Developing forward-looking orientation in integrated reporting

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Abstract

Purpose – According to the "strategic focus and future orientation" principle of the integrated reporting (<IR>) framework, <IR> should provide information useful to support investors in assessing the future financial performance of organizations. This study aims to support the operationalization of this function by improving the forward-looking orientation of the integrated report.

Design/methodology/approach – Basing on the backward- and forward-looking disclosure in <IR> and the dynamic resource-based view (DRBV), this study develops an explorative case study building a quantitative simulation model based on an integrated report.

Findings – This study provides useful insights into how operationalizing the <IR> "future orientation" and obtaining more quantitative information on the organization's capacity to create value in the future by applying DRBV and quantitative simulation modeling.

Research limitations/implications – The article presents one case study to explore the method suggested to improve the <IR> forward-looking orientation. Additional case studies applying the same research design should be certainly useful to refine the method.

Practical implications – Supporting the <IR> forward-looking orientation, this study provides additional information for the decision-making process of investors, thus contributing to the efficient and productive allocation of capital.

Originality/value – Few studies have investigated forward-looking information in integrated reports, highlighting the existence of an "information gap" referred to such disclosure. Overcoming these previous results, the study provides useful insights on how to improve the <IR> forward-looking orientation.

Keywords Simulation, Integrated reporting, Integrated thinking, Dynamic resource-based view, Forward-looking information

Paper type Research paper

1. Introduction

To support the management of sustainability in a business context, the financial reporting and strategic management literature developed some corporate reporting models characterized by a holistic vision of the organization and its capacity of creating value over time. Among different corporate reporting models such as the balanced scorecard and Global Reporting Initiative (Kaplan and Norton, 1992; Eccles and Krzus, 2011; Milne and

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Gray, 2013), this study focuses on the integrated reporting (hereafter <IR>), whose holistic approach to the organizations' processes of value creation is directly emphasized by its underpinning framework in the concept of "integrated thinking" (IIRC, 2013a; Adams, 2017; Guthrie *et al.*, 2017; McNally *et al.*, 2017; Busco *et al.*, 2017). According to the <IR> framework, integrated thinking is "the active consideration by an organization of the relationships between its various operating and functional units and the capitals that the organization uses or affects" (IIRC, 2013a, p. 2). This approach implies that the decision-making process of any organization has to consider the interrelationships existing across its business segments and functions and defines strategic decisions to solve trade-offs between different paths of action (de Villiers *et al.*, 2014; Cheng *et al.*, 2014; Giorgino *et al.*, 2020).

This study aims to investigate a specific issue that characterizes the relationship between integrated thinking and <IR> in terms of the information on the organization's activities and performance to be disclosed in the report. Indeed, according to the Guiding Principles that should underpin its preparation (IIRC, 2013a, p. 16), any integrated report should maintain the "strategic focus and future orientation" of the information being disclosed, even if most of the data at disposal are referred to past activities and performance already achieved by the organization. Stated differently, as <IR> should support the efficient and productive allocation of capitals by investors representing data that should be useful to assess the organization's capacity of creating value in the future (Adams, 2015; Melloni *et al.*, 2016; Giorgino *et al.*, 2017; Beck *et al.*, 2017), it is important to integrate the backward-looking information (hereafter BLI) and the forward-looking information (hereafter FLI) to be provided in the reports (Aljifri and Hussainey, 2007). Notably, while BLI is based on existing data, these data were captured in the past. Without a clear FLI, investors are uncertain if the future performance is only an extrapolation of the past year or if managers have identified conditions that may affect the future performance of the firm. Unfortunately, this point represents an unresolved question within the context of <IR> practices, which frequently disregard the need of operationalizing the stated principle about the "future orientation" of the information disclosed in the reports (Menicucci, 2018).

The interplays between BLI and FLI have been particularly investigated focusing on the determinants of FLI and trying to verify if specific characteristics of the organization (such as size or industry) or its governance (such as board autonomy or audit quality) can affect its forward-looking disclosure (Celik *et al.*, 2006; O'Sullivan *et al.*, 2008; Uyar and Kilic, 2012; Wang and Hussainey, 2013). However, these studies addressed mainly traditional annual reports, which are fundamentally oriented to disclose retrospective data on the organization's activities and performance (Jensen and Berg, 2012). Few studies have instead investigated FLI in integrated reports, thus highlighting the need for further investigation on the topic that still represents a potential weak point in the overall <IR> architecture (Dumay *et al.*, 2016; Stacchezzini *et al.*, 2016; Menicucci, 2018).

Starting from these premises, our study has a twofold goal, as it aims at:

(1) integrating BLI and FLI in <IR> suggesting a method to create FLI based on past information; and

(2) "operationalizing" the <IR> (i.e. improving its future orientation and its utility in supporting the decision-making process) by increasing its quantitative forward-looking disclosure.

To address its goal, the study relies on the fundamental principles of the dynamic resource-based view (hereafter DRBV – Kunc and Morecroft, 2009 and 2010; Kunc and O'Brien, 2017; Barnabè *et al.*, 2019). This approach is in line with the visual accounting stream of research (Bell and Davison, 2013; Davison, 2015), which advocates strengthening the disclosure of accounting-based information through the adoption of visual tools such as maps or images, particularly in the context of <IR> practices (Quattrone, 2017). The main principles of the DRBV are described in Section 2, as the last part of the theoretical background here adopted, also including the <IR> framework, the relationship between BLI and FLI and the analysis of FLI in integrated reports. Next, Section 3 presents our research design, relying on the development of an explorative case study (Ryan *et al.*, 2002), which implies to build a quantitative simulation model based on the most recent integrated report drafted by an oil and gas company and its latest annual financial statement. Section 4 presents the results achieved, highlighting how the development phase of the model primarily allows identifying the key strategic resources (capitals) at the organization's disposal and displaying their linkages, while the simulation phase is oriented toward understanding the determinants of value creation over time. Section 5 concludes the study discussing in which terms such a simulation model may contemporarily allow integrating FLI with BLI and increasing the quantitative forward-looking disclosure of <IR>, as required to support the decision-making process of investors.

2. The theoretical background

2.1 The integrated reporting framework

The <IR> is the model of corporate reporting developed by the International Integrated Reporting Council (IIRC) to represent and communicate the organization's process of value creation according to a holistic approach (IIRC, 2013a, p. 16). The main managerial principle emphasized in the <IR> framework is the so-called *integrated thinking*, according to which, the decision-making process of an organization needs to consider the interrelationships existing among business units, functions and resources. To explain this concept, previous studies have tried to connect the integrated thinking principle to semantically similar concepts that could have influenced the theorization provided by the IIRC (Feng *et al.*, 2017). Specifically, we refer to the concept of "integrative thinking" – suggested by Martin and Austen (1999) – which is used to indicate the managers' decision-making model aimed at solving the trade-off between profit maximization and socio-environmental responsibility in organizations or the expression of "integrated thinking," which is adopted in the Prince's Accounting for Sustainability project to indicate the necessity of embedding sustainability into the decision-making process of the organizations (A4S, 2010). Beyond the semantical similarity between the concepts aforementioned, however, the integrated thinking principle stated in the <IR> framework is not strictly related to the pursuit of social and environmental goals, but rather to the necessity of establishing connectivity among all of the business units and functions. Specifically, the framework identifies four aspects underpinning the integrated thinking process, respectively, related to the need of considering the interdependencies (or trade-offs) among the resources used, balancing the different (or conflicting) stakeholders' needs, facing the risks and opportunities coming from the external environment and connecting the organization's activities and performance over time (past, present and future) (IIRC, 2013a, p. 2). The last aspect implicitly suggests the relevance of the integrated thinking concept for the relationship between BLI and FLI in <IR> here investigated. However, deepening this relationship requires a brief introduction of the organizations' value creation process, as conceptualized by the <IR> framework.

Traditionally, the key drivers of performance and value in organizations were physical (such as buildings and machines) and financial resources, but since 1980 many scholars have been emphasizing the relevance of further types of resources characterized by an intangible consistency, as also of the resources provided by the environment (Itami, 1987; Hall, 1992; Teece, 2000; Lev, 2001). The <IR> framework identifies six categories of inputs (or capitals, according to the <IR> terminology) that contribute to the value creation process implemented over time by organizations (IIRC, 2013b). Specifically, besides the more "traditional" manufactured and financial capital, these categories include other types of capital, namely, human, intellectual, social and natural. Not all of these inputs are internal and owned by the organization, but all of them are to be managed holistically according to a business model developed as a dynamic and circular system as follows: the outcomes achieved at the end of the process affect the organization's availability of inputs, modifying its initial situation into a new condition usable for the successive production cycles (IIRC, 2013a, p. 13). In this circular process, each output absorbs inside the value of the capitals adopted for its realization, representing, in association with the outcomes, the value created (or eventually destructed) for the different categories of stakeholders and their interests.

Basing on this conceptualization of the organization's activities and the idea of integrated thinking (Adams, 2017; Guthrie *et al.*, 2017; McNally *et al.*, 2017; Busco *et al.*, 2017), the <IR> framework (IIRC, 2013a) then underlines the necessity of realizing an <IR> process aimed to consolidate the organization's information systems and to represent all of the elements describing the value creation process developed by the organization. Specifically, the framework identifies a few content elements that are fundamentally linked to each other (and not mutually exclusive) in pursuing long-term value creation (IIRC, 2013a). Among the others (such as governance and business model), two elements seem to be particularly relevant for this study as follows: "strategy and resource allocation" and "outlook." The former identifies and communicates the priorities in terms of value creation for the specific organization, while the latter aims at identifying, testing and understanding how the strategies will be achieved in the future, given the context of challenges and uncertainties that this will entail.

Moreover, the <IR> framework identifies some specific guiding principles that need to be observed in preparing an integrated report. They briefly indicate some aspects that should be considered when selecting and organizing the information to be included in the document, such as the interrelatedness among the many factors involved in the value creation process of the organization, according to the principle of integrated thinking and implying the connectivity of information.

In the perspective of this study, however, the most interesting guiding principle of the <IR> framework – that clarifies the integrated thinking concept under the perspective here investigated – is certainly the one named "strategic focus and future orientation" (IIRC, 2013a). According to this principle the report "should provide insight into the organization's strategy and how it relates to the organization's ability to create value in the short, medium and long term" (IIRC, 2013a, p. 16). This statement is directly related to the cited <IR> contents of "strategy and resource allocation" and "outlook," in the overall perspective of supporting the efficient and productive allocation of capital by investors. To this aim, an integrated report should then represent all of the data that could be useful to anticipate the organization's capacity of creating value in the medium and long term, here including both qualitative information on risks and opportunities affecting the organization's activities and quantitative information on current plants and future forecasts conditioning the performance to be achieved. In the financial reporting and strategic management literature, such a type of data is indicated as FLI.

2.2 Forward-looking information vs backward-looking information in corporate reports

While BLI refers to the past and to the financial results already achieved by the organization, FLI refers to the class of data that provides to investors additional records to assess the future financial performance of the same organization (Aljifri and Hussainey, 2007). Specifically, FLI represents additional data, frequently asked by investors, that might be useful to anticipate the expected results of their investments. They include financial or quantitative information such as forecasts on revenues and cash flows, as well as non-financial or qualitative information, such as the disclosure of risks, opportunities, business ambiguity, agency relationships and all other relevant information that might affect the future performance of the organization.

The two typologies of information (i.e. BLI and FLI) are strongly related to each other and the combination between them in any corporate report represents an issue to be solved basing on the report type (and implicit aim) considered and the strategy of corporate disclosure to be implemented. Indeed, as argued by Hussainey (2004), categorizing information as BLI or FLI is not always easy to do, as sometimes data referred to the past (for instance, an increase of the level of research and development (R&D) expenditure or an industrial accident) may also imply an expected event for the future (as an increase in the organization's cash flow or liability with the government).

Investigating the relationship between BLI and FLI in corporate reports, previous studies have mainly focused on two issues of FLI, i.e. the nature of this information and the determinants of its disclosure. Many studies have specifically analyzed corporate annual reports to identify the nature of FLI disclosed in the documents. These studies were particularly focused on the earnings forecast included in the annual reports of USA or Canadian organizations (Lev and Penman, 1990; Frankel *et al.*, 1995; Clarkson *et al.*, 1999), investigating specific attributes of the FLI disclosed. Consequently, they have for instance revealed the predominance of qualitative over quantitative FLI and of forecasts based on good news instead of bad news (Clarkson *et al.*, 1994; Bujaki *et al.*, 1999; Hutton *et al.*, 2003).

About the latter issue, previous studies have searched for possible relationships between FLI and different factors referred to the organization or its external context of the activity, again mainly developing the analysis on corporate annual reports. These studies have for instance verified that large-sized organizations are likely to provide more FLI than smaller organizations (Kent and Ung, 2003; Celik *et al.*, 2006) and that the industry activity type affects the levels of FLI in interim reports (Celik *et al.*, 2006; Elzahar and Hussainey, 2012). About corporate governance mechanisms, conflicting results have been achieved, as some scholars have not found a positive relationship between governance effectiveness (for instance, in terms of board autonomy or audit quality) and the level of FLI in annual reports (O'Sullivan *et al.*, 2008; Elzahar and Hussainey, 2012), while others have shown that board characteristics such as size or independence have not a statistically significant impact on forward-looking disclosure (Wang and Hussainey, 2013). Also, external factors could be relevant for these relationships, as tested for contexts with stringent regulations (such as the USA) that have the effect of discouraging organizations from releasing FLI (Celik *et al.*, 2006). However, even if some States have regulations prescribing mandatory disclosure for this type of information, the inclusion of FLI in corporate reports is usually related to a process of voluntary disclosure and this is particularly true for <IR> whose whole preparation is not mandatory (with some exceptions across the world such as South Africa). This implies that the managers' decision to comply with FLI in corporate reports and particularly in integrated reports always requires specific analyzes of benefits and costs deriving from the disclosure of such type of voluntary information.

2.3 Forward-looking disclosure and integrated reporting

Certainly, disclosing FLI is costly, not only for the difficulties of predicting the future with accuracy and for the possibility of lawsuits deriving from wrong predictions (Field *et al.*, 2005) but also for the negative consequences of providing to competitors useful information on the organization's activities (Healy and Palepu, 2001). In other words, disclosing FLI might generate both direct and indirect costs, particularly as a consequence of communicating outside proprietary information with strategic relevance (Uyar and Kilic, 2012).

At the same time, however including FLI in corporate reports may provide some relevant benefits for organizations. According to the agency theory (Jensen and Meckling, 1976; Fama and Jensen, 1983a, 1983b), the main advantage refers to the general motivation for voluntary disclosure, i.e. the reduction of the information asymmetry between managers and investors, that may support a more efficient allocation of capitals and a reduction in the cost of external financing for organizations (Healy and Palepu, 2001; Bujaki *et al.*, 1999).

In sum, the disclosure of forecasting future earnings certainly attracts investors and generally supports the achievement of economic, financial and social benefits (Botosan, 1997; Drake and Peavy, 1995; Lang and Lundholm, 1996). Disclosing FLI assists readers in better understanding the determinants of business value, supports potential investors in identifying which opportunities and exposures might affect the organization in the future, helps analysts in assessing an organization's prospects and forecasting its future performance given the targets and actions that will be subsequently carried out. Interestingly, FLI involves the ability to control and manage simultaneously several factors, as de Villiers *et al.* (2014, p. 1056) underlined, "moving forward, managers drew on one or more of three inter-narratives, namely, "time," "strategy" (their company's strategy meets the kinds of external expectations demanded) and "engagement." In these terms, effective disclosure of FLI should then represent an organization's strategy to achieve competitive advantages in the market and the prescription for "future orientation" when preparing an integrated report might be considered as related to this assumption.

However, understanding FLI entails the presence of ambiguity, not only in terms of the high degree of uncertainty related to the disclosure of future outcomes but also in terms of the limited effectiveness of the communication of these data. Indeed, it is recognized by several authors (Celik *et al.*, 2006; Schleicher and Walker, 2010) and even by many organizations when communicating their plans, that there is a sort of "information gap" when coming to FLI. Analyzing <IR> practices, previous studies have specifically stressed that FLI represents a potential weak point in the overall <IR> architecture, as organizations seem to be "reluctant to provide FLI in integrated reports" (Menicucci, 2018, p. 102). Particularly, it seems that organizations are not willing or able to disclose the connectivity among the organization's activities and performance over time (from the past to the future) as required by the integrated thinking principle (IIRC, 2013a, p. 2), thereby inducing Dumay *et al.* (2016, p. 170) to include FLI in the list of common reporting issues that are to be addressed when considering <IR> practices. In their study, Stacchezzini *et al.* (2016) have instead focused on external reporting pointing out at limited guidance provided by the <IR> framework on how to improve FLI in comparison to BLI in integrated reports. They argued that the integrated reports would eventually stimulate organizations to disclose leading indicators of performance, however finding limited disclosure of quantitative forward-looking indicators in the integrated reports analyzed. Similarly, Kilic and Kuzey (2018), when investigating the determinants of forward-looking disclosure in <IR> such as gender diversity and firm size, have emphasized the organizations' tendency of providing more qualitative than quantitative FLI, thus confirming the existence of an "information gap" to be solved with methods able to operationalize the integrated reports.

Moreover, it is noteworthy to remember that, according to the integrated thinking principle, an <IR> should provide a "description" of how value creation works in practice over time. This is in line with the visual accounting stream of research (Bell and Davison, 2013; Davison, 2015), which advocates increased use of maps, images and similar tools to strengthen and foster the representation, communication and disclosure of accounting-based information, (Mouritsen *et al.*, 2001), also for <IR> practices (Quattrone, 2017). For this reason, this study suggests integrating the <IR> framework and the related recommendation of providing as much as possible information about value creation in an integrated, comprehensive and connected way (even FLI), with the based principles of the DRBV (Kunc and Morecroft, 2009 and 2010; Kunc and O'Brien, 2017; Barnabè *et al.*, 2019).

2.4 Generating forward-looking information according to the dynamic resource-based view approach

The theoretical setting of the DRBV (Kunc and Morecroft, 2009 and 2010; Kunc and O'Brien, 2017) builds on the combination of the resource-based view (RBV) of the firm (Penrose, 1959; Wernerfelt, 1984; Barney, 1991; Peteraf, 1993) with system dynamics (hereafter SD – Forrester, 1961, 1968; Richardson and Pugh, 1981; Sterman, 2000).

Specifically, according to RBV (Penrose, 1959; Wernerfelt, 1984; Barney, 1991; Peteraf, 1993), an organization's performance is influenced and determined by the bundle of "resources" (either tangible or intangibles ones) and "capabilities" (i.e. the activities that the organization performs) developed or acquired over time. Therefore, it is the peculiar hierarchy of resources and their interaction because of the managers' knowledge and decision-making (Teece *et al.*, 1997; Grant, 1991) that informs strategic management, generates performance over time and allows revealing the underlying dominant logic governing such decisions and actions (Prahalad and Bettis, 1986; Prahalad, 2004). Notably, the RBV approach has demonstrated to be able to support research in a variety of fields and also in combination with quantitative techniques (Barney *et al.*, 2001 and Grant, 2016). Building on these concepts, the DRBV approach jointly considers RBV concepts and SD (Forrester, 1961, 1968; Richardson and Pugh, 1981; Sterman, 2000) principles and tools. SD is a rigorous modeling method that enables "to build formal computer simulations of complex systems and use them to design more effective policies and organizations" (Sterman, 2000, p. 7). It is particularly relevant to emphasize that the role of a DRBV model and of the whole modeling process is to gain insight into a complex problem and influence thinking and actions in management teams (Forrester, 1961, p. 49). As well-stated by Morecroft (2000, p. 15), SD is a framework for thinking about how operating policies of a company and its customers, competitors and suppliers interact to shape the company's performance over time."

With this said and according to the aims pursued, DRBV may provide a perfect fit for the <IR> framework. Similarly to <IR> (Eccles and Krzus, 2011), this approach assumes that strategic resources (or capitals, according to the <IR> terminology) need to be managed simultaneously to create value in a holistic perspective. Simultaneously, and in consideration of the more quantitative orientation (offered by SD), the approach provides the fundamental principles and tools needed to build qualitative, as well as quantitative models useful to analyze how value creation will be generated and will unfold over time due to the combined interaction of the resources aforementioned.

As a whole, if on one side several decades of contributions about a variety of domains such as business-related systems (Morecroft and Sterman, 2000; Sterman, 2000; Pidd, 2004; Qudrat-Ullah *et al.*, 2007; Morecroft, 2007), witness the breadth of scope and applications and also the enduring validity of both RBV and SD, on the other side more recent literature is emphasizing the potentials of the DRBV approach in modern managerial contexts (Kunc and Morecroft, 2009 and 2010; Kunc and O'Brien, 2017; Barnabè *et al.*, 2019). Overall, DRBV offers a holistic approach where the circular processes existing in a system (e.g. a specific business domain) can be represented – and simulated – through shared resources and feedback closed systems [1]. As mentioned, one of the fundamental aims of a DRBV model is to generate insights about a specific domain. In this context, modeling can be used to "understand the structure of a system, the interconnection between its components and how changes in any area will affect the whole system and its constituents over time" (Maani and Cavana, 2000, p. 8), thereby providing a tool able to assist decision-makers in foreseeing value creation dynamics (Sterman, 2000; Kunc and Morecroft, 2007; Kazakov and Kunc, 2016) and generate FLI. In this specific regard, it is noteworthy that previous literature already demonstrated that the DRBV approach is suitable to support managers and organizations in designing and implementing future value-creation strategies. As an example, in their 2017 article, Torres *et al.* (2017) presented and discussed a protocol (articulated in six phases and based on DRBV) for supporting strategy development. Additionally, previous literature also extensively witnessed and discussed how the potentials of SD and DRBV-based computer models may inform strategic management, support policy design and generate FLI (Sterman, 2000; Gary *et al.*, 2008; Lane, 2012; Cosenz and Noto, 2016; Kunc and O'Brien, 2017; Barnabè *et al.*, 2019).

With all of these premises in mind, this study briefly suggests combining the DRBV principles with the theoretical framework about <IR> and forward-looking orientation of corporate reports to communicate in a comprehensive and connected way how value creation works in practice over time and is also embedded in the integrated thinking concept. Specifically, we remind that this study has the twofold goal of:

(1) First, supporting the integration of BLI and FLI in <IR> suggesting a method to create FLI based on past information.

(2) Second, contributing to operationalize the <IR> "future orientation," particularly obtaining more quantitative forward-looking disclosure.

3. Research design

The research design entailed using the principles and tools of the DRBV (Kunc and Morecroft, 2009, 2010; Kunc and O'Brien, 2017) to develop an explorative case study (Ryan *et al.*, 2002) and build a simulation model used to investigate the interplays between BLI and FLI in <IR>. More information about each step of the method is presented subsequently.

While we already presented the fundamental principles of the DRBV approach, some additional details about the case study and the simulation model will be presented.

In detail, this study developed a DRBV simulation model in a Vensim software environment (Eberlein and Peterson, 1992; Ventana Systems, 2006). The simulation model was developed on the basis of the information collected from the analysis of an organization's <IR>, according to the "case study methodology" (Yin, 1994). A case study is not only a well-known research method that creates propositions from case-based, empirical evidence, aimed to capture the complexity of the object under analysis (Eisenhardt, 1989; Stake, 1995) but also a method whose potential in exploring and explaining how management accounting in practice works is widely recognized and accepted in the literature (Scapens, 1990). Specifically, this study develops an "experimental case study" for a well-known oil and gas organization – that was one of the early pioneers in the field of <IR> and has long joined the IIRC program, releasing multiple integrated reports to date. The choice of this specific company is not only justified by its relevance and the fact that it is very active in the field and practice of <IR> but also is part of a business industry that is one of the more studied, analyzed and scrutinized in terms of sustainability management and reporting practices (Roca and Searcy, 2012). These factors backed up our selection with the specific aim of developing the experimental case study. Specifically, as Ryan *et al.* (2002, p. 144) emphasize, *experimental case studies* have great potential when accounting researchers aim to develop "new accounting procedures and techniques that are intended to be helpful to accounting practitioners. These procedures and techniques are developed from existing theoretical perspectives, using normative reasoning. They are intended to indicate what should be done in practice."

Coming to the method followed to apply DRBV principles and build the simulation model to achieve the research aim, Table 1 presents the key steps we followed.

Primary sources of data are necessary to quantify, calibrate and simulate the model (see Sterman, 2000 on the typical stage of a computer simulation modeling intervention). A triangulation of data sources (Patton, 1987), which included data from the integrated report and the annual financial statement prepared by the organization analyzed for the business year 2018 and other information publicly available for this company, allowed developing the model. In detail, the model was developed to portray the most relevant resources for this company (i.e. those that were given more emphasis about value creation within the organization's <IR>) and provide a quite aggregate view of the underlying dominant logic (Prahalad and Bettis, 1986; Prahalad, 2004) characterizing this company, according to DRBV principles (Kunc and Morecroft, 2009, 2010).

As we will also describe in Table A1, the model was initialized with the company's <IR> latest data available at the time of the analysis and used for this study through the triangulation aforementioned. Subsequently, for the simulation phase of the model, the authors identified a few relevant (mainly qualitative) FLI within the integrated report analyzed, integrated this information with the quantitative data (typically, BLI) from the annual report and subsequently combined them to create specific *ad hoc* simulations scenarios (Schoemaker, 1993; Kunc and O'Brien, 2017). Stated differently, initial values in the model represent the financial BLI retrieved from the organization's reports that were subsequently used to generate FLI under specific scenarios. It is relevant to stress that the model does not aim to mimic the entire business domain under analysis, being more a theoretical model able to portray the fundamental resources and value creation processes for this company. Therefore, the model was validated (Barlas, 1996 and Sterman, 2000; Morecroft, 2007) more through structural tests (e.g. tests of structure assessment, dimensional consistency and – particularly – parameter assessment) than with behavioral-oriented tests.

4. Results

4.1 Description of the dynamic resource-based view model

Following Table 1, the first step of the analysis allowed identifying the key categories of capitals included in the <IR> and subsequently representing them as stock variables within a specific DRBV map named "resource map" (Kunc and Morecroft, 2009). To identify the categories of capitals (i.e. the resources) to be included in the map, the authors first developed a model subsystem diagram and subsequently the resource map and the quantitative model.

As Sterman (2000, p. 99) describes, subsystems diagrams show the overall architecture of a model and are particularly useful, as they "convey information on the boundary and level of aggregation in the model; [. . .] they also communicate some information about the endogenous and exogenous variables."

Notably, as portrayed in Figure 1, the subsystem diagram allowed focusing on a limited number (8) of resources, belonging to three different typologies of capitals as categorized by IIRC(2013a) and considered to be particularly relevant for the development of the quantitative model and with the ultimate aim of investigating on the integration between BLI and FLI (different colors are used in Figure 1 to denote different capitals). Specifically, we considered the following resources: equity, financial capital and debt (*financial capital*), hydrocarbon (oil and gas) reserves, refineries, power plants (pp) and coal mining assets (*manufactured capital*) and technologies, information and communication technology (ICT)

Table 1. Methodology to develop an IR-based DRBV simulation model

Steps of the process	Synthetic explanation	Additional information
Layout the resources/capitals	Identify the key resources/capitals included in the <IR> reports and visualize them as stocks	Stocks are represented as boxes (suggesting each box/stock is holding its content)
Identify the processes (flows) responsible for building or eroding resources	The information collected has to be codified to recognize and represent the processes causing the resource growth or decrease, i.e. inflows and outflows	Flows are either inflows or outflows. Inflows are represented by an arrow pointing into a stock (adding to it). Outflows are represented by arrows pointing out of the stock (subtracting from it) Valves control the flows Clouds represent the sources and sinks of the flows
Identify capabilities	Capabilities originate from either a single resource or from a set of related resources Capabilities can build other resources, generate value by attracting customers or generate activities influencing external stakeholders	The capabilities discovered in the integrated reports may be presented in the resource maps using stock or auxiliary variables. In this study, we used auxiliary variables
Portray relationships (direct and indirect) and polarities (positive and negative)	This entails representing the causal links in the organization, specifying their direction and assessing their polarity	Causal links are depicted through the use of connectors (lines), which contain the direction of the linkage and the type of linkage, that indicates a positive impact – an increase in A increases B or a negative one, – an increase in A decreases B
Identify feedback loops (reinforcing and balancing)	The resource mapping is finished with the identification of the feedback loops between resources and flows. A feedback process consists of a circular relationship between a set of concepts (or parts of a system)	A feedback loop is formed when two or more variables are circularly connected, e.g. A affects B, then B affects C and ultimately C affects A determining a circular relationship between A-B-C Feedback loops are recognized and labeled as either reinforcing (positive and generating growth) or balancing (negative and inducing stagnation)
Formulate the simulation model	After building the map, parameters have to be estimated, causal relationships among variables are to be specified and initial conditions need to be set	Initial values and parameters, as well as quantitative relationships, are derived from the organization's integrated reports. They may be immediately available (e.g. the initial value of a stock could be provided by the organization's report) or derived thanks to the information retrieved from those reports

(*continued*)

Table 1.

Steps of the process	Synthetic explanation	Additional information
Simulate and calibrate the simulation model	The model is simulated to generate dynamics. At the same time, the model is simulated under specific conditions to gain confidence in its reliability	Simulation is performed using specific computer software. The simulation is carried out in reference to a specific time horizon (how far in the future should the model consider?) The simulation results are analyzed to assess if the model reproduces dynamics adequate to the issue and domain under investigation
Perform sensitivity analysis and scenario testing	The model is tested performing sensitivity analysis. Specific scenarios can be specified and explored	Sensitivity analysis entails testing the dynamics generated by the model given the uncertainty in parameters. In reference to integrated reports, this is relevant for testing the effects of risk factors and FLI Scenarios are particularly useful to understand the effects generated by changing (or new) environmental and market conditions
Develop policy evaluation and formulate recommendations	The IR-based DRBV simulation model is eventually used to gain policy insight	This last step entails assessing the results of the simulation model to gain policy insights, subsequently redesigning rules and strategies

Source: Adapted from Kunc and Morecroft, 2009 and Barnabè *et al.*, 2019 and intellectual property (*intellectual capital*), as also portrayed in Figure 1. This figure also portrays the key outcomes (in red color) generated within this business system. Other specific resources were identified as well (belonging to the categories of the natural capital, the human capital and the social and relationship capital) but considered as exogenous to the model.

Building on this first representation of the system, we developed the resource map (Kunc and Morecroft, 2009) and subsequently quantified it using BLI retrieved from the organization's <IR>. As described by Table 1, building the resource map and then transforming the map into the simulation model entails visualizing flows going in and out from each stock and subsequently connecting the variables across the model with causal linkages (Sterman, 2000). An example, related to the stock "financial capital," is shown in Figure 2. The stock is represented as a box, which accumulates the inflow ("equity funding") and is depleted by its outflow ("investments").

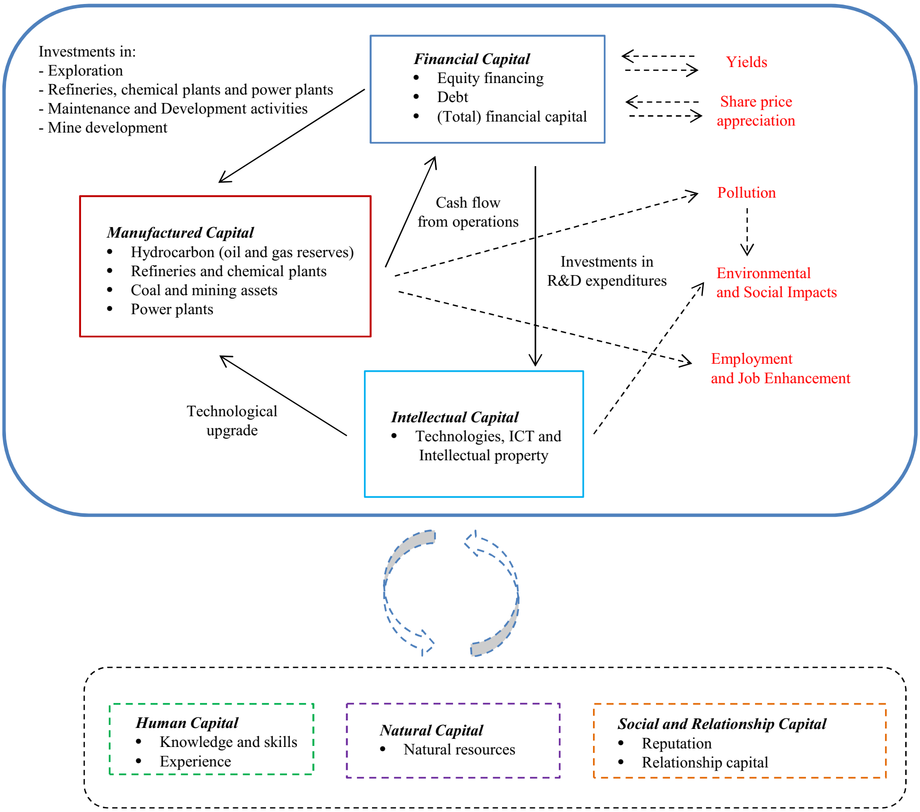

Figure 1.
Subsystem diagram for the DRBV model of the organization under analysis

Figure 2.
One "capital" at disposal seen as a stock variable, with its flows

In brief, this step of the process provides an initial representation of the capitals/resources used as inputs to the organizations' business model and the value creation process. The following step requires identifying and defining connections among such capitals and flows. For instance, the investments made by the organization in exploration activities will allow discovering new hydrocarbon reserves that will add up on those already owned and managed by the company, as depicted in Figure 3. Notably, a polarity, either positive (+) or negative (−), is assigned to each causal link to clarify how the dependent variable changes when the independent variable changes.

In brief, Figure 3 represents the basic components of a DRBV, made of *stocks, flows and causal connections*. More specifically, the map shows not only in which way the variables are connected through the use of causal linkages (in this case, the link with a "+" polarity indicates that if the organization increases its investments, this will lead to an increase in exploration activities) but also how trade-offs among capitals take place (in this case, investments drain the financial capital, but will lead to more exploration activities and subsequently to an increase of hydrocarbon reserves).

Thus, building the model step by step it is possible to depict the business environment in which a typical oil and gas organization operates, represented as an interlinked hierarchy of stocks and flows, where the basic stocks are fundamentally the main typologies of capitals described within <IR>. Specifying the causal linkages among capitals and subsequently defining their rates and quantitatively calculating the related costs and revenues are the other steps needed to represent business activities and determine the outputs of the actions carried out.

As we already mentioned when presenting the model subsystem diagram (Figure 1), the simple DRBV model described in this study considers resources across three "sectors" of this oil and gas organization, namely, financial capital, manufactured capital and intellectual capital, while the other ones (i.e. natural capital, human capital, social and relationship capital) are considered as exogenous.

In more detail, the financial sector of the model is based on the definition provided by the IIRC <IR> framework itself (IIRC, 2013a, p. 11), where it is explained that the *financial capital* is "the pool of funds, that is, available to an organization for use in the production of goods or the provision of services; obtained through financing such as debt, equity or grants or generated through operations or investments" (Figure 4).

As portrayed in Figure 4, financial capital is provided by two main sources as follows: it is either generated by equity financing or by debt being issued. Equity emissions are also influenced by share price appreciation as a result of Stock market variations (a random normal function is used to model stock market variations). The cost of the financial capital is measured by the dividends paid to equity providers or by the yields because of debt providers. The total amount of financial capital needed to perform the organization's activities is influenced by the operations activities (in terms of cash flow from operations) that we will describe subsequently.

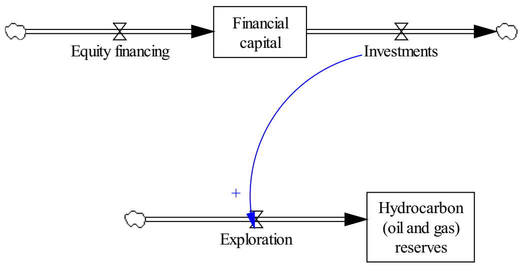

Figure 3.
Example of a causal connection

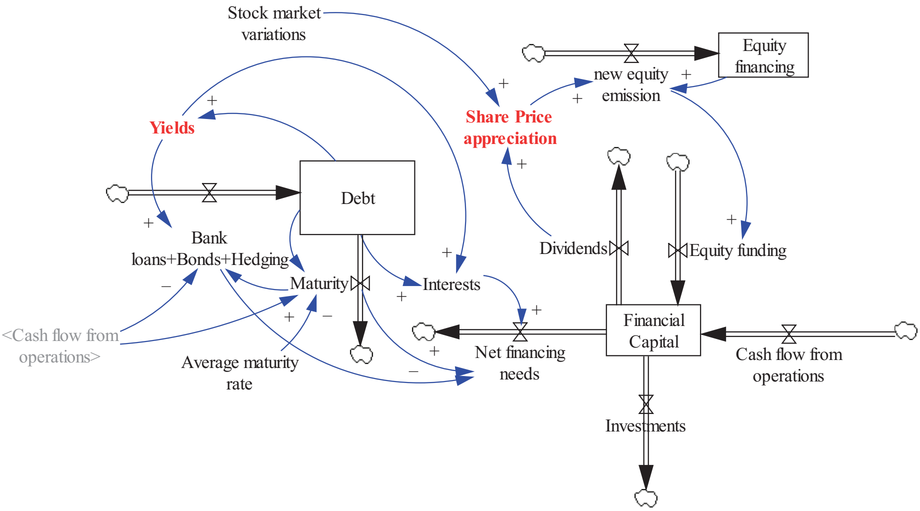

Figure 4.
Structure of the financial capital in the DRBV model

The manufactured capital is defined by the <IR> framework (IIRC, 2013a, pp. 11-12) as "manufactured physical objects (as distinct from natural physical objects) that are available to an organization for use in the production of goods or the provision of services, including buildings; equipment; infrastructure (such as roads, ports, bridges and waste and water treatment plants)." The manufactured capital for an organization involved in the oil and gas industry inevitably includes hydrocarbon reserves (both oil and gas reserves) and the infrastructures needed to transport, refine and deliver the raw materials, the products and the by-products. In this case, the organization under analysis also owns reserves of coal, which are displayed in the model (Figure 5).

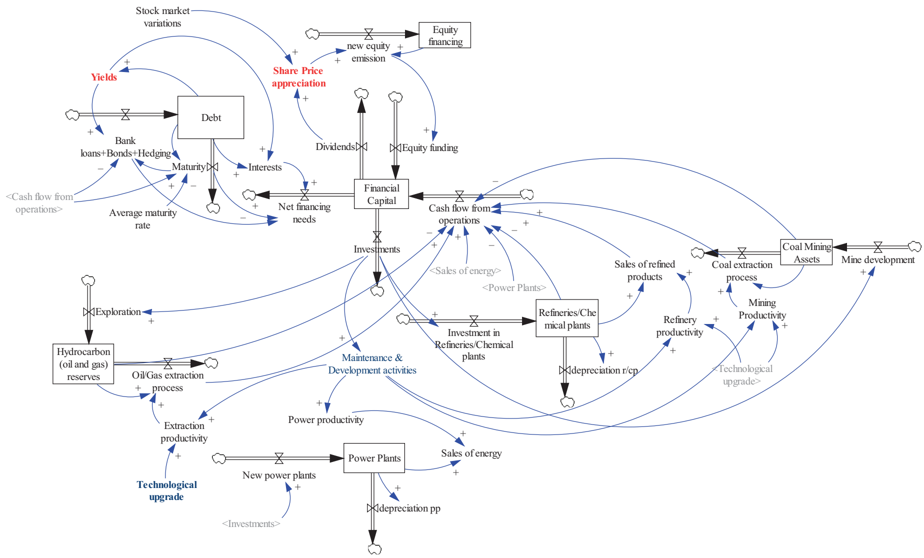

Figure 5.
Structure of the manufactured capital in the DRBV model and linkages with the financial capital

All the inflows and outflows included in this sector of the DRBV model represent business activities performed by the organization, i.e. its key operations activities. As an example, hydrocarbon reserves are increased because of exploration activities and are drained when those reserves are extracted. The same logic applies throughout the model and for the stocks and flows we portrayed.

Finally, the third typology of capital included in this DRBV model is the intellectual one. As defined by the <IR> framework (IIRC, 2013a, p. 12), this capital is "organizational, knowledge-based intangibles, including: intellectual property such as patents, copyrights, software, rights and licenses; <organizational capital> such as tacit knowledge, systems, procedures and protocols." For this model, the intellectual capital was labeled as "technologies, ICT and intellectual property." Although this is a rather general description of the intellectual capital of an organization and may be seen as the sum of items having a different dimension, the organization's <IR> and the information at disposal stimulated us in this direction. This capital is increased by "R&D expenditures," seen as a fraction of total investments.

Further expanding the DRBV model, we included the key *capabilities* for this organization. We remind that according to the DRBV methodology, capabilities can build other resources, generate value by attracting customers or generate activities influencing external stakeholders. As a methodological choice, in this study, the capabilities discovered in the integrated reports of the organization are presented in the resource maps using auxiliary variables, i.e. capabilities originate from either a single resource or from a set of related resources. Capabilities can build other resources, generate value by attracting customers or generate activities influencing external stakeholders. The capabilities discovered in the integrated reports are presented in the resource maps using auxiliary variables "maintenance and development activities" and "technological upgrade" (in teal color).

The last step of this part of the modeling process entails mapping outputs and outcomes.

We remind that *outputs* in <IR> are the key products or services that an organization produces, other by-products, which create (or erode) value and waste, while *outcomes* are the internal/external and positive/negative consequences for the capitals as a result of an organization's business activities and outputs. Outputs and outcomes emerge from the structure of the model and the interplays among capitals and activities that we have already described. For example, outputs are the refined products and energy sold on the market (see the variables "sales of refined products" and "sales of energy" in the model – Figure 6), while outcomes are "environmental and social impacts," "employment and job enhancement" and "pollution" (in red color in the model). Notably, while it is quite easy to measure and report outputs, it is somehow more difficult to measure outcomes. In this model, we subsequently generated *ad hoc* indexes used as proxy measures for such outcomes.

The whole DRBV model is portrayed in Figure 6.

4.2 Simulation dynamics

4.2.1 Overview. As we detailed in Table A1, the DRBV map was subsequently quantified using the data and information provided by the organization, that is to say, we retrieved BLI from the organization's <IR> and annual financial statement with two main aims, namely, first, to quantify the map and initialize the simulation model with the data and information provided by the organization (financial BLI); second, to simulate a "base run," thereby providing information on how BLI would affect future value creation dynamics *ceteris paribus* or could be used to generate FLI in a scenario analysis simulation mode (Kunc and O'Brien, 2017) Notably, the model is initialized with the data retrieved from the 2018 documents drafted by the organization (Table A1 in the Appendix for the full list of variables and BLI included in the DRBV model) and the time horizon for the simulation was set to 20 years. More details on the simulation phase are provided below.

4.2.2 Simulation base run. Having quantified the model with financial BLI retrieved from the organization's reports, we run a first simulation base run useful to understand the fundamental dynamics generated by the model about value creation processes in this specific business domain; for example, we set the investments equal to the investments actually made by the organization in 2018 and kept that as a constant over the whole time horizon of simulation, therefore testing the impacts generated by financial BLI – *ceteris paribus*. This subsequently implied to use the BLI retrieved from the <IR> and the organization's financial statement for all the other variables included in the model, e.g. exploration, R&D expenditures, new pp and investments in refineries/chemical plants. Similarly, BLI was used to initialize the two capabilities (maintenance and development activities and technological upgrade) that were subsequently kept as constant over the simulation time horizon. Notably, this also implies that the linkages between the variables aforementioned can be considered as simple linear relationships.

In this setting, the model is helpful to indicate if the business domain is governed by growth, tends to stasis or generates decline. As Figure 7 shows, the model overall generates growth of the key strategic resources/capitals at the organization's disposal. It is important to highlight this is a conceptual model and further validation of the structure, together with discussing additional data to calibrate it, is necessary.

As shown in Figure 7, with a steady level of investments results can be considered at best as mixed as follows: while intellectual capital tends to grow due to the longevity of the intellectual property, oil and gas reserves will progressively decrease and the stock will be depleted step by step if there is no increase in the investment to replace reserves. The first insight is the low level of investment in oil and gas reserves to keep the current level. However, another explanation is the limited representation of reserves because the model uses discovered and under exploitation reserves and does not account for reserves not

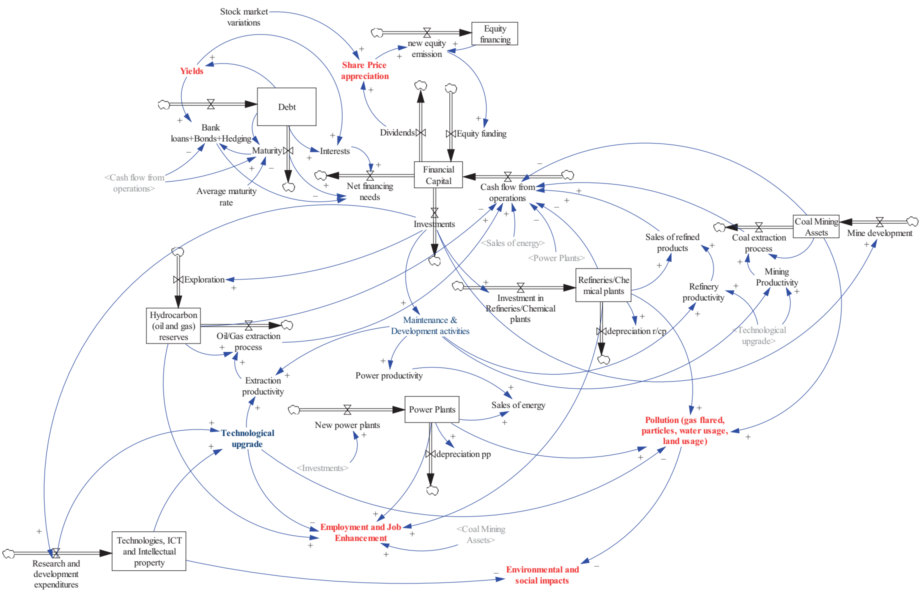

Figure 6.
Structure of the DRBV model

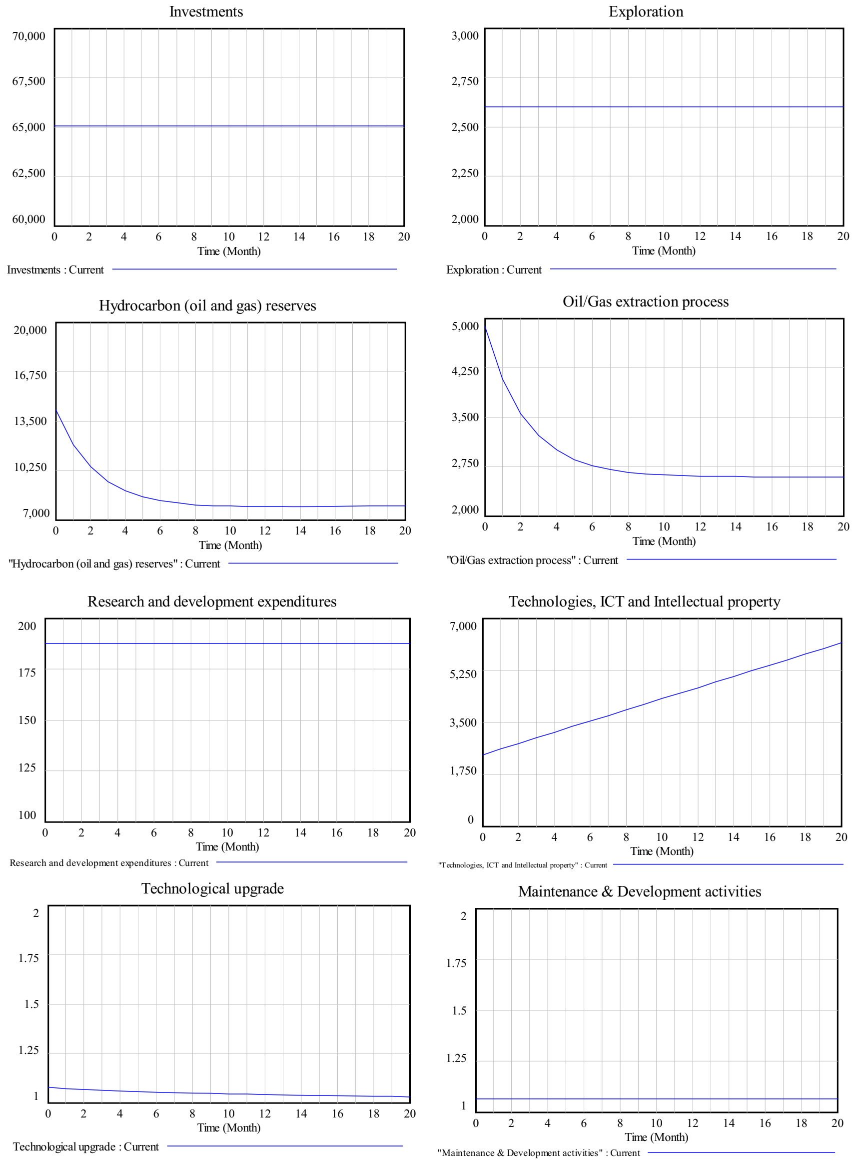

Figure 7.
Base run for the DRBV model

exploited yet. No specific improvements (yet, a decrease can be observed for the capability named "technology upgrade") will characterize the two capabilities identified for this organization and included in this model.

4.2.3 Identifying the feedback structure of the model and analyzing the integration of backward-looking information and forward-looking information. We analyzed the hierarchy of causal linkages operating in the model to understand the business dynamics over time.

Two steps were necessary, namely, identifying the feedback loops active in this business system, understanding the underlying strategies of value creation carried out in the past (witnessed by financial BLI) and planned for the future (linked to FLI) by the organization.

We provide an exemplification focusing our attention on a specific part of the model to let the structure of a feedback loop emerge and the relationship between BLI and FLI be identified and tested with the software. Specifically, this part of the model – rearranged to increase its readability – is depicted in Figure 8.

Figure 8 displays, through the "language" of DRBV, the data and information that the organization already provided in its <IR> as follows: in detail, within its <IR>, the organization explicitly states (p. 23) that "by investing in boosting our stocks of intellectual capital, we reduce the stocks of financial capital in the short term. However, in the longer-term financial capital, as well as manufactured, natural, human and social and relationship capital, are likely to be enhanced by our current commitments." This information is fundamental not only to identify a feedback loop connecting the resources and variables aforementioned but also to infer the kind of dynamics that this structure will generate over time. The model shows that an investment in "R&D expenditures" (i.e. a reduction of the financial capital) will increase the intellectual capital (here the resource "technologies, ICT and intellectual property"), which, in turn, will boost the capability "technological upgrade" and subsequently "extraction productivity." The feedback loops will be closed when the "cash flow from operations" will be increased because of the higher amount of oil/gas extracted and sold on the market, eventually increasing the stock of financial capital.

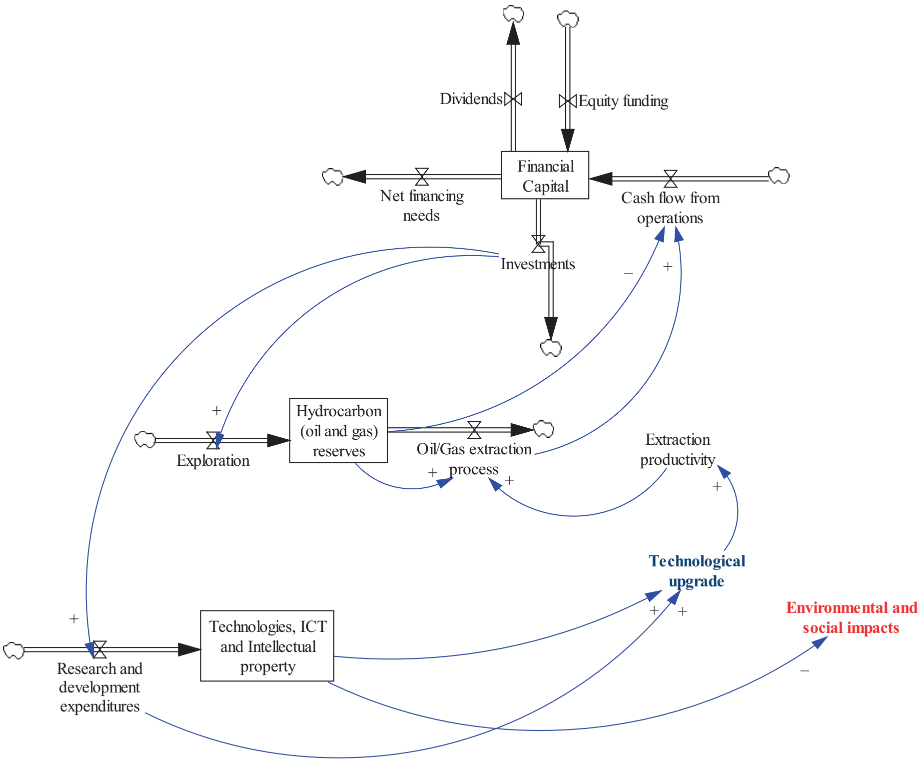

Figure 8.
Section of the DRBV model showing trade-offs among capitals

Therefore, the DRBV model transforms a verbal description of the value creation processes and the linkages among capitals into a graphical map, subsequently not only generating "new knowledge" about the system but also providing the basis for the quantitative simulation, which allows introducing the final part of our study, i.e. the analysis of the interplays between BLI and FLI. Indeed, the considerations aforementioned provide only a qualitative – even though accurate – description of how value creation dynamics will occur over time due to the interaction of the complex web of resources and variables co-existing within the model; however, the map allows gauging neither the magnitude of those dynamics nor their behavior (i.e. how they will change) over time, based on past data/performance (i.e. BLI) and planned strategies (i.e. FLI).

Therefore, the last step of our research design pointed to testing FLI within the model. In this regard, we analyzed closely the organization's 20-F report (at June 30, 2018) and inspected all the qualitative FLI provided within that document, with particular attention given to the risk factors mentioned by the organization as generators of uncertainty.

In detail, we focused on the following statement (<IR>, 2018, p. 13) as follows: "we may be unable to access, discover, appraise and develop new coal, synthetic oil, natural oil and natural gas resources at a rate, that is, adequate to sustain our business and/or enable growth." We subsequently tested this risk factor (and therefore, the related FLI) in the simulation environment to understand how exploration activities (and, subsequently, hydrocarbon reserves) would change over time in response to a higher (or lower) efficacy of investments. Stated differently, according to our research design and the research aims of this study, we run the model using BLI for the investments (2018 data were used as the initial values) in combination with several random variables to replicate the presence of uncertainty characterizing the effect of investments on exploration (and discovery) activities.

Specifically, we report in Figure 9 three sensitivity analysis tests with different random normal functions to generate three different scenarios and subsequently understand the effect of variability on the link between investments and exploration as follows:

(1) *Scenario A:* RANDOM NORMAL(0.8, 1.2, 1, 0.1, 3).

(2) *Scenario B:* RANDOM NORMAL(0.7, 1, 0.8, 0.5, 1.1).

(3) *Scenario C:* RANDOM NORMAL(0.8, 1.2, 0.2, 0.3, 1).

Notably, in Figure 9, we decided to show the graphs portraying the dynamics generated by the simulation model (and not a lengthy table with data for the whole time horizon) to provide more direct, visible and intuitive information about the effect of uncertainty in these specific scenarios and subsequently about future pathways of value creation. In detail, the graphs show that starting from BLI (i.e. the level of investments carried out by the organization in the past year), it is possible to generate FLI (in this specific case, we focused on one key business activity – "exploration" – and one key capital – "hydrocarbon (oil and gas) reserves") useful to inform decision-making and support capital allocation.

5. Discussion and conclusion

This study focused on the topic of FLI related to <IR>, which represents a reporting issue to be addressed in <IR> practices (Dumay *et al.*, 2016). Previous studies on this topic have shown that despite the "future orientation" that should guide the preparation of an <IR> organizations are not willing to provide FLI (Menicucci, 2018) and particularly, very few quantitative forward-looking indicators are disclosed in the integrated reports analyzed in comparison to BLI and qualitative FLI (Stacchezzini *et al.*, 2016; Kilic and Kuzey, 2018).

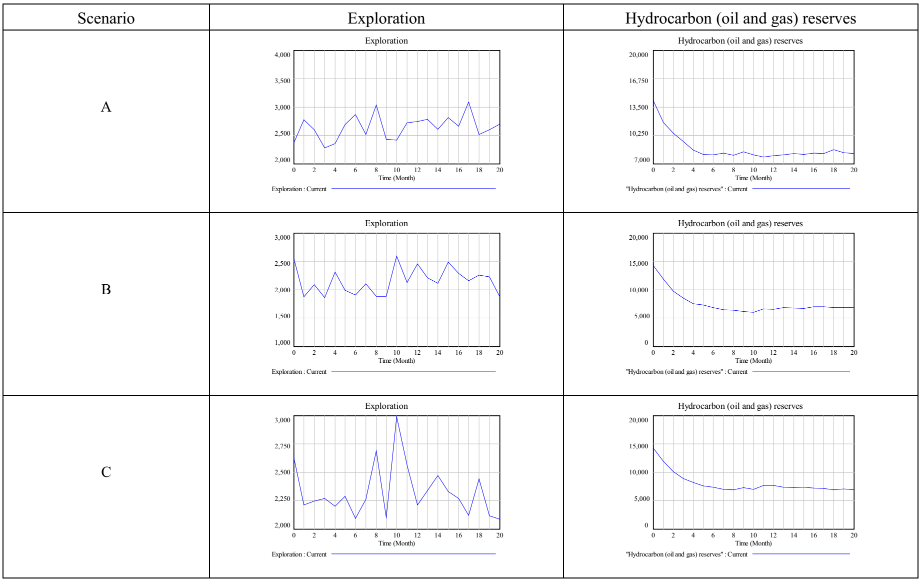

Figure 9.
Test of sensitivity analysis with FLI (Scenarios A, B and C)

Consequently, we suggested combining the theoretical framework on <IR> and forward-looking orientation of corporate reports with the DRBV principles (Kunc and Morecroft, 2009, 2010; Kunc and O'Brien, 2017; Barnabè *et al.*, 2019) with the twofold aim of integrating BLI and (mainly quantitative) FLI within <IR> and contributing to operationalize the <IR> "future orientation."

The approach considers that the value creation process in <IR> is a dynamic and systemic process including resources, interdependencies and a focus on the organization's performance leading to a continuous process of feedback-based reasoning, change and refinement of all the components aforementioned (Barnabè, 2016; Adams, 2017). FLI is fundamental to support investors' decision-making, as implicitly stated by the integrated thinking principle when it highlights the necessity of connecting the organization's activities and performance over time (IIRC, 2013a, p. 2). Our study emphasized that mathematical simulations are tools useful to support learning, sense-making and policy analysis of and in complex domains (Morecroft and Sterman, 2000; Pidd, 2004; Morecroft, 2007). In detail, we verified that when combined with specific principles (as it happens considering the DRBV approach), simulation can definitely support – and is increasingly used for – decision-making in reference to specific complex and dynamic management and environmentally-related issues (Kunc and Morecroft, 2010).

As we have shown throughout the paper, even a simple DRBV model is suitable to support managers and analysts in exploring the dynamics generated by the underlying structure of the business domain being modeled, obtaining quantitative FLI from the interpretation of BLI and qualitative FLI provided by an organization's <IR>. On this point, we remind that if BLI refers to the past and to the financial results already achieved by an organization, FLI refers to additional information useful to assess the future financial performance of the organization (Aljifri and Hussainey, 2007), but the effective combination of BLI and FLI is directly required by the integrated thinking principle when it asks for the forward-looking orientation of <IR>.

In detail and in specific reference to the aims of this study, the DRBV model allows as follows:

- identifying feedback loops and trade-offs among capitals, which form the structure of the business system under investigation, to correctly understand, which dynamics will be generated over time due to the actions carried out by the organization (Giorgino *et al.*, 2020); stated differently, as shown in Figure 6, DRBV allows transforming verbal descriptions and past-oriented financial information (i.e. BLI) about the organization's value creation processes into a graphical map, subsequently not only generating "new knowledge" about the system but also providing the basis for the quantitative simulation, that is, used subsequently;
- combining BLI and FLI within a dedicated simulation environment; specifically, we described to what extent BLI generates different FLI for the investors (compare the simulation results in Figures 7 and 9 to this aim) and how an organization should exploit the interplays between the two typologies of information to plan future value creation strategies;
- exploring the effect of uncertainty and risk factors in a quantitative and intuitive way; in detail, this study focused on FLI and provided some preliminary results in reference to a sensitivity analysis (performed according to a basic scenario analysis technique – Schoemaker, 1993; Kunc and O'Brien, 2017) focused on one specific risk factor related to the organization under analysis;
- operationalizing <IR> and providing decision-makers with a feedforward-looking process-oriented tool useful to understand and explore interdependencies and connections among the factors at disposal (e.g. the capitals), as well as the determinants of value creation (Kunc and Morecroft, 2007; Kazakov and Kunc, 2016); and
- developing a different-from-traditional representation and analysis of <IR> information through the joint use of narrative, numerical and visuals, thereby also adhering to the quite recent stream of research that advocates increased use of maps, images and similar tools to strengthen and foster the representation, communication and disclosure of accounting-based information (Bell and Davison, 2013; Quattrone, 2017).

In conclusion, the <IR> framework is certainly able to support organizations to develop a comprehensive representation of their business domain and specific business model but <IR> needs inevitably to entail the adoption of a systemic and holistic vision to *integrated thinking* and *management*. Here is where DRBV may provide great support, helping decision-makers and investors not only to transform past-oriented financial information and lengthy verbal descriptions of value creation into "new" knowledge but also to use those data and information to generate FLI and subsequently inform future decisions and actions in a quantitative and intuitive way.

However, this study has some limitations that provide interesting opportunities for further research. Firstly and foremost, it presents only one explorative case study, even though related to a well-known organization that has been very active in the field of <IR> over the past few years and also participated in the pilot program launched by the IIRC. For this reason, we will certainly look forward to applying the same research design to develop additional case studies and subsequently carry out useful comparative analyzes.

Secondly, we developed the IR-based DRBV simulation model according to an external approach, i.e. based on a thorough reading and analysis of the organization's reports, without discussing with managers and stakeholders their perspectives on the model being developed.

Therefore, the model is theoretical whose aim is to reveal the structure and hierarchy of the resources and the value creation processes for this company, rather than a complete mathematical model mimicking this company and generating detailed quantitative data. More work on the phases of calibration and validation of the model are subsequently to be planned (Barlas, 1996; Sterman, 2000; Morecroft, 2007), working with managers and CEOs through focus groups or according to a group model building technique (Vennix, 1996) to elicit their knowledge, evaluate their opinions (Ford and Sterman, 1998) and share policy insights (Lane, 2012). Notably, this further step of the project might allow developing not only a one refined and reliable simulation model but also a DRBV- and IR-based decision support system (Carlsson, 2018 and Armenia, 2019 about the combination of DSS with computer simulation techniques) to be used to run scenario analysis and further gain policy insights.

Note

1. A feedback process consists of a circular relationship between a set of concepts (or parts of a system). More details are provided in Table 1.

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Appendix

Variable	Typology of variable	Equation, initial value*
Average maturity rate	Auxiliary	= (0.24*1 + 0.41*3 + 0.35*7)
Bank loans + bonds + hedging	Flow	= Function yields to bonds (yields) + if then else (cash flow from operations*0.1 < maturity, maturity − cash flow from operations*0.1, 0)
Cash flow from operations	Flow	= [Coal extraction process*(19,797/39) − coal mining assets*(14,553/1,372)] + [“oil/gas extraction process”*(1) − “hydrocarbon (oil and gas) reserves”*(7,881/14,057)] + (sales of refined products*[(69,766 + 40,091)/119,584] − “refineries/chemical) plants”*[(61,583 + 39,503)/119,584)] + [sales of energy*(69,773/64,526) − power plants* (55,692/64,526)]
Coal extraction process	Flow	= Coal mining assets*mining productivity
Coal mining assets	Stock	= INTEG (mine development − coal extraction process, 1,372)
Debt	Stock	= INTEG (“bank loans + bonds + hedging” − maturity, 210,627)
Depreciation pp	Flow	= pp/10
Depreciation refineries/chemical plants (r/cp)	Flow	= “Refineries/chemical plants”/10
Dividends	Flow	= 8,727
Employment and job enhancement	Auxiliary	= {Coal mining assets*[31,270/(coal mining assets + “hydrocarbon (oil and gas) reserves” + pp + “refineries/ chemical plants”)] + “hydrocarbon (oil and gas) reserves”*[31,270/(coal mining assets + “hydrocarbon (oil and gas) reserves” + pp + “refineries/chemical plants”)] + pp*[31,270/(coal mining assets + “hydrocarbon (oil and gas) reserves “pp + “refineries/ chemical plants”)] + “refineries/chemical plants”*[31,270/ (coal mining assets + “hydrocarbon (oil and gas) reserves” + pp + “refineries/chemical plants”)]}*(1/ technological upgrade)
Environmental and social impacts	Auxiliary	= “Technologies, ICT and intellectual property”/1 − “pollution (gas flared, particles, water usage, land usage)”/2
Equity financing	Stock	= INTEG (new equity emission and 228,608)
Equity funding	Flow	= New equity emission
Exploration	Flow	= Investments*0.04
Extraction productivity	Auxiliary	= (4,197/14,057)*“maintenance and development activities”*technological upgrade
Financial capital	Stock	= INTEG (cash flow from operations + equity funding-dividends-investments-net financing needs and 439,235)
Function debt to yields	Auxiliary	= {[(0,0) − (200,000,0.2)], (0,0.01), (30,000,0.02), (60,000,0.03), (90,000,0.04), (120,000,0.05), (150,000,0.06), (180,000,0.07), (200,000,0.08)}
Function yields to bonds	Auxiliary	= {[(0,0) − (0.15,40,000)], (0,0), (0.01,10,000), (0.02,12,000), (0.03,14,000), (0.04,18,000), (0.05,23,000), (0.07,25,000), (0.09,27,000), (0.11,30,000), (0.13,31,000), (0.15,31,500)}
Hydrocarbon (oil and gas) reserves	Stock	= INTEG (exploration − “oil/gas extraction process,” 14,217)

(*continued*)

Table A1. Documentation of the DRBV model

Variable	Typology of variable	Equation, initial value*
Interests	Auxiliary	= Debt*yields
Investment in refineries/ chemical plants	Flow	= Investments*0.5
Investments	Flow	= 9,163 + 55,891
Maintenance and development activities	Auxiliary	= (Investments*0.15)/9,163
Maturity	Flow	= MIN (cash flow from operations*0.1, debt/average maturity rate)
Mine development	Auxiliary	= Investments*0.2
Mining productivity	Auxiliary	= 0.028*“maintenance and development activities”*technological upgrade
Net financing needs	Flow	= Interests + maturity – “bank loans + bonds + hedging”
New equity emission	Flow	= Equity financing*(share price appreciation/100)
New pp	Flow	= Investments*0.1
Oil/gas extraction process	Flow	= “Hydrocarbon (oil and gas) reserves”*extraction productivity
Pollution (gas flared, particles, water usage and land usage) function	Auxiliary	= {[(0,0) – (10,70,000)], (1,67,632), (2,67,412)}
Pollution (gas flared, particles, water usage and land usage)	Auxiliary	= “Pollution (gas flared, particles, water usage and land usage) function” [(coal mining assets + “refineries/ chemical plants” + pp)]*(1/technological upgrade)
pp	Stock	= INTEG (new pp-depreciation pp and 64,526)
Power productivity	Auxiliary	= 1*“maintenance and development activities”
Refineries/chemical plants	Stock	= INTEG (“investment in refineries/chemical plants” – “depreciation r/cp” and119,584)
Refinery productivity	Auxiliary	= 1*technological upgrade*“maintenance and development activities”
R&D expenditures	Flow	= (Investments*0.02)/6.93
Sales of energy	Auxiliary	= pp*power productivity
Sales of refined products	Auxiliary	= “Refineries/chemical plants”*refinery productivity
Share price appreciation	Auxiliary	= RAMP[(dividends/14,000), 1, 20]*stock market variations
Stock market variations	Auxiliary	= RANDOM NORMAL(0.8, 1.2, 1, 0.1, 3)
Technological upgrade	Auxiliary	= 1 + (R&D expenditures/“technologies, ICT and intellectual property”)
Technologies, ICT and intellectual property	Stock	= INTEG (R&D expenditures and 2,409)
Yields	Auxiliary	= Function debt to yields(debt)

Notes: *The third column of this table shows the equations used to calculate all the variables and, if present, their initial value. Initial values represent the financial BLI retrieved from the organization’s 2018 IR and annual financial statement

Table A1.

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