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Sustainability Disclosure in Integrated Reporting: Does It Matter to Investors? A Cheap Talk Approach

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Abstract: The purpose of this study is to investigate the value-relevance of corporate sustainability disclosure through integrated reporting. Sustainability disclosure is subject to managers' discretion. Besides, it is often hardly verifiable. In this respect, integrated reporting could provide the means for a verifiable disclosure, otherwise, in the jargon of game theory, it could be considered as a cheap talk. This paper investigates which of these hypotheses is most likely to occur in reality. In order to do this, a simple theoretical framework is introduced, where sustainability of corporate performances is modelled as a tail-risk for shareholders. Costless signaling games (cheap talk) and persuasion games are reviewed within this context, in order to derive competing theories of sustainability disclosure's value relevance through integrated reporting. These alternative theories are tested empirically consistent with the theoretical framework presented, in order to identify key-parameters. In this respect, a systematic textual analysis (artificial intelligence) of integrated reports was employed as to build a synthetic measure of sustainability disclosure. The application of this methodology on a sample of European listed companies showed that sustainability disclosure through integrated reporting has no effect on market-valuations, confirming the null hypothesis of integrated reporting resulting in a cheap talk's babbling equilibrium.

Keywords: sustainability; value-relevance; cheap talk; equilibrium; strategic accounting disclosure; textual analysis; artificial intelligence; integrated reporting; econometrics

1. Introduction

The purpose of this study is to investigate the value-relevance of corporate sustainability disclosure through integrated reporting. In this respect, sustainability is here intended as a company's ability to deliver returns to its shareholders limiting negative environmental and social spill-overs. From shareholders' perspective, sustainability could be considered as a tail-risk deriving from the nature of the business and the company's attitude toward the management of this risk. Needless to say, the effective materialization of this risk could drastically hit firms' profitability, as a result of sales drops (e.g., reputational effect), legal expenses, compensations and other penalties that might be imposed to the company.

As a matter of fact, sustainability is value-relevant, in the sense that companies with better environmental and social practices should be less risky than those adopting only minimal precautions. Nevertheless, there is a substantial difference between sustainability and sustainability disclosure. As Tirole [1] remarked in relation to the so-called stakeholder society approach to corporate governance, environmental and social performances are usually harder to be measured. For the same reason, environmental and social performances are even harder to be verified. Furthermore, sustainability disclosure is subject to the discretion of managers, who usually benefit from remuneration schemes

depending on the stock-market performance of their companies. Hence, being sustainability a tail-risk driver, managers could strategically manipulate the related disclosure in order to give the best (if any) representation possible of their companies. In this respect, this study provides an extensive analysis of the theoretical link between the verifiability and value-relevance of sustainability disclosure. In this way, a robust empirical test of the value-relevance of sustainability disclosure through integrated reporting is obtained.

Despite a great share of academic studies tend to be optimistic about the value-relevance of sustainability disclosure, empirical results (e.g., regression analysis) often provide only mixed evidences. In this respect, this paper shows how the lack of a definite evidence about a positive impact of sustainability disclosure on stock-market valuations can be explained according to a cheap talk game-theoretical framework. In particular, whenever managers incentives are mostly related to stocks performances, sustainability disclosure can become irrelevant to investors (babbling equilibrium), as managers are always better off by issuing overly optimistic messages to investors. This essential result was provided in more general terms by Crawford and Sobel [2], and this study shows how a tail-risk approach to sustainability could lead to this conclusion in absence of verifiability.

The open question remains whether integrated reporting, when compliant with the International Integrated Reporting Council's (IIRC) standards, provides the means for a verifiable and possibly value-relevant sustainability disclosure. This paper investigates empirically this hypothesis, which is viewed as alternative to the null hypothesis of integrated reporting being a cheap talk. From a theoretical perspective, the reference model adopted in this case is that of discretionary disclosure, first proposed by Verrecchia [3].

This paper considers sustainability as managers' private information, which is subject to voluntary disclosure. As anticipated, different strategic accounting disclosure models [4] are reviewed with specific reference to sustainability disclosure. Despite being both the cheap talk and discretionary disclosure models not novel in literature, for sake of clarity this paper provides detailed proofs of the most relevant theoretical results. This exercise provides also a useful review of these models for non-technical readers. In addition, it helps to understand better the empirical methodology of this paper.

The initial focus of this paper on different theories of disclosure is not just a mere intellectual exercise. One of the major limitations of several empirical studies in relation to sustainability disclosure was the lack of some formal theory to be tested, with the consequence that endogeneity should be a matter of concern in most of the regression analysis. Indeed, as Section 4 of this paper shows, value-relevance regressions of sustainability disclosure are subject to two different sources of endogeneity, that is, measurement errors and self-selection. In this respect, the theoretical framework developed in this paper helps identifying these sources of endogeneity as well as dealing with them in the most appropriate way.

Summarizing, two competing theories are presented in relation to sustainability disclosure through integrated reporting. The first is that sustainability disclosure through integrated reporting is a cheap talk, with null or limited impact on market valuations as a consequence of managers' incentives. As said, this hypothesis goes in the direction of sustainability disclosure being non-verifiable, regardless a company adopts a reporting framework consistent with the IIRC's standards. The competing hypothesis, which goes instead in the opposite direction, is that integrated reporting allows for perfectly verifiable sustainability disclosure, which positively affects stock-market valuations.

In the theoretical models presented, sustainability disclosure occurs through a synthetic message representing the probability of success of a company's business. The more a business is sustainable, the higher are the chances for shareholders to obtain some return on their investments. Of course, in reality sustainability disclosure does not happen in this way as measuring sustainability is not an easy task. Generally speaking, sustainability is disclosed mostly through qualitative statements, sometimes backed by a selection of quantitative data. In this respect, this study adopts a systematic textual analysis approach, in order to develop a proxy of managers' message in the theoretical models presented.

The methodology developed in this paper is applied to a sample of European listed companies operating in sectors where negative environmental and social externalities could affect their future economic performances. In particular, this study considers a sample of large-caps companies included in Basic Materials, Industrials, Oil & Gas and Utilities sectors $(ICB1)$. The results of this analysis suggest that, in relation to sustainability disclosure, integrated reporting is most likely a cheap talk, being it value-irrelevant to investors, with only a limited exception for utility companies. Nevertheless, the effect of sustainability disclosure on utilities companies adopting the integrated reporting is way below what should be observed if disclosure was perfectly verifiable. For this reason, this study ultimately concludes that sustainability disclosure through integrated reporting is a cheap talk resulting in a babbling equilibrium [2]. In a babbling equilibrium, sustainability disclosure has no effect on investors' expectations as it could be intentionally overly optimistic.

From a methodological perspective, it is worth noting that this study is multidisciplinary. This paper not only combines elements of game theory and accounting (i.e., models of strategic accounting disclosure), but also applies econometrics and artificial intelligence (systematic textual analysis) techniques in order to develop a consistent test of the theories presented.

The remainder of this paper is organized as follows. Section 2 provides an overview of different contributions in literature. Section 3 presents this study's theoretical framework while Section 4 the related empirical methodology. Empirical results are presented in Section 5, while Section 6 is left for the conclusions.

2. Literature Review

Integrated reporting gained considerable attention in the last few years as an evolutionary approach to corporate communication [5], specifically aimed at overcoming the limitations of "traditional" reporting in relation to non-financial disclosure. Generally speaking, integrated reporting has been identified as a unified document representing both financial and socio-environmental performances [6–9]. In this sense, integrated reporting is intended to give a more comprehensive treatment of corporate performances [10–12]. In this respect, the International Integrated Reporting Council (IIRC) has stressed that the purpose of an integrated approach is to provide also "[...] information about an organization's strategy, governance, performance and prospects in a way that reflects the commercial, social and environmental context within which it operates" [13] (p. 2). Thus, the integrated reporting framework could be considered a development of the so called "triple bottom line reporting" [14–16].

The success of integrated reporting was mostly driven by its focus on sustainability disclosure, having the latter been a topic of growing interest in corporate reporting [17–25]. More generally, non-financial communication obtained a considerable attention during the last 20 years, especially in relation to sustainability and corporate social responsibility (CSR) disclosure. This trend was supported by a growing conviction that traditional financial reporting provides both financial and non-financial stakeholders with only a limited set of information [26–30]. In a sense, traditional reporting is based only on past economic performances, which, despite being often useful to extrapolate future trends, could be insufficient to assess the actual risks underlying a company's business [31–33]. In this regard, non-financial disclosure, which is implemented through sustainability reports, CSR reports and integrated reports, provides a broad set of additional information that, if truthful and verifiable, contributes to enhance the accountability and transparency of firm's performance [34–37].

As said, sustainability disclosure, and in general, non-financial disclosure, provide valuable information to investors and other stakeholders. Recently, the European Parliament promoted the enhancement of non-financial disclosure by issuing Directive 2014/95/EU, which imposes to several European entities of "public interest" to disclose non-financial information in their annual reports [38]. Several studies have been carried out in order to verify the compliance of annual reports with this directive, and the related evidences suggest the existence of a gap in terms of sustainability disclosure [39,40].

Thus, integrated reporting could be an opportunity to overcome the limits of traditional financial reporting for what concerns sustainability disclosure. Bernardi and Stark [41] showed how the introduction of mandatory integrated reporting in South Africa (King III reform) possibly improved earnings forecast accuracy as a result of better environmental and social disclosure. Similarly, Baboukardos and Rimmel [42], considering a sample of companies listed on the South African stock market, provided some evidences supporting the hypothesis that the mandatory adoption of integrated reporting has increased equity valuations. Lee and Yeo [43], Barth et al. [44] and Zhou et al. [45] extensively studied the economic opportunities gained by adopting IR, while other authors pointed instead how integrated reporting is able to represent sustainability in a language better understandable by organizational decision-makers [46].

Nevertheless, integrated reporting has not been exempted from critics. Oprisor [47] has stressed the absence of assurance in integrated reports for what concerns non-financial information, as a consequence of lack of audit regulation. In this sense, sustainability disclosure could be said as "non-verifiable" in the jargon of information economics. Furthermore, several authors have noted that integrated reports often provided only limited information about corporate sustainability [48–50].

The lack of verifiability has been stressed also from other perspectives. Some authors pointed that integrated reporting could be a possible tool for impression management, aimed at hiding any possible corporate weaknesses from a social or environmental stance, or manipulating the tone of its information [51,52]. Roughly speaking, impression management is a reporting practice consisting in inflating intentionally the corporate outlook as to obtain specific benefits [53–56], e.g., higher stock market valuations increasing managers' compensations [57–60].

In practice, impression management consists of a set of communication techniques, such as the preference for qualitative statements, or the massive presence of graph and pictures compared to hard data [56,59,61–76]. These techniques are intended to fool "myopic" readers, by emphasizing positive information while selectively hiding negative information. In this respect, a remarkable example in relation to the empirical methodology adopted in this paper is the use of overly optimistic tones to influence investors' opinions [56,77–80].

Impression management is (implicitly) based on the hypothesis that any information disclosed is non-verifiable. From a game-theoretical perspective, whenever information is non-verifiable and disclosure is costless, a cheap talk occurs [2,81–85]. This concept will be extensively used in this study and will be better presented in Section 3 in relation to sustainability disclosure.

A key result is that, if managers are mostly concerned with the market value of their companies' shares, any value-relevant disclosure results impossible in equilibrium. In this respect, prior literature extensively claimed the need for enhanced credibility of sustainability disclosure, regardless the adoption of integrated reporting [86–92]. Besides, both positive and negative results in relation to the value-relevance of sustainability disclosure are present in literature, and several studies were only able to provide mixed or marginal evidences of a positive effect on equity valuations [93–101].

This study accepts the hypothesis that sustainability disclosure through standard reporting being non-verifiable, but considers the possibility that integrated reporting could be different in this regard. Indeed, there are also studies promoting the idea that integrated reporting should be considered reliable and authentic, suggesting that impression management being not a necessary consequence [102]. Thus, integrated reporting could be an effective tool to enforce the verifiability and quality of non-financial disclosure [6,31,32,103–106].

In this respect, this study's contribution to the existing literature is twofold. First, this paper presents a formal microeconomic model establishing a link between verifiability of sustainability disclosure and managers disclosure policy, investigating the resulting effects on stock-market valuations. Second, this theory is tested in a consistent way considering a large sample of European companies, in order to assess whether sustainability disclosure trough integrated reporting could be considered as (perfectly) verifiable and therefore value-relevant to investors.

Finally, the value relevance of integrated reporting has been studied mostly from a pure empirical perspective, without reference to a proper theory supporting the identification of key parameters in regression models [42–45,107]. Besides, only limited attention was paid to the explicit role of sustainability disclosure, which was instead object of several other studies without specific focus on integrated reporting [73,94,95,99,108–110]. Put differently, prior literature neither investigated the value relevance of integrated reporting in relation to the verifiability of sustainability disclosure, nor considered an empirical testing based on a formal theory relating the former to the latter. As anticipated, this study goes in this direction and contributes filling the gap.

3. Competing Theories and Hypothesis Development

During the last decade, several corporate episodes, either related to environmental disasters or social concerns, contributed to improve investors awareness about the role of sustainability in determining business risk. For this reason, this study defines corporate sustainability as the capability of a company to deliver returns to its shareholders limiting negative environmental and social spill-overs. In this respect, this section introduces a simple theoretical framework to establish a more precise relation between sustainability, its disclosure and the related effect on equity valuations.

In particular, being sustainability managers' private information, different signaling models are considered in order to develop competing theories of integrated reporting's value-relevance, based on alternative hypotheses for what concerns the verifiability of sustainability disclosure. For the sake of non-technical readers, the present discussion will leverage on several elements of Stocken's (2013) outstanding monography [4].

Generally speaking, managers are likely to benefit from higher valuations of their companies, which in turn depend on investors' perception of corporate risk. In several sectors, sustainability is a prominent risk-factor, and therefore managers could strategically disclose sustainability information depending on their personal interests. Consequently, completely different scenarios result depending on whether sustainability disclosure is verifiable. As anticipated, this paper accepts the general idea of sustainability disclosure being not verifiable, with a possible exception for integrated reporting, which is object of the present study.

In particular, integrated reporting, whenever compliant with IIRC's standards, could be a device intended to avoid misreporting of non-financial capitals and performances. If that was the case, sustainability disclosure could be modelled as a persuasion game where full disclosure is prevented either by disclosure costs [3] or information uncertainty [111–115]. Besides, the information disclosed in relation to sustainability would be value-relevant.

Conversely, if the non-financial contents of integrated reporting were hardly verifiable, any informative sustainability disclosure could become impossible whenever managers are mostly interested in the market value of their companies. As a consequence, valuations would be independent from the choice of drafting an integrated report, as managers could use this device just to manipulate the perception of sustainability risk. From a theoretical perspective, the models which presumes that in absence of verifiability managers can convey intentionally biased messages, without incurring legal or reputational problems, are known as costless signaling games or cheap talks [2,116,117].

The remainder of this section considers alternative equilibria in order to formalize the concepts presented in precedence. A note of warning: in this paper, the word equilibrium, which assumes a different and very specific meaning in economics, will be often encountered. In the jargon of economists, an equilibrium simply refers to the solution of the model described, that is, a situation in which agents follow explicit behavioral assumptions and all the resulting actions are consistent with each other [11]. In this respect, Section 3.1 describes the general structure of the model economy, while Sections 3.2 and 3.3 reviews respectively the concepts of cheap talk and discretionary equilibrium ("persuasion"). Finally, Section 3.4 is dedicated to summarize the previous two "competing theories" and to discuss the related hypothesis development for this study's empirical part.

3.1. Economic and Financial Environment

The economic environment presented resembles the model economy described in Camodeca, Almici and Sagliaschi [118], where intellectual capital was a key variable to explain the risks underlying corporate performances. This study considers a similar approach in order to model companies operating in sectors where environmental safety and social spill-overs could instead largely affect business risks. As a technical aside, the model economy is composed by a continuum of firms $i \in [0,1]$ and it lasts two-periods $(t = 1,2)$.

Each firm is modelled as a risky project with probability of success $\theta \in [0,1]$ and the success of a company's project is independent from those of the others. In case the project of a generic firm i is successful, its shareholders earn a random return $x_i \geq 0$ in $t = 2$ with expected value $\mu_i > 0$, which is independently distributed from θ. Conversely, when a company's project fails, shareholders obtain nothing, consistent with their status of limited liability.

This study is focused on sectors where the sustainability of firms' economic performances largely contributes to determine the related business risk, determining the occurrence of tail-events (i.e., the project's failure). This observation is modelled assuming θ being an increasing function of sustainability, the latter being in turn managers' private information. Namely, sustainability is represented as a continuous random variable (S) such that each corporate project's success occurs if it is above a random threshold (Z) independently distributed across companies, that is, $\theta = 1 - \text{Prob}(S \leq Z)$. As a consequence, the probability integral transform theorem implies that θ is independently uniformly distributed over the support $[0,1]$, i.e., $\theta \sim U[0,1]$. It is worth noting that, as sustainability is managers' private information, so does θ.

Companies are listed on a market intermediated by a large-numbers of non-impatient, risk-neutral, rational expectations market-makers engaged in minimum price-competition, i.e., Bertrand's competition. The role of market makers is to ultimately provide liquidity to uninformed investors trading in company's shares in $t = 1$. Since Bertrand's competition implies market-makers make zero profit in equilibrium, we can consider them as a proxy for risk-neutral investors. For this reason, this study will use interchangeably the expressions "market-makers" and "investors".

As said, the probability of success is known only to the company's management. Nevertheless, each manager can decide to disclose θ issuing a specific message $m = m(\theta)$ through the last annual report of her company. Put differently, m can be equivalently seen as a synthetic sustainability statement. As a consequence, the equilibrium price of company's i shares (p_i) is equal to

$$p_i = \mathbb{E}(\theta_i x_i | m) = \mathbb{E}(\theta_i | m)\mu_i, \tag{1}$$

Companies can disclose sustainability through "standard" communication devices (e.g., annual reports, websites or sustainability reports non-compliant with the IIRC's standards) or adopting an integrated approach to corporate disclosure consistent with the IIRC's standards. For ease of reading, the former will be commonly labeled as "standard reporting" for what concerns sustainability disclosure.

In general, sustainability statements are based on managers' private information which is subject to milder forms of auditing and consequently harder to be "verified" for outsiders. As the model presented in Section 3.2 shows, a necessary condition for sustainability disclosure being value-relevant (irrelevant) is the related perfect verifiability (non-verifiability).

Prior literature showed that even in presence of specific assurance practices, sustainability disclosure often does not appear to be value-relevant [86]. However, the link between value-relevance and verifiability of sustainability disclosure was considered mostly heuristically, without reference to a proper microeconomic theory of disclosure. In addition, few empirical studies were made in relation to the specific case of sustainability disclosure through integrated reporting. This study contributes to these scientific gaps adopting a game-theoretical approach to establish verifiability and value relevance

of sustainability disclosure in equilibrium, testing as well the results of this analysis on a sample of European listed companies.

This paper considers two competing and rather opposite hypotheses in relation to integrated reporting. On one hand, sustainability statements issued through integrated reports could be equivalent to those issued in other types of corporate reports for what concerns the related (non) verifiability. This hypothesis ($\mathbb{H}_0$) is formulated considering sustainability disclosure through integrated reporting as a costless and non-verifiable message to shareholders, that is, a cheap talk. On the other hand, the IIRC requires companies to meet several disclosure requirements in order to grant them the status of integrated reporters, especially in terms of sustainability reporting. This might result in additional accounting costs or effort on mangers' side, but eventually allow managers to report sustainability (θ) in a perfectly verifiable way. This is the competing hypothesis ($\mathbb{H}_1$) to the "null" hypothesis of cheap talk.

The next two Sections are dedicated to explore the previous hypotheses in greater detail. As anticipated, different value relevance implications arise depending on managers' incentives and preferences. Hence, the purpose of the next two Section remains that of representing clearly competing theories of integrated reporting's value relevance, in order to suggest a concrete methodology to test which of the two alternatives presented is more likely to "occur" in reality.

In this paper, given the "sequential" nature of managers-investors interaction, the relevant equilibrium concept involved will be that of Perfect Bayesian Equilibrium (PBE). Since managers are likely to benefit from the price of their companies' shares (p), this present paper defines a PBE by simply requiring:

1. Each manager (or sender) to choose a disclosure policy $m = m(\theta)$ that maximizes her utility function $U(\theta, p, m)$, given market makers' behavior ($p(m)$), that is, $m(\theta) = argmax_{m' \in [0,1]} U(\theta, p(m'), m') \; \forall \theta \in [0,1]$;
2. Market-makers (or receiver) to set the price of each company's share as $p(m) = \mathbb{E}(\theta|m)\mu$;
3. Market-makers (or receiver) to derive for each company the posterior distribution of $\theta|m$ ("beliefs") consistent with manager's reporting policy and according to Bayes' rule whenever possible, that is, for every message lying in the support of manager's reporting strategy.

Before proceeding, for the sake of clarity it is appropriate to stress two important theoretical aspects characterizing this study's framework. First, being θ identically and independent distributed ($i.i.d.$) across firms, the disclosure policy of a given manager is irrelevant to that of the others. Put in other words, each manager's disclosure problem can be solved in isolation. For the same reason, in what follows the index i will be dropped for ease of notation. Second, PBE is often referred as a "weak" equilibrium concept as it does not restrict receiver's "beliefs" about θ for messages lying outside the sender's reporting strategy, being the latter never played in equilibrium. Hence, it should be noticed that market-makers, as a part of their pricing policy, can set any arbitrary price for messages that are not part of the sender's reporting strategy.

3.2. $\mathbb{H}_0$: *Talk Is Cheap*

This Section investigates the impact of non-verifiability to sustainability disclosure's value-relevance, assuming disclosure being costless regardless the adoption of integrated reporting. Sender–Receiver games where communication is costless and the message space unrestricted are best known as cheap talk [116,117], a name that was coined following Crawford and Sobel seminal paper [2]. Intuitively, in this setting the sender can convey information to the receiver only if telling the truth results optimal for the former, otherwise the latter would have no reason to believe the message received as it could be intentionally biased.

The model presented below is the simplest, yet extremely powerful, examination possible of a cheap talk. This model is based on the assumption that managers are solely concerned with the

price of their respective companies' shares. Hence, being disclosure costs absent, the manager's utility function can be represented as

$$U(\theta, p, m) = p(m) = \mathbb{E}(\theta|m)\mu, \tag{2}$$

In this particular setting, managers cannot convey any information to investors. In the jargon of game theory, the only PBE of this game is called babbling equilibrium. Indeed, whatever the message managers decide to convey, investors would simply ignore it.

In order to show that no information transmission is possible, suppose there exists a PBE in which managers truthfully report θ, that is $m = \theta$. In this case, consistency implies that market-makers set $p = m\mu$ for each company. However, given this receiver's behavior, each manager could increase her utility by reporting any $m > \theta$. This means that, whenever investors conjecture managers being truthful, managers have no incentive to accurately report θ and thus always choose $m > \theta$. However, this contradicts the requirement of consistent beliefs. Since any other truthful reporting strategy of the type $m = \theta \in [\alpha_i, \alpha_{i+1})$ is dominated by reporting $m > \alpha_i$, no information transmission can occur in equilibrium. This final observation concludes the proof of the claim made in precedence.

Hence, managers are always better-off by dissembling their type if investors believe their messages. In equilibrium, market-makers correctly anticipate this behavior and disregard any message received. As a consequence, for each company i, market-makers sets the price of company's shares to

$$p_i(m) = \mathbb{E}(\theta)\mu_i = \frac{\mu_i}{2}, \tag{3}$$

regardless the specific message issued in equilibrium by the company's manager. Put differently, there are infinite economically equivalent equilibria in which a manager issues a message $m > \theta$ but her company's stocks are always priced equal to $\frac{\mu_i}{2}$.

More generally, Crawford and Sobel [2] have shown that whenever talk is cheap, that is, in absence of disclosure costs, perfect information transmission is impossible unless the sender has incentives perfectly aligned to those of the sender. In the case of integrated reporting and sustainability disclosure this ideal situation is unlikely to occur. Stock-options plans, phantom options, personal equity stakes and several other forms of remuneration contribute to misalign managers' reporting incentives from those of market-makers. While market-makers are solely interested in the accuracy of their valuations ($p_i(m) = \mathbb{E}(\theta|m)\mu_i$), managers instead are likely to benefit from inflated valuations. As a consequence, perfect information transmission results impossible.

It is worth noting that the equilibrium in which managers issue the message $m = 1$ dominates all the others in the following sense. Suppose investors acted myopically, deviating from the assumption of belief consistency by setting $p_i = m\mu_i$ As it appears evident, the best strategy for the manager would be in this case to induce $p_i = \mu_i$ by reporting $m = 1$ regardless the actual value of θ. Hence, amid all the possible babbling equilibria, those that are more likely to occur in practice are characterized by managers being intentionally overly optimistic about sustainability. This result could be considered as the formalization of the idea of integrated reporting being a device of impression management. In a similar circumstance indeed, integrated reporting and, more generally, sustainability disclosure, could help companies with poor social and environmental performances to fool investors in order to obtain a lower cost of equity.

Nevertheless, there are cases in which some information transmission is possible even when information is not verifiable, although this requires managers to be partially aligned to investors' interests. Crawford and Sobel [2] proposed to model the sender's preferences according to a utility function that includes perfect alignment to the receiver's preferences as a limiting case. In this particular context, it's convenient to generalize the manager's utility function as

$$U(\theta, p, m) = p(m) - \frac{b\mu}{2}[\theta - \mathbb{E}(\theta|m)]^2, \tag{4}$$

The parameter b introduces a trade-off between inflating prices and truthfully reporting sustainability (θ), which is invariant from the firm's expected size (μ). To see this, imagine that b in very large. In this case, manager's utility function can be approximated as $-\frac{b\mu}{2}[\theta - \mathbb{E}(\theta|m)]^2$, which is maximized whenever $p(m) = \theta\mu$, that is, when managers truthfully report $m = \theta$.

Although full disclosure remains impossible, "large" values of b allow for some information transmission. Namely, there could be equilibria in which the sender finds optimal to truthfully report $\theta \in [\alpha_i, \alpha_{i+1})$ This essential result for costless signaling games was showed first by Crawford and Sobel [2], with important implications for applied theorists. This claim is only briefly illustrated below, but all the relevant formal details are provided in Appendix A.

Suppose there exists an equilibrium in which the Sender discloses $\theta \in [\alpha_i, \alpha_{i+1})$, where $\{\alpha_i\}_{i=0}^{K}$ is an increasing sequence of length $K > 1$ such that $\alpha_0 = 0$ and $\alpha_K = 1$. The sequence $\{\alpha_i\}_{i=0}^{K}$ induces a partition of the state-space (i.e., the support of θ), and, for this reason, this type of solution takes the name of partition equilibrium. Consistency of receivers' beliefs requires that upon observing any message m consistent with $\theta \in [\alpha_i, \alpha_{i+1})$ the receiver sets

$$p = \mathbb{E}\{\theta|\theta \in [\alpha_i, \alpha_{i+1})\}\mu = \frac{\alpha_i + \alpha_{i+1}}{2}\mu, \tag{5}$$

In a PBE, receiver's beliefs are unconstrained outside the support of manager's reporting strategy. Without loss of generality, it is convenient to assume that market-makers sets $\theta = 0$ for any eventual message inconsistent with the partition reporting strategy. Under this hypothesis, which is general enough, it is immediate to conclude that the sender will always choose a message inducing a price consistent with one of the elements of the state-space's partition. Hence, it remains to assess whether there exists a (truthful) partition reporting strategy which is optimal for managers.

The optimality of sender's reporting strategy requires that $p = \frac{\alpha_i+\alpha_{i+1}}{2}\mu$ must be preferred to any other price that the manger could induce by dissembling its "type", that is, by announcing θ lying in an element of the partition different from the one including the observed value for θ. A necessary and sufficient condition for this to occur is that at each "cut-off" point α_i the sender is indifferent between reporting $\theta \in [\alpha_i, \alpha_{i+1})$ or $\theta \in [\alpha_{i-1}, \alpha_i)$, that is,

$$U(\alpha_i, m|\theta \in [\alpha_i, \alpha_{i+1}), b) = U(\alpha_i, m|\theta \in [\alpha_{i-1}, \alpha_i), b). \tag{6}$$

With some algebra (see end of Appendix A) it is possible to show that a partition equilibrium may occur if and only if $b > 4$. In this case, managers have their interests sufficiently aligned with those of investors as to allow for some information transmission. Indeed, at least a partition equilibrium of size two exists. In general, the larger is b, the larger is the maximum size of the partition (i.e., the maximum admissible value for K). Nevertheless, it should be noticed that a babbling equilibrium always exists, despite being it less informative than any alternative partition equilibrium.

It is worth noting that the message m inducing the price $p = \frac{\alpha_i+\alpha_{i+1}}{2}\mu$ could be anything consistent with θ being included in the interval $[\alpha_i, \alpha_{i+1})$. Partition equilibria are characterized by the sequence partitioning the state space. Upon receiving any message consistent with one of the elements included in the partition, the receiver, being a rational-expectation decision maker, is able to update her beliefs according to the Bayes' rule. Hence, for each partition equilibrium of size K, there are infinite many others inducing the same partition of the state-space but differing for the specific messages played in equilibrium. In other words, all the equilibria of size K are economically equivalent [2].

In reality, monetary incentives are likely to be prevailing in many circumstances, as it is more common to compensate managers in relation to the stock market performances of their companies rather than in terms of accurate sustainability reporting. Thus, under the assumption of costless and non-verifiable sustainability disclosure, the remainder of this study contemplates the possibility that integrated reporting might result at most in a "sized-2" $(K = 2)$ partition equilibrium, in which managers find optimally to truthfully report either $m|\theta \in [\alpha_0, \alpha_1)$ or $m|\theta \in [\alpha_1, \alpha_2]$. Nonetheless, this hypothesis should be viewed as alternative to the babbling equilibrium illustrated in precedence.

It should be noticed that integrated reporting plays no specific role if sustainability disclosure is perceived as non-verifiable. The equilibria established above extend to any type of corporate reporting. Put differently, costless signaling games do not provide an explanation to why only some companies decide to adopt the integrated reporting framework. The framework in the next Section shows instead how this indeterminacy could be resolved by assuming the alternative hypothesis that integrated reporting provides the means for a verifiable, and consequently truthful, disclosure of sustainability.

3.3. $\mathbb{H}_1$: *Perfect Verifiability and Value-Relevance*

This section explores the alternative hypothesis that integrated reporting allows to disclose sustainability in a fully verifiable way. In this respect, integrated reporting could be modeled as a persuasion game. Persuasion occurs when managers can credibly withhold unfavorable information but any disclosure must be truthful because of its perfect verifiability. Since investors can verify the information in their hands, the basic idea is that managers could face serious reputational costs in case of false statements, thereby offsetting any possible benefit from disclosing intentionally biased information.

In absence of disclosure costs [3] or information uncertainty [109–113], withholding information is "virtually impossible", as shown by Grossman [119] and Milgrom [120]. Stocken [4] provides a very simple proof to support the existence of a full disclosure equilibrium in absence of disclosure frictions. With reference to this study's context, assume that the receiver sets the price of a company's shares to zero in absence of integrated reporting. In this case, regardless the value of θ, every manager benefitting from the price of her company's shares is better-off by disclosing θ through an integrated report, being the latter costless. Observing that $m = \varnothing$ will never be part of the sender's reporting strategy completes the proof of this claim.

For the sake of clarity, it is worth noting that in absence of additional behavioral hypothesis, there exists also a PBE in which managers never disclose θ and the receiver sets $p = \mathbb{E}(\theta)\mu = \frac{\mu}{2}$. This solution is "weak" though, in the sense that it is enough that managers decide always to disclose θ when indifferent to do so as to break the requirement of beliefs consistency. Hence, this study assumes that a similar equilibrium cannot be observed in reality if sustainability disclosure through integrated reporting results in verifiable information. In this sense, withholding value-relevant information is "virtually impossible" in absence of disclosure frictions.

In reality, only a limited number of companies adopt integrated reporting in reality (approx. 18% of this study's sample, see Section 4.1). Thus, under the assumption of perfect verifiability, this observed fact requires the existence of some sort of disclosure friction. In relation to intellectual capital disclosure, Camodeca, Almici, and Sagliaschi [118] suggested that disclosure costs can be also intended as the private detriment induced by the additional efforts connected with adopting a more demanding accounting and reporting standard. Based on this observation, a model similar to Verrechia [3] was derived to establish intellectual capital disclosure and integrated reporting in equilibrium. This Section proceeds in a similar fashion in order to establish integrated reporting and sustainability disclosure in equilibrium, with specific reference to the sectors object of the present study's analysis.

The model presented above could be easily compared to *Framework* #2 in Stocken [4]. As in the previous Section's model, managers obtain a direct benefit from their companies' shares price; however, in case they decide to disclose θ, they must report it truthfully (i.e., $m = \theta$) and incur a private detriment associated to the additional efforts related to the adoption of a more sophisticated reporting standard [97], which is supposed to be greater the larger the company's economic size (μ). Thus, the utility function (U) of each manager can be represented as,

$$U(\theta, p, m) = p(m) - c\mu\mathbb{I}(m = \theta), \tag{7}$$

where:

- $m = \{\theta, \varnothing\}$ is the set of available messages and $m = \theta$ corresponds to the choice of drafting an integrated report;
- $\mathbb{I}(m = \theta)$ is an indicator function that is equal to 1 when integrated reporting is adopted and sustainability truthfully disclosed;
- $c\mu$ the disutility induced by the additional effort required in order to satisfy IIRC's requirements.

If $0 < c < \frac{1}{2}$ there exists an equilibrium in which companies with $\theta > 2c$ decide to adopt integrated reporting, while those with $\theta < 2$c do not. In order to prove this claim, suppose that the strategy outlined is optimal for the sender. The application of Bayes' rule requires investors to set

$$p = \theta\mu, \tag{8}$$

if $\theta > 2c$, otherwise

$$p = \mathbb{E}(\theta | m = \varnothing)\mu = \mathbb{E}(\theta | \theta < 2c) = c\mu. \tag{9}$$

It remains to show that each manager strictly prefers disclosing θ if and only if $\theta > 2c$. First, notice that, if $\theta = 2c$, then $U(\theta, m = \varnothing) = U(\theta, m = \theta) = c$. Second, if $\theta < 2c$, then $U(\theta, m = \varnothing) = c\mu > U(\theta, m = \theta) = \theta\mu - c\mu$. Finally, if $\theta > 2c$, then $U(\theta, m = \theta) = \theta\mu - c\mu > U(\theta, m = \varnothing) = c\mu$. This concluded the proof of the claim, and it can be also shown that this equilibrium is the unique of this kind (see [7] for more details). In the remainder of the paper, this equilibrium will be referred as discretionary equilibrium.

It is worth noting that similar results could be obtained assuming that with some positive probability managers could be uninformed or imperfectly informed about the true value of θ. Similar frameworks would reflect the hypotheses underlying the settings proposed by Dye [111] and Shin [113] respectively. For the moment, what matters is that, if integrated reporting provides the means to disclose sustainability in a perfectly verifiable way, then it should be value-relevant. Indeed, companies adopting the integrated reporting should trade at more expensive multiples $(\frac{p}{\mu})$ reflecting a lower business risk.

In a nutshell, under the hypothesis of perfect verifiability, companies decide to adopt integrated reporting in order to persuade investors about better business' prospects. Nonetheless, when sustainability falls below some minimum threshold, managers can credibly withhold information, as this behavior is indeed optimal once disclosure costs have been properly taken into account. Since companies deciding not to adopt integrated reporting are all valued identically, managers of companies with θ close to $2c$ face a trade-off between pooling with other companies or signaling their type (θ) at a cost c. Whenever disclosure costs prevail, investors are unable to distinguish which companies had θ slightly below $2c$ from those having θ instead much closer to zero. This basic trade-off mechanism determines the separating equilibrium observed in the model, which might be used to explain why only some companies decide to become integrated reporters whenever the latter allows for a verifiable disclosure of sustainability. As anticipated, if that is the case, companies labelled as integrated reporters by the IIRC should be valued more by investors.

3.4. Hypothesis Development

The equilibria presented in precedence helps framing the question of the value-relevance of sustainability disclosure through integrated reporting, as they are based on different assumptions for what concerns the verifiability of non-financial information. This Section helps summarizing the theoretical results obtained so far in order to better formalize a set of hypotheses to be tested on real data.

The theoretical analysis showed that integrated reporting is value-relevant provided that either company's messages are verifiable or managers' incentives are not excessively misaligned from those of uninformed investors. Alternatively, a babbling equilibrium occurs. In this equilibrium, managers issue overly optimistic messages that have no effect on equity valuations, that is, integrated reporting

is not value-relevant. The purpose of this study's empirical analysis is to establish which equilibrium most likely occurs in reality, by investigating;

1. The distribution of sustainability statements observed in integrated reports, in a sense that will be made clear in a moment;
2. Whether sustainability disclosure affects the valuation of companies considered as integrated reporters according to the IIRC.

Models of strategic accounting disclosure are extremely simple and flexible tools to describe different communication problems. However, this flexibility requires the model being abstract in terms of its key-ingredients, which in this case are managers' sustainability messages and returns of companies' projects. Thus, any empirical analysis requires first to identify suitable metrics to represents these concepts.

Starting from projects' returns, it is worth noting that $\mathbb{E}(\theta_i|m)$ could be interpreted as a "discount" factor, being a number included between zero and one. Thus, stocks' prices can be equivalently written as

$$p_i = \frac{\mu_i}{1 + r(m)}, \tag{10}$$

where $r(m)\frac{1}{\mathbb{E}(\theta_i|m)} - 1$. In this respect, this paper identifies the expected returns of a company's project as a multiple of analysts' consensus earnings forecasts $(eps_{i,FY1})$ for the current unreported fiscal year $(FY1)$, which is allowed to be function of the sector in which a company operates. This empirical assumption presumes that analysts form their forecasts without considering the case in which a company could incur serious loss as a result of the materialization of environmental and social risks.

A simple counterparty of models' sustainability messages is of course much more problematic to be identified in reality. First of all, recall that a "sustainability message" is in theory a statement made by a company's management about the probability of success of its business. Dealing with different countries and industries, it is quite difficult to identify common quantitative metrics to estimate the value implicitly disclosed through integrated reporting data. Nonetheless, quantitative statements related to sustainability are always surrounded by a large number of textual comments, that assume different sentiment in relation to the quantitative (if any) data presented. To this extent, artificial intelligence, intended as systematic textual analysis, provides great help in the present context, as explained in Section 4.2.

In order to obtain a proxy of the probability of success disclosed through integrated reporting, this study proposes to consider all the textual statements related to sustainability contained in an integrated report and measure the related overall sentiment. This approach rests on two fundamental hypotheses for companies operating in the sectors object of this study:

1. In terms of non-financial variables, the probability of success of each company is largely affected by the sustainability of its business model;
2. Considering statements related to sustainability in integrated reports, the ratio of total "positive" words to the total of those "positive" and "negative" is a valid instrument for the picture that managers attempt to give in relation to their companies' probability of success (i.e., the "message" $m = m(\theta)$).

A more detailed explanation of the procedure followed to determine "positive" and "negative" text is exposed in Section 4.2. For the moment, it is supposed that a valid instrument to proxy the empirical counterparty of managers' "messages" is available. For ease of reading, this variable is denoted as $\hat{\theta}$ and this symbol will be used for future reference.

The statistical and econometric testing of the hypotheses outlined in precedence is organized as follows. This study investigates first whether the distribution of $\hat{\theta}$ supports the possibility that integrated reporting is cheap talk but some information transmission occurs (partition equilibria). A necessary condition for this claim is that $\hat{\theta}$ appear not to be condensed only in upper-tier partitions

of the unit interval. Since this analysis shows that the former condition is not met, the focus is oriented to the alternative hypotheses that sustainability disclosure through integrated reporting results either in a babbling or a discretionary equilibrium.

Given the relation between verifiability (non-verifiability) and value relevance (value-irrelevance) of sustainability disclosure, this study's econometric analysis is intended to establish whether $\hat{\theta}$ appears to have a positive and statistically significant effects on companies' valuations. Depending on the output, one of the two alternative hypotheses of babbling and discretionary equilibria could be discarded. Namely, if $\hat{\theta}$ appears to be significantly positive, the hypothesis of babbling equilibrium could be rejected in favor of the alternative that integrated reporting results in a discretionary equilibrium.

4. Data and Methodology

4.1. Data Collection

This study considers a sample of European listed companies and operating in sectors particularly exposed to environmental and social risks. According to $ICB1$ classification, Basic Materials, Industrial, Oil & Gas, and Utility companies were included in the analysis. The focus on these sectors was driven by the consideration that sustainability is likely to be the most valuable non-financial information disclosed through an integrated report, being it a considerable tail-risk factor.

For each company included in the sample, prices and financial data were obtained quarterly from *Factset*, considering the period 2013-12-31:2018-06-29. It is worth noting that this study's dataset consists of a panel of cross-section observations. Each observation corresponds to a distinct company (i) at some point in time (t). For each observation, consensus estimates for currently unreported $(FY1)$ earnings per share $(eps^{(1)})$ were defined considering the median of all the estimates available. In this respect, price data refers to the closing price as of the date of each observation. Observations entailing either a last reported $(FY0)$ negative book-value per share $(bps^{(0)})$ or a negative $eps^{(1)}$ were excluded from the analysis, since they could be considered as outliers in the present framework.

Companies adopting the integrated reporting framework according to the IIRC were identified considering the list published on the IIRC's website (http://examples.integratedreporting.org/all_reporters, [121]). The list is dated December 2013, which was considered as starting date for this study's empirical analysis. For each observation, the closing date of the last fiscal year was obtained from *Factset's Fundamentals* database. As a general rule, it's been assumed that annual reports became available 6 months after the end of the related fiscal year. According to this rule, for each observation associated to an integrated reporter the latest available company's report was obtained as to estimate $\hat{\theta}$. In order to avoid double counting issues (see Section 4.2 below), the following "priority" logic was applied in order to consider the most relevant document for what concerns sustainability disclosure. Whenever a document listed as "integrated report" was present on the company's website, it was the only one considered in the analysis. Alternatively, the sustainability report, if available, was considered. If none of the two previous conditions was met, the annual report was used in the analysis. All the documents considered in the analysis were drafted in English.

It is worth noting that company reports of non-integrated reporters were exempted from textual analysis, consistent with this study's methodological assumption that sustainability disclosure might be verifiable only through integrated reporting. Put differently, traditional sustainability disclosure has not been considered as verifiable, consistent with many of the studies presented in Section 2. In this respect, the lack of a definite proof of positive value-relevance, even in presence of assurance [58,98], contributed to consider it as a babbling equilibrium. As D'Aquila stressed [122], the Sustainability Standard Accounting Board (SASB) recently affirmed that "by and large, companies continue to take a minimally compliant approach to sustainability disclosure, providing the market with information that is inadequate for making investment decisions" [123]. Hence, sustainability disclosure from non-integrated reporters was excluded from the purpose of the present study. Conversely,

integrated reporting, being one of the most recent and complete framework in terms of sustainability disclosure's requirements, was considered as potentially able to provide the means for verifiable sustainability disclosure.

Finally, companies with an average market cap below 3.5 Euro billions (approx. 4 USD billions) were excluded from the sample in order to preserve the focus on large-caps companies. As European Small and Mid-sized companies tend to trade at more demanding multiples because of better long-term growth potentials, this choice has the advantage to bypass the inclusion of additional control variables in the regressions presented in this study. Similarly, companies with less that 20% floating shares were excluded. According to this study's authors' experience, this is a minimum threshold to assert market prices being only limitedly influenced by the presence of insiders or other liquidity gaps.

This study's sample is ultimately composed by 180 companies, of which 32 are integrated reporters according to the list published on the IIRC's website. After excluding broken data (e.g., missing consensus estimates), this study's sample was ultimately composed of 3382 panel observations, corresponding to 19 different quarters (2013-12-31:2018-06-29) including on average 178 companies at each date. Table 1 below describes the distribution of some variables of interests, while Table 2 outlines the composition of the sample by countries and sectors (% of companies).

Table 1. Summary of main analytics.

	Mkt Cap (Average, Eur Mlns)	Price-to-Book (*FY1*)	Price-to-Earnings (*FY1*)	Return on Equity (*FY1*)	Floating Shares (%)	$\hat{\theta}$
Average	18,359	2.94x	20.65x	15.90%	75.62%	86.34%
Standard Deviation	17,528	2.22x	27.89x	10.40%	24.09%	5.46%
Min	3646	0.29x	4.28x	−3.83%	20.41%	66.80%
25%	5906	1.47x	14.22x	9.10%	57.93%	83.56%
50%	10,754	2.37x	17.16x	13.82%	82.68%	87.05%
75%	20,505	3.51x	22.08x	19.89%	98.17%	89.97%
Max	73,488	31.49x	1028.56x	149.48%	100.00%	97.35%

Table 2. Sector vs. Country composition.

	Basic Materials	Industrials	Oil & Gas	Utilities	Total
Austria	0.59%	0.59%	0.59%	0.00%	1.77%
Belgium	0.68%	-	-	-	0.68%
Denmark	-	2.31%	0.56%	0.27%	3.13%
Finland	1.18%	1.77%	0.59%	0.56%	4.11%
France	1.77%	9.58%	0.59%	1.77%	13.72%
Germany	5.35%	6.59%	-	1.27%	13.22%
Ireland	0.00%	1.74%	0.00%	0.00%	1.74%
Italy	0.00%	1.74%	0.71%	2.84%	5.29%
Jersey	1.74%	1.18%	0.59%	-	3.52%
Luxembourg	0.98%	0.00%	0.59%	-	1.57%
Netherlands	1.74%	2.93%	0.00%	-	4.67%
Norway	1.18%	-	1.09%	-	2.28%
Portugal	-	-	0.59%	0.59%	1.18%
Spain	-	3.87%	1.18%	2.90%	7.95%
Sweden	0.65%	4.58%	0.18%	-	5.41%
Switzerland	1.71%	6.18%	-	-	7.89%
United Kingdom	4.52%	11.03%	2.25%	4.05%	21.85%
Total	22.12%	54.11%	9.52%	14.25%	100.00%

Finally, Table 3 illustrates the distribution of integrated reporters across the sectors considered in this present paper. In absolute terms, all sectors with the exception of Oil & Gas companies include approximately the same number of integrated reporters (approx. 10 per sector). However, as the number of industrial companies is much larger than Basic Materials and Utilities, integrated reporting appears to be a more consolidated trend in these two sectors.

Table 3. Distribution of European Integrated Reporters across Sectors.

	Basic Materials	Industrials	Oil & Gas	Utilities	Total
Standard Reporting (Sample %)	15.55%	49.62%	8.52%	8.63%	82.32%
Integrated Reporting (Sample %)	6.56%	4.49%	1.01%	5.62%	17.68%
Integrated Reporters (Sector %)	42.2%	9.1%	11.8%	65.1%	

4.2. From Theory to Empirics: Natural Language Processing Proxy for $\hat{\theta}$

In reality, companies obviously do not disclose their probability of success as they would in a model-like situation. For what concerns sustainability, corporations focus on issuing qualitative statements backed by selected data, in order to represent environmental and social risks. Of course, these statements could be omitted or intentionally manipulated, depending on whether they result verifiable or not. To this extent, it is reasonable to posit that the "tone" of these statements is a good proxy of the "message" that would be equivalently sent to shareholders in a model-like situation.

In light of the previous observations, this study assumes a correspondence between the theoretical message of the model, m, and the overall tone of the statements related to sustainability. This paper's methodology relies on the relative frequency of positive tones $(\hat{\theta})$ as a proxy for the theoretical message (m) that managers would issue to influence market's perception about their companies' risk (θ). This relation can be represented empirically as,

$$m = \hat{\theta} + \vartheta, \tag{11}$$

where ϑ is a measurement error component which is supposed to be independently distributed from $\hat{\theta}$ or any other financial variable included in this study's analysis. It is worth noting that in absence of any statistical assumption on the distribution of this error term, the previous equation would be simply a tautology and would be of no help in supporting the identification of the key parameters of the regression models presented in the next Section.

Several studies employed textual analysis to better understand the narrative adopted in company reports [124–131]. In this respect, the analysis of tones (positive/negative/neutral) is particularly widespread, especially in terms of market's reaction [132–140].

The remainder of this Section describes how this study systematically analyzed integrated reports in order to obtain $\hat{\theta}$. As anticipated, for each company the relevant textual document was obtained directly from its website. Unfortunately, European companies are not generally required to present their annual statements in a standard format such as the 10-k format required by the SEC for US listed firms. Besides, integrated reports are generally available only in pdf format, and for this reason the companies' files employed in this study had to be converted in a "machine-readable" format.

After collecting all the relevant pdf files from companies' website, the latter were converted in the .txt format using Python's pdfpage open-source package. A bespoke routine was drafted by the authors of this study in order to preserve an overview of the parsing process. During this process, all the text elements embedded in pure "images" were lost. Nevertheless, a random sample check showed that the same concepts presented through images were mentioned or sometimes even more extensively discussed in other textual parts of the documents. As a technical aside, each document was converted with UTF-8 encoding.

The conversion algorithm proceeded sequentially considering all the pages of each integrated report and isolating the related textual items. The following step was to define a list of concepts to be searched for a sentiment analysis. This paper considered as a starting point the concept vector (Table 4) presented in Wen [141], which was based in turn on a list published in precedence by E. I. du Pont de Nemours and Company [142].

Table 4. Concept vector.

Regex	Environmental/Social Sustainability	Included in Wen (2014) and DuPont (2008)
\bbiodegrad[a-z]*\b	Environmental	Yes
\bcarbon[a-z]*\sfoot [a-z]*\b	Environmental	Yes
\bcarbon[a-z]*\sneutral [a-z]*\b	Environmental	Yes
\bconserv[a-z]*\b	Environmental	Yes
\benviron[a-z]\srespons[a-z]*\b	Environmental	Yes
\bpreserv[a-z]*\b	Environmental	Yes
\brecycl[a-z]*\b	Environmental	Yes
\breduc[a-z]*\s[a-z]*\scarbon[a-z]*\b	Environmental	Yes
\bremedia[a-z]*\b	Environmental	Yes
\brenewable[a-z]*\b	Environmental	Yes
\bsolar[a-z]*\b	Environmental	Yes
\bsteward[a-z]*\b	Environmental	Yes
\bsustaina[a-z]*\b	Environmental	Yes
\bsuperfund[a-z]*\b	Environmental	Yes
\bwind[a-z]*\spower[a-z]*\b	Environmental	Yes
\bequal\sopportunit[a-z]*\b	Social	No
\bstakeholder[a-z]*\b	Social	No
\bsocial\srespons[a-z]*\b	Social	No
\bemployees\swelfare*\b	Social	No

A concept vector formally consists of a textual file including regular expressions (regex). Each regex represents the "root" of one or more words that, respectively individually or jointly, are strongly associated with the topic of interest (i.e., sustainability). This paper extended the original list of regex included in Wen [141] in order to account for social sustainability as well as environmental sustainability. While the latter remains in general prominent in determining business risks, in some cases social sustainability could be also a matter of investors' concern. An example could be the reputational risk associated to very low levels of employees' welfare (i.e., risk of class actions), but several others could be made. As a general remark, the list of additional words included in this paper's analysis was calibrated in order to avoid duplications of the same concept.

The next step of the procedure consisted in obtaining for each pdf file all the sentences where at least one of the regex above occurred once, avoiding double counting. Following Wen [141], a bespoke Python program was written based on the natural language processing package nltk. This process is commonly referred as tokenization.

The last step was to use *Vader* as to measure the percentage of text with positive, negative and neutral tone for each sentence dealing with sustainability [143]. After having performed this task, the synthetic number of positive (negative) words occurring in each sentence was obtained by multiplying the percentage of text with positive (negative) meaning times the numbers of words included in the sentence considered. Finally, for each report, $\hat{\theta}$ was obtained considering the ratio between the sum of all the positive words to the sum of all those positive and negative, having excluded sentences with more than 150 words. (e.g., tables, where sentiment is hardly measurable). Formally, the following equation defines $\hat{\theta}$ according to this study's methodology,

$$\hat{\theta} = \frac{\sum_c \sum_{s|c \in s \ \wedge \ len(s)<150} \ VADER_{pos}(s) \cdot len(s)}{\sum_c \sum_{s|c \in s \ \wedge \ len(s)<150} VADER_{Pos}(s) \cdot len(s) + \sum_c \sum_{s|c \in s \ \wedge \ len(s)<150} VADER_{Neg}(s) \cdot len(s)}, \quad (12)$$

where:

- c is a regex included in the concept vector;
- s is any sentence included in a given pdf;
- $len(s)$ is the number of words included in sentence s;
- $s|c \in s \ \wedge \ len(s) < 150$ is any sentence with less than 150 words including regex c;
- $Vader_{Sentiment}$ is the percentage of words in sentence s with either positive or negative $Sentiment$, according to Vader.

Vader is the acronym of *Valence Aware Dictionary and sEntiment Reasoner*, a valence-based sentiment analysis algorithm for textual data which was developed by Hutto and Gilbert [143]. The use of Vader represents a step-forward compared to the approach of Wen [141], which was uniquely based on counting the frequency of positive and negative words based on common dictionaries. Vader instead is a bit more based on actual human reasoning and can understand several syntax structures that affect the tone of a statement. The developers of this algorithm indeed created a gold-standard list of lexical features aimed at enhancing context awareness in textual analysis. This was achieved including the results of large-scale linguistic experiments that were conducted leveraging on Amazon Turk's network.

One of the main differences with standard positive (negative) words counting is that Vader attributes to each word a score reflecting the intensity of its positivity (negativity). The score $(SCORE(w))$ attributed to each word (w) ranges from -4 for very negative terms to $+4$ for those very positive, while neutral words get a rating equal to zero. Vader provides a dictionary associating to each English word the related score, which in turn was obtained averaging the rating attributed by several independent reviewers. Within the context of a specific sentence, scores might be adjusted to take into account specific syntactic effects (e.g., negations) as well as the impact of punctuation (e.g., "!").

The percentage of positive text $\left(VADER_{pos}(s)\right)$ in each sentence is obtained according to Equation (13) below

$$VADER_{pos}(s) = \frac{\sum_{w \in s | SCORE(w)<0} SCORE(w)}{\sum_{w \in s} SCORE(w) + \sum_{w \in s | SCORE(w)=0} 1}, \tag{13}$$

that is, considering the ratio between the total positive scores and the sum of total number of scores plus the number of words with neutral tone $(SCORE(w) = 0)$. Similarly, the percentage of positive text $\left(VADER_{neg}(s)\right)$ in each sentence is obtained as,

$$VADER_{neg}(s) = \frac{\sum_{w \in s | SCORE(w)<0} SCORE(w)}{\sum_{w \in s} SCORE(w) + \sum_{w \in s | SCORE(w)=0} 1}, \tag{14}$$

As anticipated, the percentage of positive (negative) words is obtained multiplying $VADER_{pos}(s)$ $\left(VADER_{neg}(s)\right)$ times $len(s)$. This means that the percentage of positive (negative) text within a sentence could be larger than the number of positive (negative) words included. For this reason, this number has been defined as "synthetic" in precedence, and it represents the equivalent number of "basic" positive (negative) words that should be adopted in a sentence in order to induce the same sentiment. Besides, as Vader could be sensitive to punctuation, this paper included punctuation when measuring the length of each sentence.

A more thorough exposure of Vader would require a much longer digression which is out of this paper's scope. However, in order to illustrate how Vader works in practice, consider the following sentence from Rio Tinto's 2015 annual report [144] (p. 119) which contains the regex $\backslash benviron[a-z]b\backslash$:

> "Environmental costs result from environmental damage that was not a necessary consequence of operations, and may include remediation, compensation and penalties."

As it appears evident, the message conveyed by this statement is rather neutral. Indeed, this sentence is nothing but the definition of environmental costs reported in the annual report's section "Notes to the 2015 Financial Statement". The Vader algorithm correctly classifies this statement, attributing the majority (approx. 85%) of text to the "neutral" bucket and only a minimal part to the negative one (approx. 15%). In a sense, the "negative" part comes from the fact that the company had to mention damages and the related potential impact on earnings.

As a technical aside, this paper makes use of the Vader module included in the *sentiment* library of the Python package nltk.

4.3. Regression Analysis

This Section presents the final part of this study, that is, the assessment of whether integrated reporting is cheap talk in relation to sustainability disclosure. The analysis of the distribution of $\hat{\theta}$ (Section 5.1) has shown that, from an empiricist perspective, either a babbling equilibrium or a discretionary equilibrium can fit the data collected. In this respect, the former reflects a situation in which sustainability disclosure is not verifiable and has no effect on market valuations while the latter the exact opposite.

The following equation can be formulated in order to derive a regression model consistent with the competing theories presented,

$$p_{i,t} = \begin{cases} \frac{\mu_{i,t}}{2}, \mathbb{H}_0 : \textit{integrated reporting is cheap talk} \\ m\mu_{i,t} I(IR_i), \mathbb{H}_1 : \textit{integrated reporting is persuasion} \end{cases}, \tag{15}$$

where $\mathbb{I}(IR_i)$ is an indicator function which is equal to one if company i is an integrated reporter, otherwise to zero. Equation (15) can be written equivalently as

$$p_{i,t} = \frac{\mu_{i,t}}{2} + \pi(m - \frac{1}{2})\mathbb{I}(IR_i)\mu_{i,t}, \tag{16}$$

where π is equal to zero under the null hypothesis of cheap talk, otherwise to one. As anticipated, an empirical counterpart for $\mu_{i,t}$ is obtained considering a multiple of consensus earnings estimates for the current unreported fiscal year, which might be different depending on the sector in which each company operates (e.g., industrial companies have different long-term growth perspectives compared to utilities). For ease of notation, the relation $\mu_{i,t} = \omega \cdot eps_{i,t}^{(1)}$, will be written without referencing to the specific sector to which company i belongs.

Substituting the expression $\mu_{i,t} = \omega \cdot eps_{i,t}^{(1)}$ in Equation (16), the following equation is obtained,

$$p_{i,t} = \frac{\omega}{2} \cdot eps_{i,t}^{(1)} + \pi \cdot \omega \cdot (m - \frac{1}{2}) \cdot \mathbb{I}(IR_i) \cdot eps_{i,t}^{(1)}, \tag{17}$$

In order to test the model on actual data, it remains to substitute m with its proxy $(\hat{\theta})$. In order to do so, recall that this study presumes the following relation,

$$m = \hat{\theta} + \vartheta, \tag{18}$$

which can be used in Equation (16) obtaining

$$p_{i,t} = \omega \frac{eps_{i,t}^{(1)}}{2} + \pi\omega(\hat{\theta}_{i,t} - \frac{1}{2})\mathbb{I}(IR_i)eps_{i,t}^{(1)} + \pi\omega\vartheta\mathbb{I}(IR_i)eps_{i,t}^{(1)}, \tag{19}$$

It is useful to recall that ϑ is a zero-mean measurement error term which was supposed to be independently distributed from $\hat{\theta}$ or any other financial variable included in the analysis.

The term

$$\eta\pi\omega\vartheta\mathbb{I}(IR_i)eps_{i,t}^{(1)}, \tag{20}$$

is somewhat problematic, as it includes a measurement error component (ϑ) interacting with other regressors. In order to deal with this additional complexity, it is convenient to examine η's expected value conditional upon the whole set of regressors involved,

$$\mathbb{E}(\eta | eps_{i,t}^{(1)}, \hat{\theta}_{i,t}, IR_i) = \pi\omega\mathbb{I}(IR_i)eps_{i,t}^{(1)}\mathbb{E}(\vartheta | eps_{i,t}^{(1)}, \hat{\theta}_{i,t}, IR_i), \tag{21}$$

When integrated reporting is not adopted, $\mathbb{E}(\eta|eps_{i,t}^{(1)},\ \hat{\theta}_{i,t}, IR_i) = 0$. Conversely, when integrated reporting is adopted and $\hat{\theta}_{i,t}$ observed, there could be two different scenarios. If integrated reporting is cheap talk ($\pi = 0$), then its adoption is neither related to θ nor to m. Furthermore, m is not related to θ, as the possibility of a partition equilibrium was ruled out. Hence, in this case it appears that $\mathbb{E}(\vartheta|eps_{i,t}^{(1)},\ \hat{\theta}_{i,t}, IR_i) = \mathbb{E}(\vartheta|eps_{i,t}^{(1)},\ \hat{\theta}_{i,t}) = \mathbb{E}(\vartheta) = 0$.

If instead a discretionary equilibrium took place ($\pi = 1$), integrated reporting would be adopted provided θ being above a given threshold ($2c$). In this circumstance, m would be equal to θ and, consequently, the following equation can be formulated,

$$\mathbb{E}(\vartheta|eps_{i,t}^{(1)},\ \hat{\theta}_{i,t}, IR_i = 1) = \mathbb{E}(\vartheta|\ \hat{\theta}_{i,t}, IR_i = 1) = \mathbb{E}(\vartheta|\vartheta > 2c - \hat{\theta}_{i,t}), \tag{22}$$

The distribution of the measurement error ϑ is also problematic as m is necessary bounded between zero and one. Besides, c is an unknown parameter. This study addressed this potential endogeneity issue in a simple, approximated but easily implementable way. First, the unknown threshold $2c$ was set to the minimum value of $\hat{\theta}$ observed (66.8%). Second, the distribution of the error term was approximated as Gaussian with standard deviation (σ_ϑ) equal to that of $\hat{\theta}$ (5.46%), obtaining

$$\mathbb{E}(\vartheta|\vartheta > 2c - \hat{\theta}_{i,t}) \approx \sigma_\vartheta \frac{\varphi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})}{1 - \Phi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})}, \tag{23}$$

Heuristically, the idea underlying this hypothesis is that whenever $\hat{\theta}$ is close to one, it is less likely that m has been underestimated, as $\mathbb{E}(\vartheta|\vartheta > 2c - \hat{\theta}_{i,t}) \approx \mathbb{E}(\vartheta) = 0$. This approach is consistent with the null hypothesis of "babbling", as integrated report generally includes a large number of statements related to sustainability disclosure.

Hence, the term η could be ultimately represented as

$$\eta_{i,t} \approx \sigma_\vartheta \frac{\varphi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})}{1 - \Phi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})} \pi\omega\mathbb{I}(IR_i)eps_{i,t}^{(1)} + \epsilon_{i,t}^{(A)}, \tag{24}$$

where $\epsilon_{i,t}^{(A)} := \left[\vartheta - \sigma_\vartheta \frac{\varphi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})}{1-\Phi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})}\right] \pi\omega\mathbb{I}(IR_i)eps_{i,t}^{(1)}$ satisfies the exogeneity condition $\mathbb{E}(\eta_1|eps_{i,t}^{(1)},\ \hat{\theta}_{i,t}, IR_i) = 0$. However, it should be noticed that $\eta_{i,t}$ is linear in consensus earnings; therefore, heteroscedasticity shall be properly addressed in hypothesis testing. Before getting to this point it is necessary to summarize the results obtained so far and discuss which control variables deserve to be included.

In light of the discussion above, the following empirical model can be outlined,

$$p_{i,t} = \beta_3 \frac{eps_{i,t}^{(1)}}{2} + \beta_4 \mathbb{I}(IR_i)[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}]eps_{i,t}^{(1)} + \epsilon_{i,t}^{(A)}, \tag{25}$$

where $\psi(\hat{\theta}) = \left[\sigma_\vartheta \frac{\varphi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})}{1-\Phi(\frac{2c-\hat{\theta}_{i,t}}{\sigma_\vartheta})} - \frac{1}{2}\right]$, while $\beta_3 = \omega$ and $\beta_4 = \pi\omega$ are sector dependent parameters.

Equation (25) is of course unlikely to perfectly fit the data generating process underlying this study's sample. For this reason, this study includes the book-value per share ($bps_{i,t}^{(0)}$) as control variable and allows the presence of a disturbance term ($\epsilon_{i,t}^{(B)}$) independently distributed from any financial variable included in Equation (25) above. In order to avoid common estimation problems, all data are considered in Euro, which serves as common base currency. In addition, for each company

both sides of Equation (25) are pre-multiplied times the number of common shares outstanding $(n_{i,t})$. In this way, a constant term (β_0) is in introduced in the regression in order to allow for $\mathbb{E}(\epsilon_{i,t}^{(B)} n_{i,t}) = 0$.

The inclusion of a common intercept term in the regression would be prevented by "scaling" effects if not multiplying both sides of Equation (25) times the number of shares outstanding. Indeed, consider two companies, A and B, differing only for the number of their outstanding shares. Assume that company A has issued only one share and the related price fits the equation $p_A = \beta_0 + \beta_1 eps_{A,t}^{(1)} + u = \beta_0 + \beta_1 earnings_{A,t}^{(1)} + u$. As a consequence, the price of company's B shares reads $p_B = \frac{p_A}{n} = \frac{\beta_0}{n} + \beta_1 eps_{B,t}^{(1)} + \frac{u}{n}$, contradicting the possibility of an intercept term common to both companies.

Thus, this study's regression model reads as

$$p_{i,t} n_{i,t} = \beta_0 + \beta_2 bps_{i,t}^{(0)} n_{i,t} + \beta_3 \frac{eps_{i,t}^{(1)}}{2} n_{i,t} + \beta_4 \mathbb{I}(IR_i)[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}] eps_{i,t}^{(1)} n_{i,t} + \varepsilon_{i,t}, \tag{26}$$

where $\varepsilon_{i,t}(\epsilon_{i,t}^{(A)} + \epsilon_{i,t}^{(B)}) n_{i,t}$, $bps_{i,t}^{(0)}$ is the last reported ($FY0$) book-value per share, while β_3 and $\beta_4 = k \cdot \beta_3$ are sector specific parameters.

The last step of this study's regression analysis is to consider the possibility that self-selection can occur in this sample [145,146]. As said, $\epsilon_{i,t}^{(B)}$ is assumed to be independently distributed from any other financial variable, such as $eps_{i,t}^{(1)}$ and $bps_{i,t}^{(0)}$. Nevertheless, it could be possible that $\epsilon_{i,t}^{(B)}$ is correlated to sustainability, if the latter was disclosed in a verifiable way $(\pi = 1)$. Thus, if the alternative hypothesis of integrated reporting being value relevant was true, a self-selection bias could be effectively present in the regression [118,145,146].

Under the null hypothesis of "babbling", integrated reporting is adopted irrespectively of θ and $\hat{\theta}$ provides no information about sustainability, and therefore

$$\mathbb{E}(\varepsilon_{i,t} | bps_{i,t}^{(0)}, eps_{i,t}^{(1)}, n_{i,t}, \hat{\theta}_{i,t}, IR_i) = \mathbb{E}(\epsilon_{i,t}^{(B)} | bps_{i,t}^{(0)}, eps_{i,t}^{(1)}, n_{i,t}, \hat{\theta}_{i,t}, IR_i) = \mathbb{E}(\epsilon_{i,t}^{(B)}) = 0. \tag{27}$$

Conversely, if a discretionary equilibrium occurred $(\pi = 1)$, $\mathbb{E}(\varepsilon_{i,t} | bps_{i,t}^{(0)}, eps_{i,t}^{(1)}, n_{i,t}, \hat{\theta}_{i,t}, IR_i = 0)$ would be still equal to zero, while $\mathbb{E}(\varepsilon_{i,t} | bps_{i,t}^{(0)}, eps_{i,t}^{(1)}, n_{i,t}, \hat{\theta}_{i,t}, IR_i = 1)$ to

$$\mathbb{E}(\epsilon_{i,t}^{(B)} | bps_{i,t}^{(0)}, eps_{i,t}^{(1)}, n_{i,t}, \hat{\theta}_{i,t}, IR_i = 1) = \mathbb{E}(\epsilon_{i,t}^{(B)} | \theta \rangle 2c) = \mathbb{E}(\epsilon_{i,t}^{(B)} | \vartheta > 2c - \hat{\theta}_{i,t}). \tag{28}$$

Conditional upon π being equal to 1, this paper models $\epsilon_{i,t}^{(B)}$ and ϑ as jointly normally distributed, possibly with correlation (ρ) different from zero. This approach is consistent with Heckman's methodology to deal with endogenous selection [146]. Exploiting the properties of the bivariate normal distribution, if a discretionary equilibrium occurred (i.e., $\pi = 1$), it would be possible write

$$\mathbb{E}(\epsilon_{i,t}^{(B)} | \vartheta > 2c - \hat{\theta}_{i,t}) = \rho \frac{\varphi(2c - \hat{\theta}_{i,t})}{1 - \Phi(2c - \hat{\theta}_{i,t})}. \tag{29}$$

As a result, the error term of the regression model can be represented as

$$\varepsilon_{i,t} = \pi\rho\lambda(\hat{\theta}_{i,t}) \mathbb{I}(IR_i) + \underbrace{\varepsilon_{i,t} - \pi\lambda(\hat{\theta}_{i,t}) \mathbb{I}(IR_i)}_{u_{i,t}} = \pi\rho\lambda(\hat{\theta}_{i,t}) \mathbb{I}(IR_i) + u_{i,t}, \tag{30}$$

where $\lambda(\hat{\theta}_{i,t})\frac{\varphi(2c-\hat{\theta}_{i,t})}{1-\Phi(2c-\hat{\theta}_{i,t})}$. Substituting Equation (30) in Equation (25), this study's regression model is ultimately formulated as

$$p_{i,t}n_{i,t} = \beta_0 + \beta_1\lambda(\hat{\theta}_{i,t})\mathbb{I}(IR_i) + \left\{\beta_2 bps_{i,t}^{(0)} + \beta_3\frac{eps_{i,t}^{(1)}}{2} + \beta_4\mathbb{I}(IR_i)[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}]eps_{i,t}^{(1)}\right\}n_{i,t} + u_{i,t} \quad (31)$$

where $\beta_1\pi\rho$. Estimates for this model's parameters are obtained through the application of the Ordinary Least Squares (OLS) estimator, as the error term $(u_{i,t})$ satisfies the exogeneity condition $\mathbb{E}(u_{i,t}|bps_{i,t}^{(0)}, eps_{i,t}^{(1)}, n_{i,t}, \hat{\theta}_{i,t}, IR_i) = 0$ regardless the equilibrium occurring $(\pi = 0, 1)$. While the OLS estimator provides unbiased and consistent point estimates for the regression's coefficients, the related standard errors could be invalidated by the presence of heteroscedasticity in the regression's error term, as $\epsilon_{i,t}^{(A)}$, which is included in $u_{i,t}$, was shown to be linear in $eps_{i,t}^{(1)}n_{i,t}$. For this reason, hypothesis testing is performed considering heteroscedasticity robust $(HC3)$ standard errors [147].

Consistent with Equation (15), a babbling equilibrium occurs if β_4 is not statistically different from zero. In case this hypothesis was rejected, the occurrence of a discretionary equilibrium could be accepted provided that the hypothesis $\beta_3 = \beta_4$ is not rejected. Thus, perfect verifiability requires the difference between β_3 and β_4 to be not statistically significant, provided both being statistically different from zero. As anticipated, estimation and, consequently, hypothesis testing, will be performed assuming β_3 and β_4 being sector specific.

As the treatment of the measurement error entailed additional statistical hypotheses, the robustness of results is assessed considering the possibility to exclude ϑ from the analysis $(\vartheta = 0)$, accepting a trade-off between a simpler empirical model and a potential omitted variable bias. In this case, the regression equation reads

$$p_{i,t}n_{i,t} = \beta_0 + (\alpha_0 + \beta_1\hat{\theta}_{i,t})\mathbb{I}(IR_i) + \left\{\beta_2 bps_{i,t}^{(0)} + \beta_3\frac{eps_{i,t}^{(1)}}{2} + \beta_4\mathbb{I}(IR_i)[\hat{\theta}_{i,t} - \tfrac{1}{2}]eps_{i,t}^{(1)}\right\}n_{i,t} + \epsilon_{i,t}^{(B)}, \quad (32)$$

having assumed that, in case of a discretionary equilibrium occurred, $\mathbb{E}(\epsilon_{i,t}^{(B)}|\theta = \hat{\theta}_{i,t})$ could be approximated as linear in $\hat{\theta}_{i,t}$. Results are presented and discussed in the next section.

5. Results

5.1. The Possibility of a Partition Equilibrium: Distributional Test for $\hat{\theta}$

Figure 1 plots the empirical distribution of $\hat{\theta}$ obtained for the sample of integrated reporters described in precedence, while the related summary statistics were already reported in Table 1 of Section 4.1. As it appears evident, values below 60% have not been observed. This observation is incompatible with the possibility of a partition equilibrium in our setting. Indeed, in such an equilibrium, the support of θ would be split into two different subsets, that is, $\left[0, \alpha_1 = \frac{1}{2} - \frac{2}{b}\right)$ and $\left[\alpha_1 = \frac{1}{2} - \frac{2}{b}, 1\right]$ (see Appendix A). Unless there would be no company in this study's sample with θ falling in the interval $[0,\alpha_1)$, a message m consistent with $\theta \in [0,\alpha_1)$ should be observed. Using the fact that θ is uniformly distributed, Table 5 shows for different values of b the related threshold $\alpha_1(b)$ and the probability that none of the 32 integrated reporters had $\theta < \alpha_1(b)$, which is equal to $(1 - \alpha_1)^{32}$. This probability could be equivalently interpreted as that of a partition equilibrium occurring in our sample (type I error).

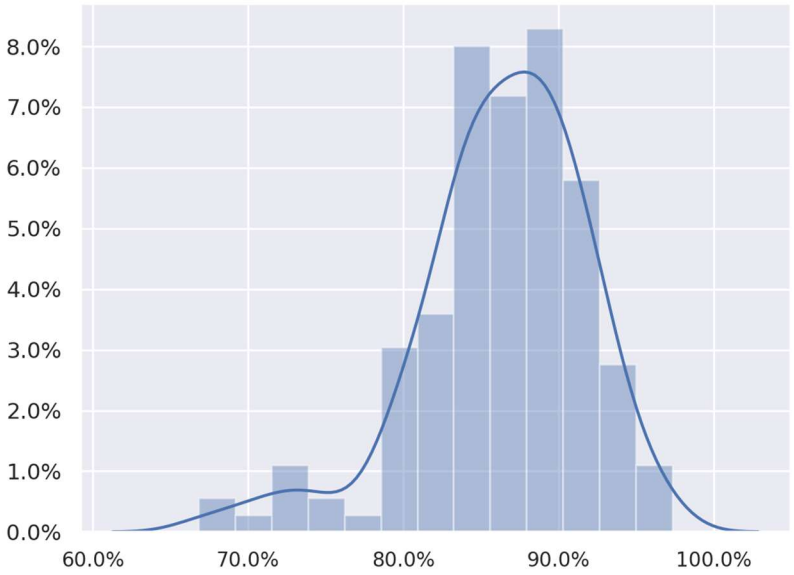

Figure 1. Empirical distribution of $\hat{\theta}$. *X*-axis: $\hat{\theta}$, *Y*-axis: % of $\hat{\theta}$ in each bin. Solid line: kernel density fitting.

Table 5. Probability that this paper's sample is drawn from a partition equilibrium.

b	α_1	Prob(min(θ_1,...,θ_{32})>α_1)
4	0.0%	0%
4.1	1.2%	67.5%
4.2	2.4%	46.2%
4.3	3.5%	32.1%
4.4	4.5%	22.6%
4.5	5.6%	16.1%
4.6	6.5%	11.6%
4.7	7.4%	8.4%
4.8	8.3%	6.2%
4.9	9.2%	4.6%
5	10.0%	3.4%
5.1	10.8%	2.6%
5.2	11.5%	2.0%
5.3	12.3%	1.5%
5.4	13.0%	1.2%
5.5	13.6%	0.9%

Conditional upon the null hypothesis of integrated reporting being cheap talk, for $\alpha_1 > 10\%$ $(b > 5)$, the probability that this study's sample is drawn from a partition equilibrium is less that 5%. Hence, unless b was close to the case in which only a babbling equilibrium exists $(b \leq 4)$, it would be definitely unlikely not to observe any message consistent with θ falling in the interval $[0, \alpha_1)$ if a partition equilibrium occurred.

In other words, a partition equilibrium could occur in this study's sample only if b was sufficiently close to the threshold below which only a babbling equilibrium exists. In a similar circumstance, the cut-off point α_1 would be extremely close to zero and for any practical purpose there would be basically no difference between a partition and a babbling equilibrium.

Nevertheless, the distribution of "messages" presented could be consistent with a discretionary equilibrium. Therefore, the preliminary conclusion of this study is that either a babbling or a discretionary equilibrium best represents sustainability disclosure through integrated reporting. The next Section is left to determine which of these two alternatives is indeed more plausible.

5.2. Testing for Babbling vs. Discretionary Equilibrium

For sake of completeness, a simple value-relevance regression is included in the analysis

$$p_{i,t}n_{i,t} = \beta_0 + \beta_1 \mathbb{I}(IR_i) + \left\{ \beta_2 bps_{i,t}^{(0)} + \beta_3 \frac{eps_{i,t}^{(1)}}{2} \right\} n_{i,t} + v_{i,t} \tag{33}$$

as a useful benchmark. Table 6 shows the result of estimating Equations (31)–(33) with OLS, considering HC3 robust standard errors in order to correctly infer the significance of the regressors involved. As it appears evident, prices tend to follow consensus earnings and, regardless measurement error is taken into consideration, β_4 is not statistically significant ($\pi = 0$) with exception of the utility sector. Hence, the babbling equilibrium hypothesis cannot be rejected for the Basic Materials, Industrial and Oil & Gas sectors.

Table 6. Results of OLS estimation.

		Equation (33)	Equation (31)	Equation (32)
Common Parameters	β_0	1.95 ***	2.06 ***	2.11 ***
	$\alpha_0 : \mathbb{I}(IR_i)$			−0.84
	$\beta_1 : \mathbb{I}(IR_i)\cdot\lambda(\hat{\theta}_{i,t})$		−0.46	
	$\beta_1 : \mathbb{I}(IR_i)\cdot\hat{\theta}_{i,t}$			0.42
	$\beta_2 : bps_{i,t}^{(0)}\cdot n_{i,t}$	0.60 ***	0.60 ***	0.60 ***
Basic Materials	$\beta_3 : eps_{i,t}^{(1)}\cdot n_{i,t}$	8.05 ***		
	$\beta_3 : 0.5\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		16.82 ***	16.22 ***
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		−1.43	
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\hat{\theta}_{i,t} - 0.5]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$			0.06
Industrials	$\beta_3 : eps_{i,t}^{(1)}\cdot n_{i,t}$	11.18 ***		
	$\beta_3 : 0.5\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		22.20 ***	22.17 ***
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		0.89	
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\hat{\theta}_{i,t} - 0.5]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$			1.65
Oil & Gas	$\beta_3 : eps_{i,t}^{(1)}\cdot n_{i,t}$	6.56 ***		
	$\beta_3 : 0.5\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		13.02 ***	13.04 ***
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		1.26	
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\hat{\theta}_{i,t} - 0.5]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$			2.79
Utilities	$\beta_3 : eps_{i,t}^{(1)}\cdot n_{i,t}$	6.78 ***		
	$\beta_3 : 0.5\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		11.05 ***	11.06 ***
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$		6.43 ***	
	$\beta_4 : \mathbb{I}(IR_i)\cdot[\hat{\theta}_{i,t} - 0.5]\cdot eps_{i,t}^{(1)}\cdot n_{i,t}$			6.59 ***
	R^2:	94.64%	94.74%	94.73%

Note: p-values are based on HC3 standard errors; *: p-value < 10%, **: p-value < 5%, ***: p-value < 1%.

For what concern Utilities, β_4 appears significantly different from β_3; the p-value for the test $\beta_3 = \beta_4$ is indeed equal to 1.4% for Equation (31) while to 2.7% for Equation (32) (Table 7 presents HC3 standard errors, covariance is equal to -0.53 and -0.67 respectively in Equations (31) and (32)).

Therefore, despite β_4 being significantly positive both in Equations (31) and (32), the alternative hypothesis that a discretionary equilibrium cannot be accepted.

Table 7. HC3 Standard Errors.

		Equation (33)	Equation (31)	Equation (32))
Common Parameters	β_0	0.12	0.12	0.12
	$\alpha_0 : \mathbb{I}(IR_i)$	0.24		0.6
	$\beta_1 : \mathbb{I}(IR_i) \cdot \lambda(\hat{\theta}_{i,t})$		0.38	
	$\beta_1 : \mathbb{I}(IR_i) \cdot \hat{\theta}_{i,t}$			0.82
	$\beta_2 : bps_{i,t}^{(0)} \cdot n_{i,t}$	0.04	0.04	0.04
Basic Materials	$\beta_3 : eps_{i,t}^{(1)} \cdot n_{i,t}$	0.35		
	$\beta_3 : 0.5 \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		0.79	0.83
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		1.14	
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\hat{\theta}_{i,t} - 0.5] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$			2.22
Industrials	$\beta_3 : eps_{i,t}^{(1)} \cdot n_{i,t}$	0.34		
	$\beta_3 : 0.5 \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		0.7	0.71
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		1.25	
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\hat{\theta}_{i,t} - 0.5] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$			1.67
Oil & Gas	$\beta_3 : eps_{i,t}^{(1)} \cdot n_{i,t}$	0.46		
	$\beta_3 : 0.5 \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		0.92	0.93
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		2	
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\hat{\theta}_{i,t} - 0.5] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$			2.62
Utilities	$\beta_3 : eps_{i,t}^{(1)} \cdot n_{i,t}$	0.6		
	$\beta_3 : 0.5 \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		1.13	1.15
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\psi(\hat{\theta}_{i,t}) + \hat{\theta}_{i,t}] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$		1.83	
	$\beta_4 : \mathbb{I}(IR_i) \cdot [\hat{\theta}_{i,t} - 0.5] \cdot eps_{i,t}^{(1)} \cdot n_{i,t}$			2.02

As a general remark, standard errors, despite being heteroscedasticity robust, are quite narrow (Table 7). It is worth noting that the intercept of the regression is approximately constant across different regression models and independent from the adoption of integrated reporting. Besides, despite being significantly positive, the impact of the intercept term (approx. 2 EUR millions) is extremely limited if compared to the average minimum size of the companies included in this study (3.5 Euro billions). This observation confirms the importance of properly modelling the impact of scale effects when introducing a constant term in value-relevance regressions.

This study concludes that sustainability disclosure trough integrated reporting does not appear to be value-relevant in most of the sectors considered, consistent with the hypothesis of a null or limited verifiability of the related information provided to investors. Sustainability disclosure has an impact on Utility companies' valuations, despite the observed effect is inconsistent with the theoretical one under the hypothesis of perfect verifiability (one half approximately). Besides, sustainability disclosure provides an infinitesimal improvement to the R^2 of a basic value-relevance regression (33), which is already close to 95% having properly introduced the presence of a common intercept. Based on these evidences, this study concludes that integrated reporting does not provide sufficient assurance to

consider sustainability disclosure verifiable and therefore value-relevant. In other words, sustainability disclosure through integrated reporting is a cheap talk resulting in a babbling equilibrium.

6. Conclusions

This study reviews different strategic accounting disclosure models in order to establish a precise link between the verifiability and the value-relevance of sustainability disclosure, with particular attention to the role of integrated reporting.

The theoretical framework presented suggests that in absence of a concrete assurance, sustainability disclosure should be value-irrelevant whenever managers largely benefit from the market value of their companies (e.g., stock-options, personal equity stakes). In the jargon of game-theory, this costless, unrestricted and non-verifiable communication is defined as cheap talk [2].

Models of cheap talk are more formally known as costless signaling games, and suggest that sustainability disclosure can be irrelevant to investors. For the same reason, this study started from the hypothesis that sustainability disclosure, in absence of integrated reporting, is in general non-verifiable, consistent with several studies in literature [86–92]. The model of cheap talk presented helps explaining why there are in reality only mixed evidences [93–101] in relation to the value-relevance of sustainability disclosure, which has been often empirically tested without reference to a specific theoretical framework supporting the identification of the key parameters involved.

Nevertheless, integrated reporting, having been only recently established, allows potentially for a verifiable sustainability disclosure, thanks to the continuous efforts of the IIRC to strengthen the quality of non-financial information. In this respect, this study has tested empirically whether integrated reporting is a cheap talk, considering both the possibilities of a partition and babbling equilibrium, or a discretionary equilibrium. In the case of a partition or discretionary equilibrium, sustainability disclosure should affect equity valuations, while in the case of a babbling equilibrium it should not. The main difference between a partition equilibrium and a discretionary equilibrium model lies in the type of messages disclosed. Discretionary equilibria tend to favor the issuance of "positive" messages only, while partition equilibria necessary include the possibility to observe "negative" messages.

In order to test empirically which equilibrium describes better what occurs in reality, this paper makes use of a systematic textual analysis of integrated reports in order to build a synthetic measure of sustainability disclosure $(\hat{\theta})$ that can be put in relation with the theoretical equilibrium disclosure policies (i.e., the managers' messages).

Based on the empirical evidences collected, this study concludes that a partition equilibrium is unlikely to fit the distribution of $\hat{\theta}$. For the same reason, the null hypothesis $(\mathbb{H}_0)$ of a babbling equilibrium is tested against the alternative $(\mathbb{H}_1)$ of a discretionary equilibrium through a value-relevance regression consistent with the theoretical framework introduced in this paper. The results of this analysis suggest that sustainability disclosure through integrated reporting is not value relevant. With the exception of Utility companies, the regression coefficient associated to $\hat{\theta}$ does not appear significantly different from zero at any reasonable confidence level.

For what concerns Utilities, sustainability disclosure $(\hat{\theta})$ positively affects valuations, with large degree of confidence. However, the size of this effect is different from what should be observed in case a discretionary equilibrium occurred, that is, whenever sustainability disclosure could be considered as perfectly verifiable.

This study concludes that integrated reporting, despite the efforts made by the IIRC, does not provide the means for a verifiable disclosure of corporate sustainability. In this sense, integrated reporting is mostly a cheap talk. This finding is consistent with Melloni's evidence [148] that integrated reporting is often associated to poor social and environmental performances, being it a practice of impression management. Nevertheless, it should be noticed that there are also different positions in literature. For instance, Baboukardos and Rimmel [40], considering a sample of companies listed on the

South African stock market, provided some evidences supporting the hypothesis that the mandatory adoption of integrated reporting (King III reform) has increased equity valuations.

Finally, several policy and research implications could be drawn from the results of this work. Starting from the latter, this paper shows that assessing the value-relevance of sustainability disclosure requires a formal theory to be tested. Otherwise, regression analysis could be designed arbitrary with the chance of incurring empirical issues, such as endogenous selection and measurement errors, invalidating the related estimates and hypothesis testing. Thus, researchers should devote a greater share of their time to formalizing the disclosure theory that they would like to test on actual data, before proceeding with any further statistical or econometric analysis. This consideration is reminiscent of that made by Bertomeu [149] in relation to the use of empirical models in accounting research: empirical assumptions should be always stated explicitly and put in relation with the theory to be tested, with particular attention to the difference between the theoretical parameters of the model (e.g., the theoretical message, m) and the empirical metrics adopted (e.g., the proxy message $\hat{\theta}$).

The results of this paper provide also useful insights for policy makers. Generally speaking, the fact that sustainability disclosure through integrated reporting appears to be value-irrelevant suggests a lack of verifiability, resulting in overly optimistic disclosure. The sustainability of the economic performances is a prominent tail-risk factor in many sectors, and, for the same reason, any truthful information in relation to this matter would be valuable to investors. Hence, value-irrelevance stems from the lack of tight reporting standards and, consequently, of the related assurance.

Nevertheless, tighter reporting standards could be insufficient if not enforceable. In this respect, the recent attention of the European authorities to the quality of non-financial disclosure (Directive 2014/95/EU) supports this study's claim for a stronger enforcement of non-financial disclosure's standards. Besides, the word standard presumes the universal adoption of the same principles. For what concerns sustainability disclosure, the presence of different reporting frameworks, such as the IIRC's integrated reporting or the SASB's standards, introduces a further layer of complexity for regulators. Going forward, investors would benefit from common principles in relation to sustainability disclosure. Only in this way, regulators could enforce the compliance of sustainability disclosure thanks to commonly agreed reporting standards, preventing cheap talks.

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Appendix A.

This appendix presents a simplified proof of the results contained in Crawford and Sobel (1982), with specific reference to the model adopted in the context of this present study.

Define $\delta(\theta, \alpha_i) := U(\theta, m|\theta \in [\alpha_i, \alpha_{i+1}), b) - U(\theta, m|\theta \in [\alpha_{i-1}, \alpha_i), b)$. Optimality of sender's strategy requires that $\delta(\theta, \alpha_i) \geq 0$ for $\theta \in [\alpha_i, \alpha_{i+1})$ and $\delta(\theta, \alpha_i) < 0$ for $\theta \in [\alpha_{i-1}, \alpha_i)$. Because U is continuous in θ, the intermediate value theorem implies that $\delta(\theta, \alpha_i)$ must be zero at each cut-off point α_i. Otherwise, there would be a positive real number ε such that either $\delta < 0$ for $\theta \in [\alpha_i, \alpha_i + \varepsilon)$ or $\delta > 0$ for $\theta \in [\alpha_i - \varepsilon, \alpha_i)$. In both cases, the strategy of the sender would not be optimal. Therefore, at each cut-off point the sender must be indifferent between reporting $\theta \in [\alpha_i, \alpha_{i+1})$ or $\theta \in [\alpha_{i-1}, \alpha_i)$, that is,

$$U(\theta, m|\theta \in [\alpha_i, \alpha_{i+1}), b) = U(\theta, m|\theta \in [\alpha_{i-1}, \alpha_i), b). \tag{A1}$$

This claim can be alternatively proved by direct inspection. With few algebraic steps, it is immediate to show that $\delta(\theta, \alpha_i) = \delta(\alpha_i, \alpha_i) + b\mu\frac{\alpha_{i+1}-\alpha_i}{2}[\theta - \alpha_i]$. Suppose by contradiction that $\delta(\alpha_i, \alpha_i) < 0$; for every $\theta \in [\alpha_i, \alpha_i - \frac{2\cdot\delta(\alpha_i,\alpha_i)}{b\mu(\alpha_{i+1}-\alpha_i)})$ it follows that $\delta(\theta, \alpha_i)$ is negative, that is, $m|\theta \in [\alpha_{i-1}, \alpha_i)$ is strictly preferred to $m|\theta \in [\alpha_i, \alpha_{i+1})$, contradicting the hypothesis of optimality of the sender's strategy. Similarly, suppose by contradiction that $\delta(\alpha_i, \alpha_i) > 0$; for every $\theta \in$

$[\alpha_i - \frac{2\cdot\delta(\alpha_i,\alpha_i)}{b\mu(\alpha_{i+1}-\alpha_i)},\alpha_i)$ it follows that $\delta(\theta,\alpha_i)$ is positive, that is, $m|\theta \in [\alpha_i,\alpha_{i+1})$ is strictly preferred to $m|\theta \in [\alpha_{i-1},\alpha_i)$, contradicting the hypothesis of optimality of the sender's strategy. Conversely, if $\delta(\alpha_i,\alpha_i)=0$, then $\delta(\alpha_i,\alpha_i)<0$ for every $\theta<\alpha_i$ and $\delta(\alpha_i,\alpha_i)>0$ for every $\theta>\alpha_i$, consistent with the optimality of the sender's strategy.

Equation (A1) is known as "indifference" or "non-arbitrage" condition and, as shown, it is necessary in order to ensure the optimality of sender's sender partition strategy. Nonetheless, since δ is strictly monotone increasing in θ, this condition is also sufficient. The proof of this claim starts with noting that

$$\frac{\partial\delta(\theta,\alpha_i)}{\partial\theta} = -\frac{b\mu}{2}\frac{\partial}{\partial\theta}\left\{\left[\theta-\frac{\alpha_i+\alpha_{i+1}}{2}\right]^2-\left[\theta-\frac{\alpha_{i-1}+\alpha_i}{2}\right]^2\right\}, \tag{A2}$$

that is,

$$\frac{\partial\delta(\theta,\alpha_i)}{\partial\theta} = b\mu\frac{\alpha_{i+1}-\alpha_i}{2}, \tag{A3}$$

Since $\alpha_{i+1}>\alpha_i$, it follows that δ is indeed strictly monotone increasing over the support of θ. Hence, it is possible to write

$$\begin{cases} U(\theta,m|\theta\in[\alpha_i,\alpha_{i+1}),b) \geq U(\theta,m|\theta\in[\alpha_{i-1},\alpha_i),b),\ \theta\geq\alpha_i \\ U(\theta,m|\theta\in[\alpha_{i-1},\alpha_i),b) > U(\theta,m|\theta\in[\alpha_{i-2},\alpha_{i-1}),b),\ \theta>\alpha_{i-1} \end{cases}, \tag{A4}$$

which implies that

$$U(\theta,m|\theta\in[\alpha_i,\alpha_{i+1}),b) > U(\theta,m|\theta\in[\alpha_{i-2},\alpha_{i-1}),b), \tag{A5}$$

for $\theta\geq\alpha_i$. Proceeding recursively, it is immediate to conclude that for every $k>0$ and $\theta\geq\alpha_i$ it results,

$$U(\theta,m|\theta\in[\alpha_i,\alpha_{i+1}),b) > U(\theta,m|\theta\in[\alpha_{i-k-1},\alpha_{i-k}),b). \tag{A6}$$

Hence, whenever $\theta\in[\alpha_i,\alpha_{i+1})$, pretending $\theta\in[\alpha_{i-k-1},\alpha_{i-k})$ is never preferred to truthfully report $m|\theta\in[\alpha_i,\alpha_{i+1})$ Similarly, it is possible to write

$$\begin{cases} U(\theta,m|\theta\in[\alpha_i,\alpha_{i+1}),b) > U(\theta,m|\theta\in[\alpha_{i+1},\alpha_{i+2}),b), & \theta<\alpha_{i+1} \\ U(\theta,m|\theta\in[\alpha_{i+1},\alpha_{i+2}),b) > U(\theta,m|\theta\in[\alpha_{i+2},\alpha_{i+3}),b), & \theta<\alpha_{i+2} \end{cases}, \tag{A7}$$

which implies that

$$U(\theta,m|\theta\in[\alpha_i,\alpha_{i+1}),b) > U(\theta,m|\theta\in[\alpha_{i+2},\alpha_{i+3}),b) \tag{A8}$$

A recursive application of the previous inequality leads to the conclusion that for every $k>0$ and $\theta\geq\alpha_i$,

$$U(\theta,m|\theta\in[\alpha_i,\alpha_{i+1}),b) > U(\theta,m|\theta\in[\alpha_{i+k-1},\alpha_{i-k}),b) \tag{A9}$$

Thus, combining conditions (A6) and (A9), the non-arbitrage condition (A1) results also sufficient in order to ensure the optimality of sender's strategy.

In order to establish the existence of a non-degenerated partition equilibrium (i.e., $K=1$), recall first that at each cut-off point α_i the indifference condition (Equation (A1)) must be satisfied, that is,

$$\frac{\alpha_i+\alpha_{i+1}}{2}\mu - \frac{b\mu}{2}\left[\alpha_i-\frac{\alpha_i+\alpha_{i+1}}{2}\right]^2 = \frac{\alpha_{i-1}+\alpha_i}{2}\mu - \frac{b}{2}\left[\alpha_i-\frac{\alpha_{i-1}+\alpha_i}{2}\right]^2. \tag{A10}$$

Rearranging the previous expression yields,

$$\frac{\alpha_i+\alpha_{i+1}}{2} - \frac{b}{2}\left[\alpha_i-\frac{\alpha_i+\alpha_{i+1}}{2}\right]^2 = \frac{\alpha_{i-1}+\alpha_i}{2} - \frac{b}{2}\left[\alpha_i-\frac{\alpha_{i-1}+\alpha_i}{2}\right]^2,$$

$$\frac{\alpha_i + \alpha_{i+1}}{2} - \frac{\alpha_{i-1} + \alpha_i}{2} = \frac{b}{2}\left[\frac{\alpha_i - \alpha_{i+1}}{2}\right]^2 - \frac{b}{2}\left[\frac{\alpha_i - \alpha_{i-1}}{2}\right]^2,$$

$$\frac{\alpha_{i+1} - \alpha_i}{2} - \frac{\alpha_i - \alpha_{i-1}}{2} = \frac{b}{2}\left[\frac{\alpha_i - \alpha_{i+1}}{2} + \frac{\alpha_i - \alpha_{i-1}}{2}\right]\left[\frac{\alpha_i - \alpha_{i+1}}{2} - \frac{\alpha_i - \alpha_{i-1}}{2}\right],$$

$$1 = -\frac{b}{2}\left(\frac{\alpha_i - \alpha_{i+1}}{2} + \frac{\alpha_i - \alpha_{i-1}}{2}\right), \tag{A11}$$

that is,

$$\alpha_{i+1} = 2\alpha_i - \alpha_{i-1} + \frac{4}{b}. \tag{A12}$$

By definition, the union of the intervals in the partition must be equivalent to the support of θ, which is the interval $[0,1]$. Thus, every partition equilibrium of size $K > 1$ must satisfy the condition

$$\sum_{i=0}^{K-1} \alpha_{i+1} - \alpha_i = 1 \tag{A13}$$

Using the fact that, in equilibrium, $\alpha_{i+1} = 2\alpha_i - \alpha_{i-1} + \frac{4}{b}$, it is possible to write

$$\alpha_{i+1} - \alpha_i = \alpha_i - \alpha_{i-1} + \frac{4}{b}. \tag{A14}$$

Substituting the previous expression in Equation (A13), the following equation is obtained

$$\sum_{i=0}^{K-1} \alpha_{i+1} - \alpha_i = K\alpha_1 + \frac{4}{b}\sum_{i=0}^{K-1} i = 1, \tag{A15}$$

which is equivalent to,

$$K\alpha_1 + \frac{2}{b}K(K-1) = 1. \tag{A16}$$

Provided there exists $\alpha_1 \in (0,1)$ satisfying Equation (A16) above, the difference Equation (A14) admits a unique solution consistent with the boundary conditions $\alpha_1 = 0$ and $\alpha_K = 1$. In this sense, every equilibrium of size K is unique, although the set of messages supporting the elements of the partition played in equilibrium could be infinite (each message must be consistent with the element of the partition that is being truthfully reported in equilibrium, and for each element of the partition there are infinite messages supporting it).

Finally, the existence of a non-degenerated partition equilibrium requires there exists $\alpha_1 \in (0,1)$ such that Equation (A16) is satisfied at least for $K = 2$. Evaluating Equation (A16) at $K = 2$ immediately suggests that a sized-2 partition equilibrium exists if and only if $b > 4$.

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