты" зеленых" финансов (мнение экспертов Финансового университета). *Банковские услуги*, *11*, 2–9.

Adler, M., & Dumas, B. (1983). International portfolio choice and corporation finance: A synthesis. *The Journal of Finance*, *38*(3), 925–984.

Ameriks, J., Kézdi, G., Lee, M., & Shapiro, M. D. (2020). Heterogeneity in expectations, risk tolerance, and household stock shares: The attenuation puzzle. *Journal of Business & Economic Statistics*, *38*(3), 633–646.

Ang, A., Hodrick, R. J., Xing, Y., & Zhang, X. (2006). The cross-section of volatility and expected returns. *The journal of finance*, *61*(1), 259–299.

Arrow, K. J. (1965). Aspects of the theory of risk-bearing. *(No Title)*.

Arrow, K. J., & Debreu, G. (1954). Existence of an Equilibrium for a Competitive Economy. *Econometrica*, *22*(3), 265–290. JSTOR. https://doi.org/10.2307/1907353

Artzner, P., Delbaen, F., Eber, J., & Heath, D. (1999). Coherent measures of risk. *Mathematical finance*, *9*(3), 203–228.

Avdasheva, S., & Tsytsulina, D. (2015). The effects of M&As in highly concentrated domestic vis-à-vis export markets: By the example of Russian metal industries. *Research in International Business and Finance*, *34*, 368–382.

Bansal, R., & Viswanathan, S. (1993). No arbitrage and arbitrage pricing: A new approach. *The Journal of Finance*, *48*(4), 1231–1262.

Banz, R. W. (1981). The relationship between return and market value of common stocks. *Journal of financial economics*, *9*(1), 3–18.

Barberis, N., Shleifer, A., & Vishny, R. (1998). A model of investor sentiment. *Journal of financial economics*, *49*(3), 307–343.

Basu, S. (1983). The relationship between earnings' yield, market value and return for NYSE common stocks: Further evidence. *Journal of financial economics*, *12*(1), 129–156.

Bawa, V. S., & Lindenberg, E. B. (1977). Capital market equilibrium in a mean-lower partial moment framework. *Journal of financial economics*, *5*(2), 189–200.
Bena, J., & Li, K. (2014). Corporate innovations and mergers and acquisitions. *The Journal of Finance*, *69*(5), 1923–1960.
Bernard, V. L., & Thomas, J. K. (1989). Post-earnings-announcement drift: Delayed price response or risk premium? *Journal of Accounting research*, *27*, 1–36.
Bettinazzi, E. L., & Zollo, M. (2017). Stakeholder orientation and acquisition performance. *Strategic Management Journal*, *38*(12), 2465–2485.
Binder, J. (1998). The event study methodology since 1969. *Review of quantitative Finance and Accounting*, *11*, 111–137.
Black, F., & Scholes, M. (1973). The pricing of options and corporate liabilities. *Journal of political economy*, *81*(3), 637–654.
Boh, W. F., Evaristo, R., & Ouderkirk, A. (2014). Balancing breadth and depth of expertise for innovation: A 3M story. *Research Policy*, *43*(2), 349–366.
Branch, B., & Chichirau, C. (2010). Mispricing vs risk premia in R&D-intensive firms. *International Review of Financial Analysis*, *19*(5), 358–367.
Breeden, D. T. (1979). An intertemporal asset pricing model with stochastic consumption and investment opportunities. *Journal of financial Economics*, *7*(3), 265–296.
Browne, O., Cumming, D., Hutchinson, M. C., Kirshner, S. N., & O'Reilly, P. (2023). Why Avoid Participating in an Accelerator? Countersignalling by High-Quality FinTech Ventures. *British Journal of Management*.
Campbell, J. Y., Giglio, S., Polk, C., & Turley, R. (2018). An intertemporal CAPM with stochastic volatility. *Journal of Financial Economics*, *128*(2), 207–233.
Chan, L. K., Lakonishok, J., & Sougiannis, T. (2001). The stock market valuation of research and development expenditures. *The Journal of finance*, *56*(6), 2431–2456.
Chan, S. H., Martin, J. D., & Kensinger, J. W. (1990). Corporate research and development expenditures and share value. *Journal of Financial Economics*, *26*(2), 255–276.
Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, *2*(6), 429–444.
Chiang, T. C., & Zheng, D. (2010). An empirical analysis of herd behavior in global stock markets. *Journal of Banking & Finance*, *34*(8), 1911–1921.
Cho, J.-W., Choi, J. H., Kim, T., & Kim, W. (2016). Flight-to-quality and correlation between currency and stock returns. *Journal of Banking & Finance*, *62*, 191–212.
Christofi, M., Pereira, V., Vrontis, D., Tarba, S., & Thrassou, A. (2021). Agility and flexibility in international business research: A comprehensive review and future research directions. *Journal of World Business*, *56*(3), 101194. https://doi.org/10.1016/j.jwb.2021.101194
Cochrane, J. (2009). *Asset pricing: Revised edition*. Princeton university press.
Constantinides, G. M. (1990). Habit formation: A resolution of the equity premium puzzle. *Journal of political Economy*, *98*(3), 519–543.
Damodaran, A. (2012). Investment valuation: Tools and techniques for determining the value of any asset (T. 666). John Wiley & Sons.

Daniel, K., Hirshleifer, D., & Subrahmanyam, A. (1998). Investor psychology and security market under-and overreactions. *the Journal of Finance*, *53*(6), 1839–1885.

De Giorgi, E., & Post, T. (2008). Second-order stochastic dominance, reward-risk portfolio selection, and the CAPM. *Journal of Financial and Quantitative Analysis*, *43*(2), 525–546.

Delbaen, F., & Schachermayer, W. (1998). A simple counterexample to several problems in the theory of asset pricing. *Mathematical Finance*, *8*(1), 1–11.

Dixit, A. K., & Pindyck, R. S. (1994). *Investment under uncertainty*. Princeton university press.

Dong, D., Wu, K., Fang, J., Gozgor, G., & Yan, C. (2022). Investor attention factors and stock returns: Evidence from China. *Journal of International Financial Markets, Institutions and Money, 77*, 101499.

Eberhart, A. C., Maxwell, W. F., & Siddique, A. R. (2004). An examination of long-term abnormal stock returns and operating performance following R&D increases. *The journal of finance*, *59*(2), 623–650.

Epstein, L. G., & Zin, S. E. (1991). Substitution, risk aversion, and the temporal behavior of consumption and asset returns: An empirical analysis. *Journal of political Economy*, *99*(2), 263–286.

Fama, E. F., Fisher, L., Jensen, M. C., & Roll, R. (1969). The adjustment of stock prices to new information. *International economic review*, *10*(1), 1–21.

Fama, E. F., & French, K. R. (1989). Business conditions and expected returns on stocks and bonds. *Journal of financial economics*, *25*(1), 23–49.

Fama, E. F., & French, K. R. (1992). The cross-section of expected stock returns. *the Journal of Finance*, *47*(2), 427–465.

Fama, E. F., & French, K. R. (2008). Dissecting anomalies. *The journal of finance*, *63*(4), 1653–1678.

Fama, E. F., & MacBeth, J. D. (1973). Risk, return, and equilibrium: Empirical tests. *Journal of political economy*, *81*(3), 607–636.

Fernández, P. (2019). Valuing real options: Frequently made errors. SSRN.

Ferrari, S., & Cribari-Neto, F. (2004). Beta regression for modelling rates and proportions. *Journal of applied statistics*, *31*(7), 799–815.

George, G., Kotha, R., & Zheng, Y. (2008). Entry into insular domains: A longitudinal study of knowledge structuration and innovation in biotechnology firms. *Journal of Management Studies*, *45*(8), 1448–1474.

Giglio, S., Maggiori, M., Stroebel, J., & Utkus, S. (2021). Five facts about beliefs and portfolios. *American Economic Review*, *111*(5), 1481–1522.

Gokhberg, L., Fursov, K., & Roud, V. (2023). Technology measurement in statistics and beyond: Reviving technological innovation concept. В *Handbook of Innovation Indicators and Measurement* (сс. 240–258). Edward Elgar Publishing.

Greenhalgh, C., & Rogers, M. (2010). Innovation, intellectual property, and economic growth. В *Innovation, intellectual property, and economic growth*. Princeton University Press.

Griliches, Z. (1981). Market value, R&D, and patents. *Economics letters*, *7*(2), 183–187.

Gu, L. (2016). Product market competition, R&D investment, and stock returns. *Journal of Financial Economics*, *119*(2), 441–455.

Gu, S., Kelly, B., & Xiu, D. (2021). Autoencoder asset pricing models. *Journal of Econometrics*, *222*(1), 429–450.
Gupta, A. K., Smith, K. G., & Shalley, C. E. (2006). The interplay between exploration and exploitation. *Academy of management journal*, *49*(4), 693–706.
Hall, B. H. (1993). The stock market's valuation of R&D investment during the 1980's. *The American Economic Review*, *83*(2), 259–264.
Hansen, L. P., & Singleton, K. J. (1983). Stochastic consumption, risk aversion, and the temporal behavior of asset returns. *Journal of political economy*, *91*(2), 249–265.
Harikae, S., Dyer, J. S., & Wang, T. (2021). Valuing real options in the volatile real world. *Production and Operations Management*, *30*(1), 171–189.
Harrison, J. M., & Pliska, S. R. (1981). Martingales and stochastic integrals in the theory of continuous trading. *Stochastic processes and their applications*, *11*(3), 215–260.
Harvey, C. R., & Liu, Y. (2021). Lucky factors. *Journal of Financial Economics*, *141*(2), 413–435.
He, Y., Hu, W., Li, K., & Zhang, X. (2022). Can real options explain the impact of uncertainty on Chinese corporate investment? *Economic Modelling*, *115*, 105927.
Hirshleifer, D., Hsu, P.-H., & Li, D. (2013). Innovative efficiency and stock returns. *Journal of financial economics*, *107*(3), 632–654.
Hogan, W. W., & Warren, J. M. (1974). Toward the development of an equilibrium capital-market model based on semivariance. *Journal of Financial and Quantitative Analysis*, *9*(1), 1–11.
Ioulianou, S. P., Leiblein, M. J., & Trigeorgis, L. (2021). Multinationality, portfolio diversification, and asymmetric MNE performance: The moderating role of real options awareness. *Journal of International Business Studies*, *52*, 388–408.
Ivashkovskaya, I., Grigorieva, S., & Nivorozhkin, E. (2020). *Strategic Deals in Emerging Capital Markets*. Springer.
Jagannathan, R., & Wang, Z. (1996). The conditional CAPM and the cross-section of expected returns. *The Journal of finance*, *51*(1), 3–53.
Jeon, B. N., Zheng, D., & Zhu, L. (2017). Exchange rate exposure: International evidence from daily firm-level data. *Journal of Economic Integration*, 112–159.
Junni, P., Sarala, R. M., Taras, V., & Tarba, S. Y. (2013). Organizational ambidexterity and performance: A meta-analysis. *Academy of Management Perspectives*, *27*(4), 299–312.
Kahneman, D., & Tversky, A. (2013). Prospect theory: An analysis of decision under risk. В *Handbook of the fundamentals of financial decision making: Part I* (сс. 99–127). World Scientific.
Karminsky, A. M., Alekseevna, E. A., & Alekseevna, C. D. (2022). Ecological, Social and Governance Impact on the Company's Performance: Information Technology Sector Insight. *Procedia Computer Science*, *214*, 1065–1072.
Karolyi, A. G., & Wu, Y. (2021). Is currency risk priced in global equity markets? *Review of Finance*, *25*(3), 863–902.
Khotari, S., & Warner, J. B. (2006). Econometrics of Event Studies. Forthcoming. Handbook of Corporate Finance: Empirical Corporate Finance. North-Holland: Elsevier.

King, D. R., Wang, G., Samimi, M., & Cortes, A. F. (2021). A meta-analytic integration of acquisition performance prediction. *Journal of Management Studies, 58*(5), 1198–1236.
Korhonen, P., Stenfors, S., & Syrjänen, M. (2003). Multiple objective approach as an alternative to radial projection in DEA. *Journal of Productivity Analysis, 20*, 305–321.
Kung, H., & Schmid, L. (2015). Innovation, Growth, and Asset Prices. *The Journal of Finance*, *70*(3), Article 3. JSTOR.
Lafuente, E., & Berbegal-Mirabent, J. (2019). Assessing the productivity of technology transfer offices: An analysis of the relevance of aspiration performance and portfolio complexity. *The Journal of Technology Transfer*, *44*(3), 778–801.
Lev, B., Sarath, B., & Sougiannis, T. (2005). R&D reporting biases and their consequences. *Contemporary Accounting Research*, *22*(4), 977–1026.
Lev, B., & Sougiannis, T. (1996). The capitalization, amortization, and value-relevance of R&D. *Journal of accounting and economics*, *21*(1), 107–138.
Lichtenthaler, U. (2010). Technology exploitation in the context of open innovation: Finding the right 'job'for your technology. *Technovation, 30*(7–8), 429–435.
Lin, T. T., & Huang, S.-L. (2010). An entry and exit model on the energy-saving investment strategy with real options. *Energy Policy*, *38*(2), 794–802.
Lintner, J. (1965). Security prices, risk, and maximal gains from diversification. *The journal of finance*, *20*(4), 587–615.
MacKinlay, A. C. (1997). Event studies in economics and finance. *Journal of economic literature*, *35*(1), 13–39.
Maletič, M., Maletič, D., & Gomišček, B. (2016). The impact of sustainability exploration and sustainability exploitation practices on the organisational performance: A cross-country comparison. *Journal of Cleaner Production*, *138*, 158–169.
March, J. G. (1991). How decisions happen in organizations. *Human-computer interaction*, *6*(2), 95–117.
Mehra, R., & Prescott, E. C. (1985). The equity premium: A puzzle. *Journal of monetary Economics*, *15*(2), 145–161.
Merton, R. C. (1973a). An intertemporal capital asset pricing model. *Econometrica: Journal of the Econometric Society*, 867–887.
Merton, R. C. (1973b). Theory of rational option pricing. *The Bell Journal of economics and management science*, 141–183.
Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics*, *5*(2), 147–175. https://doi.org/10.1016/0304-405X(77)90015-0
Nadarajah, S., & Secomandi, N. (2023). A review of the operations literature on real options in energy. *European Journal of Operational Research*, *309*(2), 469–487.
Newey, W. K., & West, K. D. (1987). Hypothesis testing with efficient method of moments estimation. *International Economic Review*, 777–787.
OECD, E. (2018). Oslo manual 2018: Guidelines for collecting, reporting and using data on innovation. *Paris: OECD. DOI*, *10*, 24132764.
Øksendal, B., & Sulem, A. (2019). Stochastic Control of Jump Diffusions Stochastic control. B *Applied Stochastic Control of Jump Diffusions* (cc. 93–155). Springer.

Pástor, Ľ., & Stambaugh, R. F. (2009). Predictive systems: Living with imperfect predictors. *The Journal of Finance*, *64*(4), 1583–1628.

Petkova, R. (2006). Do the Fama–French factors proxy for innovations in predictive variables? *The Journal of Finance*, *61*(2), 581–612.

Petkova, R., & Zhang, L. (2005). Is value riskier than growth? *Journal of Financial Economics*, *78*(1), 187–202.

Pratt, J. W. (1965). Bayesian interpretation of standard inference statements. *Journal of the Royal Statistical Society. Series B (Methodological)*, *27*(2), 169–203.

Rachev, S. T., Stoyanov, S. V., & Fabozzi, F. J. (2011). *A probability metrics approach to financial risk measures*. John Wiley & Sons.

Rahman, M., Lambkin, M., & Hussain, D. (2016). Value creation and appropriation following M&A: A data envelopment analysis. *Journal of Business Research*, *69*(12), 5628–5635.

Renneboog, L., & Vansteenkiste, C. (2019). Failure and success in mergers and acquisitions. *Journal of Corporate Finance*, *58*, 650–699.

Rockafellar, R. T., Uryasev, S., & Zabarankin, M. (2006). Generalized deviations in risk analysis. *Finance and Stochastics*, *10*, 51–74.

Rosenberg, B., Reid, K., & Lanstein, R. (1985). Efficient capital markets: II. *Persuasive Evidence of Market Inefficiency*, *11*(3), 9–16.

Ross, S. A. (2013). The arbitrage theory of capital asset pricing. В *Handbook of the fundamentals of financial decision making: Part I* (сс. 11–30). World Scientific.

Rubinstein, M. (1976). The valuation of uncertain income streams and the pricing of options. *The Bell Journal of Economics*, 407–425.

Ruefli, T. W., Collins, J. M., & Lacugna, J. R. (1999). Risk measures in strategic management research: Auld lang syne? *Strategic management journal*, *20*(2), 167–194.

Sakhartov, A. V. (2018). Stock market undervaluation of resource redeployability. *Strategic Management Journal*, *39*(4), 1059–1082.

Sercu, P. (1980). A generalisation of the international asset pricing model. *DTEW Research Report 8002*.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The journal of finance*, *19*(3), 425–442.

Simar, L., & Wilson, P. W. (2000). A general methodology for bootstrapping in non-parametric frontier models. *Journal of applied statistics*, *27*(6), 779–802.

Solnik, B. H. (1974). An equilibrium model of the international capital market. *Journal of economic theory*, *8*(4), 500–524.

Switzer, L., & Picard, A. (2015). Idiosyncratic volatility, momentum, liquidity, and expected stock returns in developed and emerging markets. *Multinational Finance Journal*, *19*(3), 169–221.

Trigeorgis, L. (1996). Real options: Managerial flexibility and strategy in resource allocation. MIT press.

Trigeorgis, L., & Reuer, J. J. (2017). Real options theory in strategic management. *Strategic management journal*, *38*(1), 42–63.

Wanke, P., Maredza, A., & Gupta, R. (2017). Merger and acquisitions in South African banking: A network DEA model. *Research in International Business and Finance*, *41*, 362–376.
Wreford, A., Dittrich, R., & van der Pol, T. D. (2020). The added value of real options analysis for climate change adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(3), e642.