

Corporate investment

Advancing theoretical perspectives using agent-based techniques

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Abstract

This chapter explores the significance of agent-based modeling and simulation in advancing theories in the field of corporate investment. It sheds light on three primary contributions of agent-based techniques, namely: testing assumptions in analytical models, modeling human behavior realistically, and analyzing contingency effects and resulting dynamic and non-linear effects. Firstly, agent-based modeling enables the rigorous testing of assumptions made in analytical models. By employing agent-based simulations alongside analytical approaches, researchers can critically evaluate the robustness of existing theories. This comparative analysis helps identify the limitations and refine the assumptions underlying corporate investment models, leading to more accurate and reliable theoretical frameworks. Secondly, agent-based techniques offer a more flexible and realistic means of modeling human behavior in corporate investment. By incorporating factors such as biases, adaptive behavior, learning processes, and social norms, agent-based models can capture the complexities of decision-making processes. This enhanced representation of human behavior facilitates the development of a comprehensive behavioral theory of corporate investment, providing valuable insights into the factors influencing investment decisions and outcomes. Lastly, agent-based modeling allows for the systematic exploration of contingency effects on corporate investment theories. Contingency factors, including firm

characteristics, industry dynamics, and economic conditions, significantly influence investment strategies. By integrating these contingencies into agent-based models, researchers can analyze their interactions and understand how they shape investment behavior, leading to a deeper understanding of the dynamic nature of corporate investment decisions.

Keywords: corporate investment theory, scientific inquiry, capital structure, capital budgeting, theory development, behavioral corporate investment

1 Introduction

The proper allocation of financial capital constitutes a critical component of corporate investment decisions. When executed correctly, such decisions can bolster a firm's competitiveness, augment shareholder wealth, and ensure financial stability (Hasan 2013; Sureka et al. 2022). However, misallocation of financial resources can have adverse ramifications for the organization. Several factors can impede the efficient allocation of financial resources, including decision makers' personal traits, cognitive biases, age, experience, and national culture (Burns and Stalker 2006; Sureka et al. 2022), information asymmetries, and goal conflicts between managers and investors (Bushman and Smith 2001; Chemmanur, Paeglis, and Simonyan 2009), and a misfit or partial fit of the capital budgeting system in place in an organization with pertinent internal and external contingencies (Burns and Stalker 2006; Sureka et al. 2022). In order to address contemporary issues and further advance theoretical understanding in the domain of corporate investment, it is imperative for future research to continually explore and leverage new research methodologies.

This chapter builds upon this argument and investigates the potential contributions of agent-based modeling and simulation to advance theory development in the field of corporate investment. While the scope of corporate investment is wide-ranging by nature, this chapter specifically focuses on capital structure decisions made by firms and capital alloca-

tion decisions made within firms, and the deliberately omits issues that pertain to financial markets. Section 2 focuses on the exploration of the impact of agent-based techniques in this field by discussing Peirce's stages of scientific inquiry and the potential contributions to theory building that can be expected from agent-based modeling and simulation within this framework. The objective of Section 3 is to provide an overview of the corporate investment research landscape and its underlying theoretical foundations. Section 4 seeks to elucidate the potential contributions of agent-based techniques to theory development in a more concrete manner. Finally, the chapter concludes with Section 5.

2 Potential contributions of agent-based methods to theory development

2.1 Some notes on Peirce's stages of scientific inquiry

To evaluate the potential contributions of agent-based modeling and simulation in the realm of theory development, it is instructive to consider the stages of scientific inquiry introduced by Peirce (e.g., Peirce 1934, 2014). Peirce identifies three phases: (i) abduction, (ii) induction, and (iii) deduction. Abduction involves forming explanatory hypotheses, or unconfirmed theories, from observations. This step is fundamental to the process of theory development, as it is the only step in Peirce's framework that introduces new ideas (see also Peirce 1958). However, it is typically low in terms of empirical validity (Minnameier 2017). Deduction aims to increase empirical validity by drawing predictions from the explanatory hypotheses that can be tested by inductive evaluation. Thus, abduction shows that something, e.g., a factor influencing investment behavior in a certain way, *may be* (in

terms of an explanatory hypothesis), deduction evolves the consequences of the explanatory hypothesis and proves that something *must be* (i.e., it draws a prediction given certain premises), while induction tests the prediction made by deduction and shows that something *actually is or is not operative*. As such, an accepted theory must progress through all three stages. The importance of abduction in this triad has been stressed by Hookway (2012) and Misak (2002), among others, since deduction and induction cannot proceed beyond the concepts and hypotheses developed in the initial stage of abduction.¹

This triadic theory development framework can benefit from agent-based methods in two ways (Nersessian and MacLeod 2017). First, if the aim of agent-based modeling and simulation is to explore, explain, and understand real-world phenomena or justify theories, then agent-based approaches can provide a suitable means of research (Sec. 2.2). Second, when the research objective is to observe the aggregate behavior and dynamics of large populations of agents, such as organizations and markets, agent-based methods are particularly well-suited and can contribute to the process of theory building by aiding hypothesis development (Sec. 2.3).²

2.2 Contribution to drawing general conclusions from specific results

When the aim of research is to validate theories and gain a better understanding of real-world phenomena, simulations are developed based on theoretical models. Research in this context can either focus on exploring the boundary conditions of the theory using

1. A comprehensive discussion of the literature related to the triad of abduction, deduction, and induction is provided by Minnameier (2017).

2. It is worth noting that Nersessian and MacLeod (2017) distinguish between theory-driven and non-theory-driven simulations, wherein the former refers to models that aim to represent and explore a theory or a family of theories, and the latter involves, among others, observing emergent macro-level properties of systems with modeling assumptions at the micro-level that typically built on well-established theories or empirical findings (see also Wall and Leitner 2021; Wall 2016; Leitner and Wall 2015).

agent-based techniques or on analyzing the relationship between theories and simulations (Winsberg 1999; Nersessian and MacLeod 2017). In the former approach, the agent-based model is constructed based on one or multiple theories, and the conditions and parameters are systematically varied to identify the range of parameters where the theory holds, thereby generalizing the theory to this parameter space, or where the simulated system behaves differently from the theory's predictions (Halas 2011). Also, agent-based techniques allow for rich contextualization and for isolating the effects of specific factors, which might be a difficult endeavor for more conventional research methods (Adomavicius et al. 2021).

As emphasized by Winsberg (1999), the process of transferring a theoretical to an agent-based model is not only the mere computerization of theories, but requires extra-theoretical techniques, such as simplification and approximation, and fixing premises (Nersessian and MacLeod 2017). As a consequence, research also puts emphasis on the role of scientific modeling practices in the relationship between theories and simulations. In this vein, a particular emphasis is often placed on the use of simulation standards to standardize the process of modeling and experimentation to assure the robustness of findings and explore the boundary conditions of theories (see, for example, Hauke, Achter, and Meyer 2020; Mosler et al. 2001). Thus, if the modelling and experimentation processes are standardized and follow scientific principles, agent-based methods might play a role in advancing the process of theory development, facilitating the move from specific results to the derivation of more generalized conclusions (see also Lorscheid et al. 2019).

2.3 Contribution to generating explanatory hypotheses

Agent-based modeling and simulation is a crucial methodology when the research objective is to observe the aggregate behavior of large populations of agents, such as markets or

organizations, rather than to explore or justify theories (Nersessian and MacLeod 2017). Of particular importance in the context of this contribution is the unique feature of agent-based models to reveal how micro-level behavior aggregates to macro-level outcomes. This is a crucial capability since it exceeds that of formal or logic-based methods of theory development when interactions and resulting dynamics are highly non-linear (Grüne-Yanoff and Weirich 2010).

One of the main contributions of agent-based techniques to the theory development process is in the development of explanatory hypotheses that provide insight into the dynamics of a particular phenomenon under investigation in the abductive phase (Josephson and Josephson 1996).³ Integrating empirically and/or theoretically sound behavioral assumptions into agent-based models that go beyond rationality can increase the creativity and innovation of research, as the resulting explanatory hypotheses are not bound by mathematical tractability (Gilbert and Troitzsch 2005; Carley 1999; Halas 2011).⁴ If the agent-based model can generate the emergent phenomenon under investigation and produce replicable results, it is likely that the modeling assumptions are correct. After explanatory hypotheses are formed, the process of theory development can continue by inductive reasoning (from simulation results, related to Sec. 2.2) or deductive reasoning (from modeling assumptions) (as, for example, suggested by Carley 1999).⁵

3. It should be noted that agent-based techniques are regarded as a complement to, rather than a replacement for, other techniques in abductive reasoning (Smaldino, Calanchini, and Pickett 2015).

4. This contribution of agent-based modeling and simulation to theory development can also be contextualized by the concept of cognitive niche construction, meaning that researchers and simulation interact and certain cognitive functions (in the context of abductive reasoning) are delegated from the researcher to the computer simulation. This is done to help researchers cope with the innate complexity of the researched phenomena (Hecker et al. 2009; Smaldino, Calanchini, and Pickett 2015; Dodig-Crnkovic and Cicchetti 2017).

5. A more detailed discussion on the role of agent-based modeling and simulation in abductive reasoning is provided by Halas (2011). For a more detailed discussion of the role of agent-based techniques in theory development, the reader is also referred, among others, to Smaldino, Calanchini, and Pickett (2015).

3 The structure and theoretical foundations of corporate investment research

3.1 Structure of corporate investment research

The field of corporate investment is a diverse research area with a multitude of theories employed. A study by Stein (2003) explored the landscape of corporate investment research and structured it into corporate investment research at the firm level and within firms. Similar categories for corporate investment research are put forward by Hicks (1975) and Somers (1955), who argue that the main criteria for corporate investment decisions are either the maximization of profits or the maximization of the firm's market value.

A substantial body of literature pertaining to *corporate investment at the firm level* has been dedicated to the examination of the capital structure of organizations (Stein 2003). Capital structure, in this context, largely refers to the optimal combination of debt and equity that an organization must possess in order to ensure its operational stability and allow for investing into lucrative projects (Kumar, Colombage, and Rao 2017; Myers 1993; Kumar, Colombage, and Rao 2017). The interdependence between investment and financing decisions within organizations is widely acknowledged, as investment in lucrative projects necessitates funding, which may, in turn, trigger the requirement for a re-structuring of funding sources. Such re-structuring has immediate repercussions on an organization's capital structure, capital cost, risk exposure, and financial performance.⁶ Optimizing financing

6. It is worth noting that the concept of capital structure and its relationship with an organization's financing decisions is a complex topic that has been extensively discussed in the literature. For a more comprehensive understanding of the different facets of capital structure and its interplay with financing decisions, the reader is, among others, referred to Kruk (2021), Kumar, Colombage, and Rao (2017), and Khémiri and Noubbigh (2018).

decisions to minimize capital costs positively affects shareholder value and increases firm value. This underscores the significance of efficient capital structure decisions for organizations (Kumar, Colombage, and Rao 2017). For review of the capital structure literature, the reader is referred to Graham and Leary (2011), Bajaj, Kashiramka, and Singh (2021), and Sisodia and Maheshwari (2022).

Capital budgeting is a prominent area of inquiry in corporate investment research *within firms*, aimed at achieving efficient allocation of financial resources to investment projects (Stein 2003). A sizable corpus of research in this domain is devoted to (i) assessing the benefits of investment opportunities, (ii) estimating the overall capital costs, and (iii) appraising the investment opportunities in light of whether their benefits exceed the cost of capital (Kolb 1968). Discounted cash-flow methods, such as net present value and internal rate of return, are frequently employed for this evaluation (Fisher 1930; Hirshleifer 1958). Other relevant approaches include the adjusted present value, payback and discounted payback periods, profitability indices, and the accounting rate of return (Graham and Harvey 2002; Cooper et al. 2002; Mubashar and Tariq 2019). Real options have also been posited as important aspects that need to be considered in the evaluation of investment projects (Dixit and Pindyck 2009; McDonald 2006; Rigopoulos 2015). The importance of efficient capital allocation is widely recognized, as it enhances a firm's competitiveness, ensures its survival in the market (Seitz and Ellison 1999; Bennouna, Meredith, and Marchant 2010), safeguards shareholders' wealth, and mitigates the financial risks associated with resource allocation (O'Sullivan and Sheffrin 2008; Sureka et al. 2022; Ghahremani, Aghaie, and Abedzadeh 2012). Prior research on capital budgeting processes and their determinants is well-documented, with recent systematic reviews and bibliometric studies provided in Sureka et al. (2022), Haka (2006), and Sarwary (2019) (with a focus on small and medium

sized enterprises).

3.2 Theoretical foundations of corporate investment research

3.2.1 Modigliani-Miller theory

The Modigliani-Miller theory (also: irrelevance proposition theorem), as it was introduced in Modigliani and Miller (1958), provides a seminal and widely adopted starting point for the analysis of capital structure. The authors posit that in idealized circumstances an organization's value is not influenced by its capital structure. Such circumstances are mainly represented by efficient markets that are free from the presence of taxes, costs of financial distress, agency costs, and information asymmetries. In this view, the value of the organization is determined by the net present value of expected cash flows generated by its assets, rather than its capital structure. When organizations make financing decisions, i.e., decide upon the debt-to-equity ratio, they only divide the cash-flow between investors. They assume that everyone has the same access to financial markets and, in consequence, can create any leverage on their own, which is why an organization's leverage ultimately has no effect on its value (Luigi and Sorin 2009). In Miller and Modigliani (1961), the authors add that not only the capital structure but also the dividend policy has no effect on an organization's value. In a subsequent work, Modigliani and Miller (1963) and Miller (1977) further develop their concept by incorporating the effects of taxes and demonstrate that organizations may actually increase their value by financing with debt, because considering taxes in the context of this context creates a tax-shield that 'shields earnings from taxes' and leads to advantages due to the deductibility of interest payments. However, if there is no offsetting in the form of cost of debt, the tax-shield may imply relying fully

on debt-financing, which ultimately led to considering a trade-off of costs and benefits of relying of debt (Luigi and Sorin 2009).

Over time, many adaptations of the original theory emerged. For example, Hamada (1969) joined the model with taxes with the capital asset pricing model, Stiglitz (1969) and Rubinstein (1973) relax the assumption of risk-free debt (that is included in the original model). In recent research, the Modigliani-Miller theorem was adapted by Brusov et al. (2011) and Brusov et al. (2018) for companies of arbitrary age and arbitrary lifetime, whereas the original Modigliani-Miller theory assumes that companies and cash flows exists indefinitely.⁷

3.2.2 Trade-off theory

The label trade-off theory describes a family of theories that have in common that a firm evaluates the benefits of costs of different leverage plans (Frank and Goyal 2008). The concept of the trade-off theory was first introduced by Kraus and Litzenberger (1973), who took into account the costs and benefits of an organization's capital structure. Specifically, in their initial model, they particularly considered benefits in the form of tax advantages and expected bankruptcy costs (Miglo 2010).⁸

Bradley, Jarrell, and Kim (1984) refined this concept and introduced a *static version* of the trade-off theory. One of the most important benefits of debt financing is the tax-shield effect, leading to a tax advantage. On the other hand, the major cost is represented by financial distress and personal tax expenses of bondholders. Other important factors

7. For a more comprehensive discussion of the extensions of the Modigliani-Miller theory, the reader is referred to Brusov and Filatova (2023).

8. For more extensive reviews of factors that might lead to costs, the reader is referred to the reviews by Frank and Goyal (2008) Graham and Harvey (2001) (with a focus on tax effects), Leary and Roberts (2005) (with a focus on adjustment cost assumptions), and Haugen and Senbet (1978) (with a focus on bankruptcy costs).

that might be considered include agency costs due to a conflict of interest between equity shareholders and debt holders or shareholders and managers, as well as asymmetrically distributed information (Jensen and Meckling 1976). One fundamental critique of this model is that it is static even though firms are not, which leads to problems of how to capture retained earnings and the interpretation of mean reversion, i.e., the tendency of the leverage ratio to lean towards a mean value in the long run (Frank and Goyal 2008).

Kane, Marcus, and McDonald (1984) proposed a *dynamic version* of the trade-off theory that takes into account temporal aspects. The idea of a dynamic model is also in line with the argumentation brought forward by Myers (1984), who states that firms have a target value for the cost-benefit trade-off in mind and gradually move towards this point. The considered temporal aspects include, for example, considerations of fluctuations in the state of the economy and an organization's financial performance. However, setting up dynamic models require to specify further factors that can be omitted in static models. For the dynamic version of the trade-off theory, these additional factors include, for example, the decision makers' expectations and costs of adjusting the capital structure. Also, firms might have a preference for retaining and accumulating earnings to reduce the costs of debt financing over time, which can be explicitly modeled in the dynamic version and might result in lower leverage as compared to the static version of the model (Miglo 2010). The first dynamic models (Kane, Marcus, and McDonald 1984; Miller 1977) considered mainly taxes, and costs for bankruptcy and uncertainty. However, they allowed firms to re-balance without any transaction costs, resulting in relatively high debt levels to take advantage of tax saving. Fischer, Heinkel, and Zechner (1989) added transaction costs for re-capitalization to the dynamic trade-off model, resulting in more realistic representations of a firm's re-balancing behavior, reflecting the negative relation between debt and profit

(Frank and Goyal 2008).

3.2.3 Pecking order theory

The pecking order theory was introduced by Myers and Majluf (1984) and is inspired by Donaldson (1961). It posits that organizations tend to rely more heavily on internal financing as opposed to external financing. This preference is rooted in the concept of information asymmetry and the belief that firms aim to minimize financing costs that arise from asymmetrically distributed information. The theory suggests that firms prioritize internal financing over debt financing and debt financing over equity financing (Frank and Goyal 2008; Sunder and Myers 1999). This preference order, known as the pecking order, is derived from the adverse selection model presented in Myers and Majluf (1984).⁹ According to the pecking order theory, the most cost-effective and preferred source of financing is internal funding, such as liquid assets or retained earnings, which is generated within the firm and minimizes information asymmetry and its associated costs. When external financing is necessary, however, the providers of funding demand a higher rate of return to compensate for the risk posed by information asymmetry concerning the quality of the firm (Luigi and Sorin 2009). This results in what is known as the ‘lemon premium’ (Akerlof 1970).

The theory suggests that, in accordance with the objective of minimizing costs, the second preferred source of financing is debt financing, followed by equity financing (Frank and Goyal 2008). According to a strict interpretation of the order, equity financing is only pursued when debt financing is no longer feasible. Debt financing is considered to be cheaper for various reasons, such as the absence of dilution of ownership, the tax deductibility of

9. It is important to note that the proposed ordering may also be influenced by other factors, such as adverse selection (Myers and Majluf 1984; Myers 1984; Cadsby, Frank, and Maksimovic 1990), agency conflicts (Myers 2003), and excessive managerial optimism (Baker, Ruback, and Wurgler 2007).

interest, and a lower perceived risk for investors. To analyze dynamic effects, such as the impact on a company's market-to-book value and the evolution of its capital structure over time, a dynamic model that iterates the static pecking-order model is required (Fama and French 2002). There are several extensions to the basic model that incorporate additional asymmetric information. For a comprehensive review of the topic, the reader is referred to Frank and Goyal (2008).

3.2.4 Theories of conflict of interest

Agency theory This family of theories is rooted in the premise that managers may make decisions that are not aligned with the interests of shareholders, and explores the conflicts that arise from the separation of ownership and control in firms. This dichotomy can manifest in various forms that concern both corporate investment research at the firm level (e.g., between equity shareholders and debt holders) and inside firms (between equity shareholders and managers) (Jensen and Meckling 1976).

At the firm level, conflicts between equity and debt shareholders may arise, as debt contracts may provide incentives for sub-optimal investments and wealth might be transferred from debt to equity shareholders. Niu (2008) comes up with three distinct clusters of agency conflict sources. First, there might be a direct wealth transfer from debt to equity shareholders via dividend payments. Second, there might be asset substitution. For example, in the event of a successful investment project, equity shareholders would receive the majority of financial gains, while debt holders would bear the consequences of any losses (Muradoglu and Sivaprasad 2011). To counteract these effects, rules exist that allow debt holders to take over and liquidate assets in case of default. In this context, Williamson (1988) posits that debt financing may be particularly suitable for redeployable assets. Third,

there might be a tendency for under-investment due to an overhang in debt (Myers 1977).

There is a rich body of literature that relates the efficiency of corporate investment decisions *within firms* that mainly addresses conflicts between managers and owners. However, as Kang, Kumar, and Lee (2006) point out, the results are not clear with as to whether agency conflicts result in over- or under-investment. Harris and Raviv (1991) point out that, mostly, conflicts between shareholders and managers result from conflicts on operating decisions such as project selection. In more detail, the sources for agency problems between equity shareholders and managers are manifold and include in-congruent risk preferences (Ross 1973; Amihud and Lev 1981), diverging objectives (e.g., firm value maximization vs. individual objectives) (Jensen and Meckling 1976), moral hazard, i.e., the performance of investments depends only on the costly effort of managers (Holmström and Weiss 1985; Lambert 1986), effects of investment performance on the manager's reputation (Campbell, Chan, and Marino 1989), private information about investment projects (Myers and Majluf 1984; Miller and Rock 1985), differing time preferences (Masulis 1988), and the case that managers receive private benefits of investments (Zwiebel 1996; Fluck 1999). The main focus of this body of literature is the design of compensation contracts that lead to corporate investment decisions (made by managers) that are consistent with the stakeholders' preferences (Kang, Kumar, and Lee 2006).¹⁰

Corporate control theory The control theory, which explores the relationship between equity and debt in the context of corporate investment, was first introduced by Harris and Raviv (1988, 1991) and Israel (1991). This theory posits that a firm's capital structure impacts the distribution of voting power between investors and management. According

10. For a more in-depth discussion of agency theory in general, the reader is referred to Eisenhardt (1989), and for a review of the literature on agency costs in the context of corporate investment, the reader is referred to Stein (2003) and Harris and Raviv (1991).

to Harris and Raviv (1988), the optimal capital structure is determined by the trade-off between the risk of bankruptcy and the voting power of management. The use of debt is viewed as a means of increasing management's voting power through the repurchasing of equity from outside investors. Israel (1991) further asserts that debt also influences the ownership structure of equity capital. Stulz (1988) also recognizes that debt can be used to repurchase shares and increase voting power at relatively low reservation values, thereby limiting the shares available to investors to those with higher reservation values. Optimal capital structure decisions must therefore consider not only the higher price that investors must pay, but also the decreased probability of value-increasing acquisitions.

Stakeholder theory According to Titman (1984), financing decisions have a far-reaching impact that extends beyond just shareholders, managers, and investors. There exists a complex relationship between a firm and its stakeholders, such as customers, workers, and suppliers, where the individual interests of these parties may be in conflict (as also noted by Lasfer 1995; John and Senbet 1998). The management of the firm, acting as a representative of shareholders, holds significant power that can be used to prioritize their own objectives at the expense of not only capital lenders, but also other stakeholders. To address this imbalance, Titman (1984) argues that capital structure decisions can play a crucial role in managing the relationship between the firm and its stakeholders.

3.2.5 Behavioral theories

Market timing theory Baker and Wurgler (2002) were among the first to introduce the concept of the market timing theory to explain the timing of corporate investment decisions. Specifically, the market timing theory assumes that a firm's investment decisions are con-

tingent on the perception of the current state of the market and the perceived future state of the market, which, however, is a phenomenon that was also demonstrated in earlier studies (Taggart 1977; Marsh 1982; Jalilvand and Harris 1984). Luigi and Sorin (2009) point out that there are two streams within equity market timing theory that consider either rational or irrational decision makers. In the case of *rational decision makers*, firms create opportunities to issue equity: they release positive information which, in turn, reduces the problem of information asymmetry between the firm and stockholders and increases stock prices. In the case of *irrational decision makers*, firms issue equity when they *believe* stock prices to be overvalued and repurchase their shares when they *believe* stock prices to be undervalued (Mostafa and Boregowda 2014; Baker and Wurgler 2002). It is not necessarily required for the market to be inefficient though, the theory builds on the assumption that managers can effectively time the market (Luigi and Sorin 2009). The market timing is a potential candidate that advocates an evolutionary perspective on corporate investment, meaning that in this framework, it could be analyzed how learning and experience affects the formation of expectations and, in consequence, corporate investment decision making.¹¹

Behavioral consistency theory and norms The behavioral consistency theory posits that individual behavior is consistent across multiple contexts and situations (Epstein 1979; Funder and Colvin 1991). This theory has been extended to the domain of corporate investment, where it is argued that managers exhibit similar behavior in leverage decisions made in both their professional and private capacities (Cronqvist, Makhija, and Yonker 2012). The authors provide empirical evidence for this assumption, indicating that managers tend to imprint their personal preferences on the firm, a phenomenon that is particularly ob-

11. For a more detailed review of recent research on equity market timing, the reader is referred to Alti (2006).

servable in the presence of weaker governance mechanisms. In a similar vein, Foerster et al. (2017) show that the personal asset allocation of financial advisors is a strong predictor of the assets they select for their clients.

Lam, Zhang, and Lee (2013) also aim to explain the behavior of managers involved in capital structure decisions by examining the context in which these decisions are made. In line with the work of Akerlof (2007), they propose that behavioral norms may have a significant impact on capital structure decisions and provide empirical evidence for a relationship between national culture and firms' capital structures. Their findings are moderately surprising, because it is known that there is a relationship between national culture and risk-aversion (Breuer, Riesener, and Salzmann 2014), and risk-aversion has been established as a factor that affects capital structure decisions (Barton and Gordon 1988).

Behavioral finance According to Ricciardi and Simon (2000), the field of behavioral finance seeks to reconcile the gap between theory and practice by examining finance and investment from a human perspective. As Shefrin (2001) and Vasiliou and Daskalakis (2009) have noted, two primary issues must be considered. The first issue concerns 'behavioral costs' resulting from erroneous decision-making that can undermine value creation. These costs may take the form of heuristics employed to reduce decision-making effort (Hirshleifer 2001), to cope with time constraints (D'acunto et al. 2022), or to overcome limited cognitive capacities and information overload (Hirshleifer and Teoh 2003). It is important to note that this perspective on behavioral issues is primarily relevant *within* a firm. The second issue, however, is particularly relevant to corporate investment research *at the firm level*, as both analysts and investors may make errors that result in a discrepancy between market prices and fundamental values. This two-fold approach to incorporating behav-

ioral factors into corporate investment research aligns with the recommendations of Baker and Wurgler (2013), who propose distinguishing between situations in which managers or investors suffer from irrationality. It should be noted that their argumentation is directly related to the market timing theory introduced above since irrationality may affect timing decisions (Barberis and Thaler 2003).¹²

4 Agent-based modeling and simulation for theory development in the field of corporate investment

4.1 Modeling assumptions in analytical approaches to theory development

Importance of analytical research methods in theory development The field of corporate investment theory development is characterized by a significant reliance on analytical research methods, as demonstrated by the works of Harris and Raviv (1991), Stein (2003), and Zattoni et al. (2020). The theories discussed in Sec. 3.2 are primarily derived from formal mathematical models with closed-form solutions. For example, the Modigliani-Miller theory, as discussed in Sec. 3.2.1, was first proposed by Modigliani and Miller (1958) through the development of a theoretical model and the derivation of basic propositions. Recent extensions have similarly utilized analytical research methods, as evident in the works of Brusov et al. (2018) and Brusov and Filatova (2023). In a similar vein, the trade-off theory (Sec. 3.2.2) draws heavily from analytical models that account for costs related

12. Recent reviews of the field of behavioral finance include those by Sharma and Kumar (2020), Kumar et al. (2022), Bosch-Rosa and Cornet (2022), the latter of which focuses on the impact of cognitive skills on financial decision-making.

to agency conflicts and asymmetrically distributed information, as discussed in Sec. 3.2.4. Finally, the pecking order theory is rooted in an adverse selection model, first proposed by Myers and Majluf (1984).

While it is widely recognized that research methods that rely on analytical models have high internal validity, they tend to exhibit lower external validity when compared to research approaches that utilize agent-based modeling and simulation (Wall and Leitner 2021). Empirical validity can be added through inductive reasoning, as suggested by Peirce's framework of scientific inquiry (Sec. 2.1), which is often done in corporate investment research (e.g. Sisodia and Maheshwari 2022; Sureka et al. 2022; Santos and Farinelli 2015). However, analytical models, particularly those based on agency theory, have been found to suffer from diminishing marginal contributions to theory (Kohn 2004, 2021). Axtell (2007) argues that this development may be due in part to the strong assumptions about rationality, agent heterogeneity, interactions, and equilibrium solutions shared by analytical models based on agency theory, which ensure their mathematical tractability, i.e., they allow researchers to infer deductions from the models using analytical methods. To address the limitations of analytical modeling, some researchers advocate for relaxing these assumptions and shifting towards a process-oriented perspective that is closer to actual human behavior (Royston 2013; Wall and Leitner 2021; Hämäläinen, Luoma, and Saarinen 2013; Axtell 2007; Kohn 2004). This entails moving away from a long-standing tradition of focusing on equilibrium states and towards observing the resulting dynamics.

Future research Agent-based modeling and simulation can contribute to theory development in corporate investment research by allowing researchers to derive deductions from modeled assumptions through numerical simulation (Cohen 1960; Fioresi and Mollona

2010). Guerrero and Axtell (2011), Leitner and Behrens (2015a) and Leitner and Behrens (2015b), Leitner, Brauneis, and Rausch (2015) and Leitner, Rausch, and Behrens (2017), Leitner and Wall (2021, 2022), and Reinwald, Leitner, and Wall (2022), among others, have suggested this approach. In particular, they suggest to ‘agentize’ analytical models, i.e., to transfer analytical into agent-based models, which allows to systematically analyze the model’s robustness to modelling assumptions. This, in turn, allows to study the boundary conditions of theoretical models and, as discussed in Sec. 2.2, might allow to generalize findings. Future research should take up on this line and systematically explore the boundary conditions of corporate investment theories and test their robustness to modeling assumptions.

4.2 Modeling human decision-making behavior

Modeling human behavior in agent-based models can pose a challenge as there exists a well-established way to model rational behavior, but no universally applicable approach for modeling boundedly rational behavior. Relaxing assumptions about rationality can result in a ‘wilderness’ of bounded rationality (Sims 1980). Consequently, it is often suggested that phenomena should be examined from the perspectives of both fully rational decision makers and ‘zero intelligence agents’ (Cliff and Bruten 1997; Ladley 2012). This request has led to the emergence of a behavioral theory of corporate investment (see Sec. 3.2.5). Agent-based research approaches can make a key contribution to this recent development by aiding in the phase of abductive reasoning. In this sense, agent-based modeling can facilitate the creation of explanatory hypotheses for observed phenomena that are informed by existing knowledge about human behavior, which can subsequently be further developed through simulation-based deductive and inductive reasoning. As discussed in Sec. 2.1, ab-

duction represents the phase in scientific research where innovation takes place. Therefore, it is believed that agent-based modeling and simulation is a valuable tool that can promote the further development of a behavioral theory of corporate investment.

4.2.1 Behavioral biases, adaptive behavior, norms, and networks

Behavioral biases It is well known that corporate investment decisions are affected by *behavioral biases* of decision makers.¹³ Recent research has sought to develop a deeper understanding of how behavioral biases impact investment decisions and how these findings can be used in modeling. For example, Leitner and Behrens (2015a) and Leitner and Behrens (2015b) have examined the effect of imperfect foresight of decision makers on capital allocation efficiency within organizations that utilize a hurdle-rate based allocation mechanism, using agent-based modeling and simulation. Additionally, their research has explored how investment project evaluations made by overconfident managers can have further adverse effects for capital allocation *within firms* (see also Leitner, Brauneis, and Rausch 2015; Leitner, Rausch, and Behrens 2017). Huang (2020) supports this line of research by providing empirical evidence for a relation between over-optimism, over-pessimism, and the efficiency of corporate investment decisions. Bhandari and Hassanein (2012) are concerned with biased investment decision system. By means of an agent-based simulation, they propose a decision-support system with the aim to de-bias investment decisions that are affected by behavioral biases. Related to corporate investment *at the firm level*, Rzeszutek et al. (2021) have analyzed the impact of overconfident managers on capital structure decisions, employing an agent-based approach.

13. An extensive review of behavioral biases in the context of investment decision making is provided in Jain, Jain, and Jain (2015), and a corresponding conceptual framework is proposed in Agrawal (2012). Research on behavioral biases in corporate investment is informed by the seminal work of Tversky and Kahneman, available in Tversky and Kahneman (1974), Kahneman et al. (1982), and Kahneman (2011).

Adaptive behavior The concept of *adaptive rationality* extends the behavioral biases discussed above by considering temporal effects. According to Haselton et al. (2009), biases must be analyzed in a more differentiated manner that accounts for context effects, meaning that biases may occur in some situations but not in others, and content effects, referring to situations in which only certain types of information may trigger biases.¹⁴ For example, this could take the form of decision makers adapting their concerns regarding risks over time, as proposed by Zhou et al. (2017). Previous research on adaptive behavior may also be relevant to corporate investment decision-making from an evolutionary perspective, such as that advocated by the dynamic version of the trade-off theory (Sec. 3.2.2) or the market timing theory (if considered for multiple periods) (Sec. 3.2.5) (Leiblein, Chen, and Posen 2017).

Norms and networks The behavioral stream of corporate investment theory has begun to acknowledge the impact of norms on corporate investment behavior, as discussed in Sec. 3.2.5. However, the current focus has been primarily on the connection between national culture and corporate investment behavior (Lam, Zhang, and Lee 2013).¹⁵ Nevertheless, it is reasonable to assume that social norms and social networks also affect corporate investment behavior. Social norms refer to the regulations that control the actions of group members (Bicchieri 2005), and contravening such standards can result in negative emotional states, such as guilt and shame (Elster 1989; Gao, Li, and Lu 2021). Prior research has demonstrated that social networks and conformity to norms are linked. Firstly, social norms may develop as a result of the conduct of peers in social networks (Khodzhi-

14. For extensive discussions of the concept of adaptive rationality, interested readers are referred to Haselton et al. (2009) and Hertwig and Pedersen (2016).

15. For additional information on social capital (social norms and networks), please refer to Adler and Kwon (2002).

matov, Leitner, and Wall 2022, 2021). Secondly, dense social networks may encourage norm-compliant conduct because they reduce the cost of non-conformity (Portes 1998). Concerning corporate investment choices, norms may involve acceptable investment practices, such as considering the welfare of stakeholders and ensuring equitable distribution of capital both within firms and at the firm level.

Future research To develop a comprehensive behavioral theory of corporate investment, agent-based techniques show promise in facilitating this process. However, further research is necessary to fully comprehend the impact of behavioral biases and adaptive behavior on investment decision-making. It is important to systematically test existing theories against these biases, and agent-based modeling and simulation can be an effective tool to investigate these relationships. Through exploring the parameter space of the agent-based model, behavioral biases can be disentangled from other effects.

Regarding norms and networks, agent-based modeling can serve as a valuable research method. It allows for the modeling of the emergence of norms from the bottom-up and the analysis of how various network characteristics impact behavior in accordance with norms. To extend the notion of norms to emergent social norms and examine the interplay between corporate investment behavior, norms, and social networks, future research should be conducted in the context of developing a comprehensive behavioral theory of corporate investment.

4.2.2 Search, learning, and information processing

Most of the theories discussed in Sec. 3.2 assume rational agents who can make optimal decisions instantaneously. However, in practice, decision makers often are confronted

with limitations in rationality and have to adopt a search-and-learn perspective (Chang and Harrington Jr 2006). This means that decision makers make adaptation decisions, such as adjusting the capital structure or allocation, in order to approach the optimal solution. They then evaluate the effectiveness of their decisions ex-post, determining whether these adjustments brought them closer to the optimal solution or not (Nelson and Winter 1982). This section takes a closer look at this search-and-learn perspective.

Search A central question in the context of searching – in an evolutionary sense – is how decision makers make their gradual adjustments towards the optimum. For the context of corporate investment, the gradual adjustment can, for example, concern the adaptation of a firm’s capital structure or a revision of the capital allocation within a firm. There are multiple ways to model such search procedures. Gavetti and Levinthal (2000) and Wall (2016) distinguish between forward- and backward-looking search. In the former case, gradual adjustments are made based on the belief about the expected relationship between the adjustments and their consequences. This type of search is considered in the dynamic trade-off and market-timing theories (Sections 3.2.2 and 3.2.5), where beliefs are expressed as perceived future states. In backward-looking search, in contrast, decision makers rely on their accumulated past experience to make future adjustment decisions. One particular issue in the context of backward-looking search is how decision makers accumulate new experience. One approach is to optimize in line with one of the corporate investment theories discussed in Sec. 3.2 but with limited information. This method is suggested by Leitner and Wall (2021, 2022) to accumulate experience in the context of principal-agent models. Alternatively, accumulating experience could be driven by a decision maker’s willingness to take risks, i.e., to navigate uncertain terrain of capital structure or capital allocation,

where, in the sense of forward-looking search, only beliefs between actions and outcomes exist. One further mechanism for accumulating experience could be mimicking behavior (also: imitation). Bernard, Kaya, and Wertz (2021) empirically show that mimicking is indeed a decision-making strategy in corporate investment, and it increases with the publicly availability of financial statements.¹⁶

Learning and information processing Once information about actions and their consequences are learned or observed, decision makers *process, assign meaning to, and store* it in their memory. Corporate investment theories based on the assumption of rational decision makers typically overlook the presence of *limitations in information processing*, which is mostly regarded unrealistic. According to Rodgers (2006), information processing is a comprehensive cognitive process that not only includes the processing of information, but also information restriction, selection, and aggregation prior to processing. In this chapter, information processing errors are understood in a wider sense, covering human errors in all information processing stages. The behavioral biases discussed in Sec. 4.2.1 are one class of information processing errors, but there are other sources of information processing errors that might prove relevant in the field or corporate investment, including errors that occur due to memory and perceptual limitations. Memory errors involve false recall, false recognition, or forgetting of information (Roediger and McDermott 1995), while perceptual errors occur when prior knowledge influences the assessment of a perceived situation, leading to faulty assessments (Galloway 2000).

In the context of corporate investment, Gong, Li, and Wang (2011) are concerned with

16. Please note that imitation here does not refer to human-to-robot imitation but rather to human-to-human imitation (also: observational learning), more specifically to a situation in which one (human) decision maker imitates the behavior in the context of corporate investment decisions at the firm level and/or within firms of another (human) decision maker. For more information on learning by imitation, the interested reader is referred to Riedmiller and Merke (2003) and Douglas Greer, Dudek-Singer, and Gautreaux (2006).

information processing errors and demonstrate the relationship between information processing capabilities and forecasting errors, which can lead to poor efficiency of investment decisions. Lu, Chen, and Liao (2010) are concerned with the uncertainty of information and show that limited information can affect a firm's capital structure decision, i.e., investors charge a risk premium on information uncertainty and asymmetry, whereby uncertainty in information might be due to errors in all phases of information processing. Liu et al. (2017) propose a model of default, valuation, optimal capital structure, credit spread, and tax advantage under the assumption of limited information about future cash flows, while most prior studies assume cash flows to be constant and observable by decision makers, implying the absence of limited information. However, despite evidence of the relationship between information processing errors and corporate investment decisions, there has been limited research on the role of learning in overcoming such issues.

Future research Three potential avenues for future research emerge from issues around search, learning, and information processing. First, one possible direction for future research is employ agent-based modeling and simulation to analyze the efficiency of specific mechanisms for the gradual adjustments at both the firm and within-firm levels, including adaptations of a firm's capital structure or revisions of the capital allocation. Additionally, it would be interesting to determine which search mechanisms emerge as dominant when decision makers have the freedom to autonomously choose their search method. This approach could allow for a determination of which search procedure is the best fit for the environment in which the search takes place, following the principles of 'survival of the fittest'.

Second, research could be enriched by findings on information processing from the

field of cognitive psychology, examining the decision makers' memory, perception, and cognitive load-bearing capacity, and analyzing the effects of cognitive limitations on long-term corporate investment performance. This line of research intersects with the issues of behavioral biases and adaptive rationality discussed in Sec. 4.2.1, and aligns with recent developments in the field of behavioral finance (see Sec. 3.2.5). In particular, the potential contribution of agent-based techniques in abductive reasoning (Sec. 2.3) could advance the field of behavioral finance in this respect.

Third, agent-based modeling and simulation can provide insights into the interrelation between human decision-making behavior and corporate investment efficiency, providing a feasible platform for testing counter-measures to contain the adverse effects of information processing errors. Ultimately, this could help select the most appropriate strategies for containing information errors for implementation in corporate practice.

4.3 Dynamic and non-linear relationships

Determinants of corporate investment decisions Corporate investment decisions are influenced by a multitude of factors that traditional theoretical models often fail to fully cover, due to a high number of variables and heterogeneous and interacting actors. For instance, Frank and Goyal (2009) provide a comprehensive review of factors impacting capital structure decisions, identifying industry leverage, market-to-book assets ratio, tangibility, and profits as significant determinants in American firms. Similarly, Öztekin (2015) analyzes capital structure decisions across 37 countries and reveal that the quality of institutions has a significant effect. More recently, Kumar, Colombage, and Rao (2017) review the literature and highlight the importance of firm-specific factors (e.g., size, tangibility, age), industry-specific factors (e.g., Capex, industry leverage), and economy- and time-specific

factors (e.g., interest rate, inflation) in shaping capital structure decisions. A comprehensive and systematic analysis of how such contingencies affect corporate investment theories is, however, missing.

These factors are interrelated in complex and nonlinear ways that prove challenging to capture through theoretical models. Therefore, to develop a comprehensive theory of corporate investment, it is essential to systematically explore the effects of these contingencies and disentangle their influence.

Future research Agent-based modeling and simulation is an effective approach that can address the difficulties associated with developing theories on corporate investment decisions due to the multitude of factors involved. Specifically, agent-based techniques permit researchers to incorporate intricate contingencies into their models (Wall and Leitner 2021). This capability enables to systematically analyze and isolate the effects of contingencies over time, as well as their interactions, in order to gain a more comprehensive understanding of the dynamics that can emerge in the context of corporate investment decisions. As discussed in Section 2.2, agent-based techniques can assist researchers in identifying the boundary conditions of theories. In future research, it would be beneficial to explore theories and their boundary conditions in the context of various capital structure determinants and their interactions (see also Kumar, Colombage, and Rao 2017).

5 Conclusions

This chapter has investigated the potential impact of agent-based modeling and simulation on theory development in the corporate investment field. Specifically, it has been contended that agent-based techniques can surmount the limitations of theory development resulting

from the modeling assumptions typically included in analytical research approaches. Mathematical models that permit closed-form solutions are typically generated by analytical approaches, whereas agent-based models provide greater modeling assumption degrees of freedom because they are usually solved by numerical simulation. However, this approach also poses challenges in modeling human behavior. Therefore, it has been argued that agent-based techniques can aid the corporate investment field in systematically analyzing and isolating the behavioral effects, such as biases, adaptive behavior, norms, search and learning procedures, to advance the development of a behavioral theory of corporate investment. Another significant contribution to theory development identified in this chapter is the inclusion of rich contingencies in agent-based models, allowing for the systematic analysis of how theories are affected by them.

To end this chapter, I wish to emphasize the need for increased collaboration among researchers in the field of corporate investment who use empirical, experimental, and agent-based methods. As outlined in Section 2, scientific theory must undergo all stages of inquiry, and I am confident that the utilization of agent-based techniques can substantially enhance corporate investment research and lead to the creation of a comprehensive behavioral corporate investment theory. However, it is important to recognize that agent-based techniques should be viewed as a supplementary tool rather than a replacement for other research methodologies in order to achieve this goal.

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