



Article

Relationship between Entropy, Corporate Entrepreneurship and Organizational Capabilities in Romanian Medium Sized Enterprises

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Abstract: This paper analyses the relations between entropy, organizational capabilities and corporate entrepreneurship. The results indicate strong links between strategy and corporate entrepreneurship, moderated by the organizational capabilities. We find that companies with strong organizational capabilities, using a systematic strategic approach, widely use corporate entrepreneurship as an instrument to fulfil their objectives. Our study contributes to the limited amount of empirical research on entropy in an organization setting by highlighting the boundary conditions of the impact by examining the moderating effect of firms' organizational capabilities and also to the development of Econophysics as a fast growing area of interdisciplinary sciences.

Keywords: entropy; strategy; organizational capabilities; corporate entrepreneurship

1. Introduction

Changes and transformations of social–economic systems in this era are rooted in science and technology progress and changes [1]. Now days, the survival of organizations requires finding solutions and new ways of dealing with problems which very dependent on innovation, invention, creation of products, processes, and new managerial methods. What has become increasingly apparent to researchers is that when pursuing new opportunities with limited resources, the entrepreneur must use innovative approaches in the face of these uncertainties [2]. In a recent study, Hills et al. found that companies with entrepreneurial orientation display a different strategic orientation, commitment to opportunities and threats [3]. These companies tend to rely on experience, immersion and intuition.

Entropy is a basic concept in physical science. In information theory entropy represents the uncertainty arising from the content of a message. In other words, entropy is an index to measure the uncertainty that is expressed by a probability distribution [4]. Recent studies [5–7] link entropy with economic activities. These studies have shifted the attention from one way analysis to a multidisciplinary approach based on Econophysics [8]. In this respect, we consider that our article is one of the first who try to link entropy, entrepreneurship and organizational capabilities.

In our paper, we attempt to explore the moderating effect of entropy on the relationship between organizational capabilities and corporate entrepreneurship responses to changes in company's environment system. In an attempt to improve our understanding of this issue, this article makes several contributions to the field. First, our findings refine earlier results [9,10] by suggesting that entropy requires adequate organizational capabilities in order to fully appreciate the effects on corporate entrepreneurship. Although [11] finds that entropy encourages organizational actions with increased novelty and risk, our results demonstrate that the lack of required organizational capabilities may suppress, in some conditions, potential entrepreneurial activities and push organizations to rely on existing practices and routines. Second, our study offers a theoretical and pragmatic

framework that incorporates the processes involved with entropy in corporate entrepreneurship and organizational capabilities.

The above linkages between entropy and organizational novel actions as theorized by [8] rely on the implicit assumption that effortful distant search provides organizations with a repertoire of novel solutions. However, this assumption may be problematic, as organizations differ in their capabilities to search for new information and process such information to deal with environmental changes. Several studies [12–14] maintains that organizational characteristics such as rules, programs, vertical information systems, and lateral relations, represent the information-processing capacities in the gathering of data and the transformation of data into information, and that organizations differ in their design features and information-processing capacities. The differentiated information-processing capacities suggest that organizations may vary in their abilities to cope with information requirements brought by firm's environment. Although interpretations of environmental issues tend to trigger distant search, the effectiveness of the search and the resulting pursuit of novel actions rely on whether organizations possess the appropriate information-processing capacities to identify new approaches. Thus, we argue the importance of not only examining entropy on corporate entrepreneurship but also including relevant capabilities such as information—processing type capacities.

The novelty and relevance of our paper related to the field consist in the fact that, as far as we know, it is one of the first articles that tries to create a link between entropy and entrepreneurial and managerial concepts. Using a comprehensive literature review, we develop a personal approach regarding concepts from physics, entrepreneurship and management sciences.

2. Literature Review

2.1. Entropy and Entrepreneurial Environment

A long-time focus within the strategy field has been on how executives interpret changes in the organizational environment [15,16]. Strategic issues refer to events that have a potential impact on the organization's managerial and economic performance [17,18]. A dominant framework in the strategic issue diagnosis literature is the threat-opportunity framework [16], which proposes that executives tend to categorize strategic issues as either threat or opportunity, and such categorizations incur different decision-making processes and organizational actions. Such interpretations have been found to affect various organizational actions [9,19].

In strategy and organization science, entropy has only started to receive researchers' attention very recently, especially regarding its role with organizational responsiveness and adaptation to the environment [20–22]. However, even the limited amount of literature has been inconsistent about the connections between entropy and organizational responsiveness [23]. On the one hand, [9] appears to propose that although entropy exists within corporate executives, organizational actions only relate to specific threat or opportunity interpretations at the subunit level.

The systemic approach to corporate entrepreneurship is necessarily reflected in the consideration of the interface with the environment involved [24]. The starting point in this approach is knowledge and understanding of the concept of a firm environment. It can be defined as the company's exogenous elements of economic, managerial, demographic, cultural, scientific, psycho-sociological, educational, ecological, political and legal significance, which significantly mark the performance and the results of its activities [25].

The contemporary entrepreneurial environment presents simultaneously some features [26,27]: contextual turbulence, represented by numerous, rapid and unexpected changes, the rapid evolution of business opportunities and increasing uncertainties, which are a result of many changes that cannot be anticipated and quantified with sufficient precision. Among the main causes of uncertainty, the most frequently mentioned are changing market structures, technological relations and interdependencies between resources which influence greatly organizational strategies and policies.

The entrepreneurial environment is composed of two different types: real and perceived [28]. The real entrepreneurial environment designates all the contextual elements that influence corporate entrepreneurship in all phases of its work, inducing changes in its decisions, actions and behaviours [28]. The perceived entrepreneurial environment designates those elements of the real entrepreneurial environment that a corporate entrepreneur considers as having a significant influence on his actions and performance. The more elements of the real entrepreneurial environment are perceived and taken into account, the more the corporate entrepreneur's decisions, actions and behaviours are more complete and thoroughly substantiated, with natural positive effects in the performance of the respective firm.

The entrepreneurial environment marks the corporate entrepreneur's activities on multiple levels, being an interdependent relationship [26,29]. Corporate entrepreneurs are constantly adapting to the entrepreneurial environment, which ensures their economic survival. Moreover, most corporate entrepreneurs shape the entrepreneurial environment, often based on the principle of learning by doing. This means that corporate entrepreneurs learn from experience, based on mistakes and successes, respectively, by improving their decision-making and acting, so that their influence on the environment is amplified [30].

2.2. Concept of SMEs

There are a number of approaches to the concept of small and medium sized enterprises (SMEs), which start from somewhat different concepts of the terms [31–33]. For pragmatic reasons, in the last years a prevailing tendency has emerged for defining SMEs according to the number of employees, regardless of the field of activity. This approach has been generalized by the European Union in Recommendation 2003/361 and the European Union (EU) new SME definition from 2005. In this paper we use EU definition of SMEs. Undoubtedly, expressing the size of an enterprise by a single indicator, the number of employees, is not rigorous enough, because with the same number of employees due to the sometimes substantial differences in terms of activity profile, technical endowment, management etc., the other dimensional elements of the organization, and primarily those of an economic nature, turnover, social capital, profit, may be sensitively different. The great advantages of using the employee criterion lies in the ease of expressing its size and understanding, avoiding the apparent change in the size of the firm under the impact of economic factors, especially inflation and exchange rate and comparability of the size of firms, even if they are from different countries or branches.

2.3. Corporate Entrepreneurship

There are an appreciable number of papers on corporate entrepreneurship, though not many compared to other areas of economic theory and practice, in which many of its issues are addressed in sensitively different ways [26,34]. Starting from some of these papers, we consider that corporate entrepreneurship consists in the development of certain autonomous entrepreneurial activities within an existing company, usually of large or medium size, by some of its employees, using some of the technical resources, which are not utilize properly. More specifically, corporate entrepreneurship consists in the establishment of one or more autonomous entrepreneurial nucleus within existing companies, which performs activities with a high innovative character, capitalizing niches or market opportunities. The emergence of corporate entrepreneurship came as a result of major changes on economic system [35]. The conditions of corporate entrepreneurship development were: (a) the rapid increase in the number of large and medium-sized enterprises, together with the complexity and diversity of their incorporated activities; (b) the low rates of capitalization of the resources of many large and medium-sized companies, especially in technical and human resource areas; (c) the partial change of the content of the organizations, reflected in the strategic vision on the evolution of the organization, the flexibility of the operational approaches, the emphasis on fast and efficient innovation, the complex motivation of the employees and the primacy of the firms competitiveness.

Naturally, corporate entrepreneurship is operationalized by corporate entrepreneurs. A corporate entrepreneur differs from a classic entrepreneur through several elements: he undertakes a lower degree of risk due to the manifestation of the entrepreneurial approach within a large or medium sized firm that offers resources that a normal entrepreneur does not benefit from; time constraints are lower due to access to company resources; corporate entrepreneur is more disciplined, more rigorous in decisions and actions due to written and unwritten rules of a large or medium company. In addition to these elements, we add another one that we consider to be very important, the corporate entrepreneurs obtaining significantly lower incomes than entrepreneurs, under the conditions of similar projects. This distinction explains to a great extent why most people with an exceptional entrepreneurial spirit use it through independent entrepreneurial approaches.

3. Model and Hypotheses

The limitations of current conceptualizations of entropy in strategy and management lead us to introduce a heuristic systematic model and apply it to the analysis of entropy in the organizational setting [36–38]. This model proposes that conflicting interpretations of environment information motivate executives to engage in information searches, and they may co-occur and exert independent, additive, or interactive effects on judgment, with individuals' motivation and ability deciding which mode is more dominant (See Figure 1). Following the model, we propose that executives engage in heuristic or systematic information searches based on their level of knowledge of organizational capabilities, which subsequently influence corporate entrepreneurship. Below we argue that environment and decision complexity associated with corporate entrepreneurship will motivate executives towards the systematic mode, and organizational capabilities will be an important moderator. Here we stress organizational capabilities rather than individual abilities because executives, as opposed to people in an individual setting, have access to and often rely on organizational resources to collect and process information for them [39].

The heuristic mode is the less effortful, and executives will tend to simplify the decision making process due to limited information processing capabilities [36]. People do not actively evaluate the information, but use experience, schemas, and other rules of thumb to interpret the situation and make their judgment. Thus, using such heuristics reduces cognitive effort, ignores other information, and makes frugal and quick decisions. As the heuristic mode tends to rely on extant schemas and action repertoires, it may constrain available coping options and decrease the possibility of corporate entrepreneurship activities, which require innovative and far-reaching thinking. Therefore, this approach will yield less creativity and simpler strategies which would be negatively related to more complex strategies such corporate entrepreneurship [36].

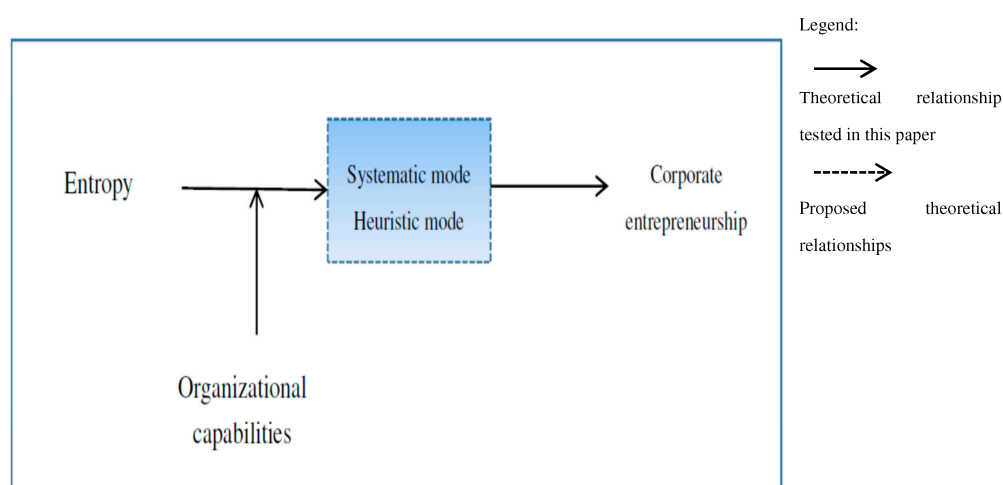


Figure 1. The theoretical model.

In contrast, the systematic mode is more effortful, and is characterized as a “comprehensive, analytic orientation in which perceivers access all informational input for its relevance and importance to their judgmental task” [36]. Executives actively scrutinize the information, examine the content, evaluate alternative interpretations, and finally reach a deliberately-formed decision. As the systematic mode is more effortful, executives must possess sufficient cognitive capacity to engage in systematic information processing. The process of gathering, interpreting and discussing information is much more exhaustive than the heuristic approach. These characteristics of the systematic mode separate the systematic mode from the heuristic one regarding their associations with corporate entrepreneurship. Different from the heuristic mode, the systematic mode enables executives to be more exposed to information from inside and outside the medium size company through extensive scanning of the environment; such information exposure is likely to increase executives’ receptiveness and alertness to entrepreneurial opportunities by seeing new connections between independent events [40,41]; finally, the systematic mode may also help executives to overcome feelings of doubt and increase their confidence of corporate entrepreneurship opportunities through careful assessment of multiple perspectives.

Hypothesis 1. *Entropy will have a positive relationship with corporate entrepreneurship. This hypothesis is similar to the findings of [34] that executives’ interpretations are positively associated with the riskiness and novelty of organizational actions, as corporate entrepreneurship is often risky and involves new activities.*

When executives are reluctant about strategic issues, the perceived complexity may motivate them to search for information, with heuristic processing modes initiated. Executives tend to rely on extant schemas and reduce their corporate entrepreneurship. Many factors will contribute to the cognitive effort and complexity decision making process [42], but environmental conditions, decision complexity, and organizational internal characteristics are the most important contingent factors [13]. Here we focus on the influence of environmental conditions and decision complexity, and discuss the impact of organizational internal factors in the next section.

Environmental characteristics will influence the information process. In a more certain environment, executives may have a clear perspective and confidence on the interpretation of the environment through their past experience [43]. They can rely on their past rules and mainly apply the heuristic mode in their decision making process. In a more uncertain environment, executives will be motivated to engage in increasingly complex processes, as past experience does not give enough schemas to act upon. Deciding which opportunities to pursue in spite of some doubt about either the feasibility of the opportunities or the impact on organizational performance places a huge demand on executives to acquire information, develop and assess alternatives, and mobilize organizational resources to take appropriate actions [44].

Hypothesis 2. *Executives’ entropy interacts with companies’ organizational capabilities to affect corporate entrepreneurship such that when organizational capabilities are weak, entropy and corporate entrepreneurship will have an inverted-U shaped relationship.*

Although executives’ entropy tends to enhance the systematic mode and leads to corporate entrepreneurship, organizational factors may also influence which modes gain favour with executives. Specifically, organizations must have the abilities to engage in such decision making processes [43]. We argue that organizational capabilities interact with executives’ entropy to influence both modes of information processing. When companies have strong capabilities, executives would be primarily in the systematic mode and thus would be able to exert great influence due to stronger available capabilities to seek, absorb, analyse, and interpret events, trends, and information inside and outside the company. In contrast, when companies’ capabilities are weak, the low information processing ability may reduce executives’ inclination to engage in the systematic mode but also their confidence level with corporate entrepreneurship.

4. Methods

4.1. Data and Sample

We tested the hypotheses with two waves of survey data, to eliminate common method bias and reduce the possibility of reverse causality. The first wave asked about respondents' perceptions of change, the independent and control variables, and the background information of the medium size company, and the second wave focused on the actions of the companies as responses to change. In our research we consider "executive" any senior manager on a medium/large company who act as an entrepreneur on a certain area of interest for the company (business unit, project etc.). Literature regarding corporate entrepreneurship calls this type of employee as an "intrapreneur" [45–47], but in our research we prefer to name him "executive". We conducted a pilot study with 32 master students from Entrepreneurship Master Programme at Bucharest University of Economic Studies- Faculty of Management, and we made minor wording changes after the pre-test to enhance the clarity.

We initially selected a random sample of 731 medium size companies (50–249 employees) from Bucharest provided by the National Trade Register Office. During the 1st wave of data collection, conducted during the winter of 2016, we sent three rounds of mails to entrepreneurs/executives of the companies, and trained interviewers (students from Entrepreneurship Master Programme) to make multiple follow-ups with them to conduct structured interviews based on the questionnaire. The first wave resulted in a sample of 291 usable questionnaires, representing a response rate of 39.8%. We conducted the 2nd wave of the survey in the springtime of 2017 on the same 291 entrepreneurs/executives using the same procedure applied in the 1st wave of data collection. We received 197 usable questionnaires. As 31 entrepreneurs/executives among the 197 respondents in the 2nd wave reported that their companies had not taken any specific actions to cope with the change, we removed these 31 companies and retained the remaining 166 companies as the final sample, for an effective response rate of 22.7%. On average, 78% of them were established after 1995 and hired 53 employees. International joint ventures or wholly-owned foreign subsidiaries accounted for 14.48%, and 85.52% were domestic private companies. Some companies which reported low levels of corporate entrepreneurship activities may have not taken any actions in response to the change. As we have the action variable in the 2nd survey, we use the action dummy (1 = Yes and 0 = No as answers to whether their companies have taken actions specifically to cope with the change) as a screening variable to separate companies with actions from those without any action.

A potential threat to research quality is sample selection bias. We compared responding and non-responding companies in both waves, and the *t*-tests demonstrated no significant differences in company size and age. Another comparison between the 291-company sample and the 166-company sample based on *t*-tests on the interpretations of the change showed no significant difference between the two groups on interpretations. Second, it is likely that some non-responding companies failed during the change. The non-significance of the company age control variable in our regression analyses suggests that a survivor bias is unlikely to have biased our results [48]. Finally, complex data relationships such as the expected interaction effects suggest that common method bias should not have led to the significant findings of interaction effects, as quadratic and interaction effects can be severely deflated through common method variance and would be more difficult to detect if common method bias existed [49]. Respondents would normally not be capable of guessing the interaction hypothesis [43]. These analyses suggest that common method bias is unlikely to have led to the significant findings and that non-response bias is not a significant concern.

4.2. Measurement

We measure all construct using a 10-point Likert scale. The measurement items and their validity assessment appear in the appendixes (see Appendixes A,B). Among all the variables, corporate entrepreneurship is included in the 2nd survey, and all the other variables are included in the 1st survey.

Therefore, we calculate entropy using our own formula:

$$\text{Entropy} = \text{Intensity} - \text{Similarity} \quad (1)$$

$$\text{Intensity} = (\text{Real entrepreneurial environment} + \text{Perceived entrepreneurial environment})/2 \quad (2)$$

$$\text{Similarity} = \text{Abs} (\text{Real entrepreneurial environment} - \text{Perceived entrepreneurial environment}) \quad (3)$$

where Abs refers to the absolute value.

In our paper we consider that the overall entropy score comprises two parts. The first part denotes the intensity of the two environments, calculated as the mean of the two interpretations; and the second part refers to the similarity of the two types of environment, based on the absolute difference between the two entrepreneurial environments. We consider that operationalization of entropy has three desirable characteristics. First, with the larger of the real and perceived environments held constant, entropy increases as the smaller one increases and reaches the maximum when the two are equal. Second, as the two interpretations move apart further (i.e., more polarization), entropy decreases. Third, when the two interpretations are equal, entropy increases with the two. We measure the degree of real environment using six items, considering them as opportunities and perceived environment by four items, considering them as threats for interpretation of change with items adapted from [26]. We eliminate one item for real environment because of a low factor loading.

4.3. Dependent Variable

We used [34] a 14-item scale to measure the three dimensions of corporate entrepreneurship, including innovation (five items), venturing (five items), and strategic renewal (four items). We asked respondents to evaluate to what extent their companies have conducted these activities as responses to change. We eliminated four items because of low loadings, and kept four items for innovation, and three items each for venturing and strategic renewal. Confirmatory factor analysis (CFA) reveals that a higher-order corporate entrepreneurship factor explains the common variance among the three dimensions ($\chi^2(32) = 51.40$, $p < 0.001$, CFI = 0.95, RMSEA = 0.05). All factor loadings are highly significant ($p < 0.001$) and above the usual 0.70 benchmark except one item (0.64). We aggregate over the three dimensions for an overall corporate entrepreneurship score (Appendix A).

4.4. Independent and Control Variables

Organizational capabilities, we use the three items in [21] to measure it. The three items are used to assess companies' managerial, technological and marketing capabilities.

Financial slack and human resource (HR) slack, organizations need slack resources to take actions. We adapt the measures in [48], with two items for financial slack and two for HR slack.

Environmental uncertainty is likely to affect organizational responses. We measured environmental uncertainty with two items from [50]. This construct includes competitive uncertainty, general uncertainty, technological uncertainty, and potential for future growth and profits. The two items in our research are selected from those related to perceived general uncertainty.

Entrepreneurial orientation, corporate entrepreneurship activities regarding change may be caused by the entrepreneurial strategic orientation of an organization which embodies the pursuit of entrepreneurial activities in its culture, decision-making processes, and organizational practices. To control the dispositional propensity of organizations involving in corporate entrepreneurship activities, we include entrepreneurial orientation with nine items from [51].

Other control variables include entrepreneur experience in the company, entrepreneur age, entrepreneur gender, entrepreneur functional background, company age, company size, ownership, location and industry. We measure entrepreneur experience in the company as the number of years entrepreneurs have worked in their company [52]. Entrepreneur gender is a dummy variable, with 1 indicating female and 0 for male [53]. Entrepreneur functional background is a dummy variable,

with 1 indicating that entrepreneurs having a background mainly in the backend and 0 referring to entrepreneurs with a background in the customer end [54]. We measured company age as the logarithm of the number of years of operation by the company and company size as the logarithm of the number of employees [55,56]. We apply the industry categorization method used by National Bureau of Statistics of Romania and include six dummy variables to refer to six industries, namely manufacturing, transportation and warehousing, information service and software, finance, real estate, and scientific research and technological service, with the rest combined as the comparison group. We also include ownership as a control variable. There is only a small percentage of international joint ventures and wholly-owned joint ventures, so we measure company ownership with a dummy variable, where 1 = one owner and 0 = two or more owners.

4.5. Construct Validity

We assessed construct validity of our measures by running two confirmatory factor analyses with structural equation modelling, one on corporate entrepreneurship and the other on the rest of the multi-item measures (Appendix B). The results demonstrated that the model fits the data satisfactorily ($\chi^2(304) = 527.80$, $p < 0.001$, CFI = 0.93, RMSEA = 0.06). All indicators load significantly on the corresponding latent constructs, and all factor loadings are highly significant, with the lowest at the value of 0.62. Although the composite reliability of threat is below 0.70, the value of 0.63 is generally acceptable for questionnaire scales [52]. Overall, these measures demonstrate adequate convergent validity and reliability [54]. To assess discriminant validity, we calculated average variance extracted (AVE) for all multi-item constructs. All AVE estimates are above 0.50, and are greater than the highest squared construction correlation (SIC) estimates. These tests provide good evidence of discriminant validity [57,58].

5. Analysis and Results

To test our hypotheses, we used the sample of 166 companies and employed a stepwise hierarchical moderated regression analysis, which allowed us to compare alternative models with and without interaction terms [59,60].

As Hypothesis 2 we included both the linear and quadratic terms of entropy. Squared terms represent nonlinear components, and we standardized the independent variables before entering them into regression models and creating interaction terms. An interaction effect exists if the interaction term contributes significantly to the variance explained in the dependent variables over the main effects of the independent variables. For all models, we used several regression diagnostics to assess whether modelling assumptions were satisfied. We conducted a Kolmogorov–Smirnov test to check for normality, which supported the univariate normality assumption. In addition, the variance inflation factors (VIF) were below the common cut-off threshold of 10, indicating that multicollinearity was not a concern [58]. Summary statistics and correlations for the sample of 166 firms are reported in Table 1.

In Table 2 we present the results of the standardized regression estimates to allow for a direct comparison between coefficients with respect to their relative explanatory power of the dependent variables. Models 1–5 show the hierarchical regression analyses for corporate entrepreneurship. Model 1 includes the control variables. Models 2–4 add the main effect of entropy, the squared term of entropy, and the two-way interaction term between entropy and organizational capabilities, sequentially. Model 5 adds the curvilinear interaction term between organizational capabilities and the squared term of entropy.

Table 1. Statistics and correlations.

Correlations	Mean	S.D.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20
1. Experience	10.88	7.33	1.00																		
2. Age	40.76	5.31	0.38 ***	1.00																	
3. Gender	0.22	0.41	0.00	−0.06	1.00																
4. Functional background	0.46	0.50	−0.09	−0.08	0.07	1.00															
5. Company age (log)	1.25	0.39	0.39 ***	0.16 **	−0.01	−0.05	1.00														
6. Company size (log)	3.45	0.95	0.30 ***	0.24 ***	0.06	−0.13 *	0.344 **	1.00													
7. Ownership	0.27	0.44	0.27 ***	0.16 *	0.13 *	−0.15 *	0.153 *	0.277 **	1.00												
8. Manufacturing	0.37	0.48	−0.10	−0.10	−0.11	0.13	0.01	0.03	−0.249 **	1.00											
9. Transportation	0.10	0.30	0.07	0.02	0.06	0.00	−0.06	−0.07	0.05	−0.251 **	1.00										
10. IT&C	0.19	0.40	0.06	−0.01	−0.11	−0.12	0.05	0.12	0.209 **	−0.376 **	−0.159 *	1.00									
11. Finance	0.14	0.35	0.11	0.17 *	0.09	−0.03	0.04	0.00	0.02	−0.313 **	−0.133 *	−0.199 **	1.00								
12. Real estate	0.03	0.18	0.00	0.05	−0.09	−0.02	−0.05	−0.09	−0.09	−0.140 *	−0.06	−0.09	−0.07	1.00							
13. R&D	0.06	0.24	−0.04	0.05	0.11	0.05	0.04	−0.09	0.08	−0.194 **	−0.08	−0.12	−0.10	−0.05	1.00						
14. Entrepreneurial orientation	5.94	1.21	0.03	0.06	−0.09	0.05	−0.139 *	−0.149 *	−0.08	0.02	−0.09	0.03	0.02	0.08	−0.04	1.00					
15. Environmental uncertainty	3.380	1.62	0.01	−0.04	−0.03	−0.02	0.01	0.03	0.07	−0.09	0.04	0.09	−0.06	−0.03	0.05	−0.171 *	1.00				
16. Financial slack	5.560	1.82	0.06	−0.06	0.09	0.08	0.03	0.10	−0.01	0.04	0.03	−0.08	−0.03	−0.08	0.07	0.211 **	−0.09	1.00			
17. HR slack	5.02	2.02	0.15 *	0.03	0.20	0.04	0.11	0.231 **	0.207 **	−0.139 *	0.02	0.07	−0.02	0.00	0.07	0.07	−0.08	0.205 **	1.00		
18. Organization capabilities	7.09	1.62	0.08	−0.05	−0.01	0.09	−0.06	−0.149 *	−0.11	0.07	−0.09	0.00	0.01	0.02	−0.06	0.452 **	−0.149 *	0.262 **	0.09	1.00	
19. Entropy	2.21	2.07	0.11	0.01	0.13 *	0.06	−0.01	0.03	−0.01	−0.12	0.00	0.141 *	0.07	0.04	0.05	−0.136 *	0.361 **	−0.12	−0.11	−0.152 *	1.00
20. Corporate entrepreneurship	5.31	1.22	0.04	0.01	0.11	0.12	−0.08	−0.05	0.06	−0.04	0.00	0.05	−0.05	0.13	−0.05	0.481 **	−0.13	0.141 *	0.142 *	0.392 **	−0.07

*** Correlation is significant at the 0.001 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Table 2. Standardized regression estimates.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Experience	0.00	−0.01	−0.01	−0.01	−0.01
Age	0.00	0.00	0.00	0.00	0.01
Gender	0.42 *	0.37	0.39	0.38	0.45 *
Functional background	0.22	0.19	0.19	0.18	0.15
Company age (log)	−0.07	−0.06	−0.05	−0.06	−0.08
Company size (log)	0.11	0.10	0.11	0.11	0.13
Ownership	0.23	0.25	0.24	0.25	0.20
Manufacturing	0.14	0.11	0.15	0.16	0.22
Transportation and warehousing	0.60	0.57	0.56	0.57	0.54
Information service and software	0.34	0.26	0.30	0.29	0.25
Finance	−0.12	−0.18	−0.13	−0.12	−0.13
Real estate	0.87	0.82	0.88	0.87	1.04
Scientific research and technological service	−0.09	−0.13	−0.14	−0.12	−0.01
Entrepreneurial orientation	0.38 ***	0.39 ***	0.37 ***	0.39 ***	0.35 ***
Environmental uncertainty	−0.04	−0.07	−0.06	−0.06	−0.04
Financial slack	0.01	0.02	0.03	0.03	0.06
HR slack	0.04	0.05	0.05	0.06	0.07
Organizational capabilities	0.21 *	0.23 *	0.22 *	0.20 *	0.04
Entropy		0.11	0.12	0.09	0.15
Entropy squared			0.04	0.04	−0.09
Organizational capabilities × Entropy				0.04	0.02
Organizational capabilities × Entropy squared					0.19 ***
R ²	0.245 ***	0.23	0.247	0.243	0.283 **
F	3.62 ***	3.54 ***	3.41 ***	3.26 ***	3.67 ***
F change	3.62 ***	1.618	0.788	0.318	9.03 **

Unstandardized coefficients included. N = 166. *: $p < 0.05$ (2-tailed); **: $p < 0.01$; ***: $p < 0.001$.

We conducted two supplementary analyses. First, we ran additional regression analyses to examine if entropy has an impact on whether companies take actions. Among the 197 companies, 31 had not taken any actions (Action = 0). We used Action as the DV and entropy, its squared term, the related interactions with organizational capabilities, financial slack, and HR slack, and control variables as predictors. Neither entropy nor its interactions with organizational capabilities or HR slack were significant, but the interaction between the intensity component of entropy and financial slack on Action was marginally significant ($p = 0.06$). Thus, we did not find entropy as a significant predictor for either Action or corporate entrepreneurship, and the boundary conditions for entropy to affect Action versus corporate entrepreneurship are different. These findings may imply the need to re-evaluate current conceptual perspectives about the linkage between entropy and organizational actions. First, organizational actions can take many different forms, which have different characteristics and may require distinct resources [61]. As a result, contrasting companies with various types of actions with those without any action may have blurred the intrinsic differences among these companies. Second, both our theorization and empirical findings support that entropy is related to corporate entrepreneurship under certain boundary conditions, but entropy coping strategies may include options such as procrastination and various types of information processing strategies [35,62]. Future research may need to explore the association between entropy and other types of actions, such as efficiency approaches.

Hypothesis 1 proposes a positive association between entropy and corporate entrepreneurship, which is not supported in the result in Model 2 ($\beta = 0.12$, $p > 0.05$). The t -value of entropy in this model is at 1.26, with p -value at 0.20.

Hypothesis 2 proposes a moderated relationship between entropy and organizational capabilities on corporate entrepreneurship. The results in Model 5 suggest that the interaction term between organizational capabilities and the squared term of entropy is positive and significant ($\beta = 0.20$, $p < 0.01$). To help interpret this effect, we followed [46] and ran simple slope tests to interpret this effect. When organizational capabilities are weak, the simple slopes of the regression curves change from positive and significant effects for low entropy ($\beta = 0.75$, $p < 0.05$), non-significant effects for

intermediate entropy ($\beta = 0.14$, NS), and negative and significant effects for high entropy ($\beta = -0.45$, $p < 0.05$). When organizational capabilities are strong, the regression curve for low ($\beta = 0.07$, $p < 0.50$), intermediate ($\beta = 0.23$, $p < 0.05$) and high ($\beta = 0.37$, $p < 0.05$) entropy is significant and positive. To clarify these curvilinear relationships at various levels of organizational capabilities, we use the unstandardized parameter estimates to depict the effects in Figure 2.

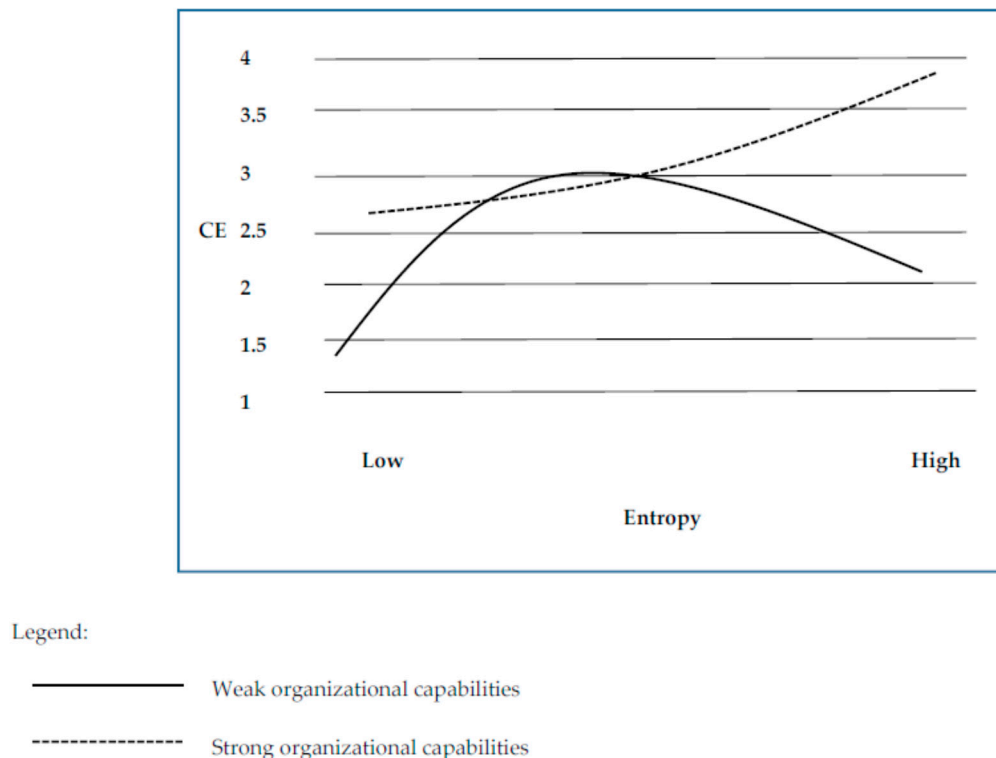


Figure 2. The Impact of entropy on corporate entrepreneurship.

To clarify these curvilinear relationships at various levels of organizational capabilities, we used the unstandardized parameter estimates to depict the effects in Figure 2, which shows that when organizational capabilities are weak, entropy has an inverted-U shaped relationship with corporate entrepreneurship which is strongly positive initially but switches to negative at high levels of entropy; when organizational capabilities are strong, corporate entrepreneurship increases with entropy. Thus, our results provide support to Hypothesis 2.

Among all the control variables, entrepreneurial orientation is significantly positive, suggesting that companies which are oriented towards entrepreneurship are more likely to respond to change by taking corporate entrepreneurship actions. Including entrepreneurial orientation also controls the propensity components which have resulted in corporate entrepreneurship activities. This further suggests that the significant interaction between entropy and organizational capabilities is unlikely to be a spurious finding, and that entropy does lead to corporate entrepreneurship activities as responses to change rather than as general organizational behaviours. Moreover, we did not find significant effects for either ownership or industry, which may indicate that corporate entrepreneurship responses are not industry or ownership specific. Thirdly, both financial slack and slack do not affect corporate entrepreneurship activities significantly, and this may result from the two-sided functions of slack. Slack itself can either induce complacency and inefficiency, thereby impeding corporate entrepreneurship activities, or facilitate entrepreneurship by allowing investment in exploratory activities. Fourthly, we did not find environmental uncertainty to be significantly related to corporate entrepreneurship. Studies have proposed opposite organizational responses to environmental uncertainty, with the threat perspective arguing that organizations tend to escalate

commitment to extant strategies [63] and the resource theory positing that organizations focus on modifying the external environment to secure critical resource flows. One possibility for this null finding is that executive' interpretations of the environment and organizational characteristics jointly influence organizational actions to respond to environmental changes [19]. Another possibility is that we only measure perceived general environmental uncertainty, while various types of uncertainty may influence corporate entrepreneurship in distinct ways. Finally, variables related to executive characteristics, including executive experience in the company, age, functional background, are not significantly related to corporate entrepreneurship [50,64]. Executive gender is significant in some models, but its effect is not stable across the models. [65,66].

6. Discussion and Conclusions

In our research we did not find strong evidence for the main effect of entropy, but our empirical findings provided strong support to our theoretical prediction that the effect of entropy on corporate entrepreneurship varies with organizational capabilities. When organizational capabilities are weak, entropy has an inverted-U curved relationship with corporate entrepreneurship and when organizational capabilities are strong, the relationship between entropy and corporate entrepreneurship is significantly positive [67].

The contrast of the impact of entropy on corporate entrepreneurship (strong vs. weak) suggests the important influence of organizational capabilities and also challenges existing proposals about the positive connection between entropy and organizational innovations [68,69]. When organizational capabilities are weak, the limited information processing capabilities may decrease the intention of executives to rely on the systematic mode and impair executives' judgmental confidence [70]. For instance, as executives become highly uncertain, the lack of appropriate information—processing capacities can be so influential that a preference reversal will occur. That is, executives may have to switch to the heuristic model when they find that their efforts to collect more information are in vain, which finally leads to decreasing corporate entrepreneurship activities. In contrast, when organizational capabilities are strong, the systematic mode become more favourable for executives and provides a satisfactory level of judgmental confidence in corporate entrepreneurship activities.

We did not find support for the main effect of entropy (Hypothesis 1), and our findings suggest that the effect of entropy varies with situational factors. Our study indicates that entropy relates to corporate entrepreneurship in distinctive patterns when organizational capabilities vary, thereby setting the boundary conditions and providing a contingency perspective to the debate about the link between entropy and organizational actions [71,72].

Also, our research suggests several other ways to advance the research on entropy in the organization settings. We theorize the heuristic and systematic processing modes as the process mechanisms through which entropy is connected to organizational actions, though we have not been able to test the mechanisms [50,73]. Some other mechanisms may also mediate the link between entropy and organizational actions, such as business process management and knowledge management. In the meantime, executives' experience, tenure, and personality variables may influence how executives choose between the two modes, but we do not find the significant effects for the executives related variables. Executive personality variables, others than those included in our models, may be more crucial predictors, and future studies should include executive personality variables and examine the various mechanisms directly [74–76].

Finally, our study contributes to the corporate entrepreneurship literature by underscoring the influence of entropy [6,51]. Entropy is new to the field of entrepreneurship, with only few studies focused on this research area of entrepreneurship and most literature only introduces the concept of entropy without directly modelling it in empirical studies [6,38,62,77].

Different from the above studies, we not only highlight the impact of entropy on corporate entrepreneurship, but also conceptualize the influence of entropy with a clear theoretical perspective. Our study includes important decision making processes that link entropy as part of this process.

Future research may further explore how entropy may influence executives' decision to pursue initiatives and how top managers' attitudes towards bottom-up initiatives affect behaviours of these managers [78].

In our opinion, future studies should investigate the connections among entropy, organizational actions, and performance, because there has been no research in strategy/organization which directly tests these relationships. Such a longitudinal study is difficult to implement for a few reasons. It requires the identification of broad and ill-defined strategic issues which are salient and important to a large number of firms, necessitate at least two (or three) waves of surveys, the first one on entropy, a second on organizational actions, and a third on organizational performance if objective data is not available. Despite the apparent difficulties, such research may be necessary to untangle the mystery of the relations between entropy and organizational performance.

Our findings are very relevant for any organization since understanding and reacting to the external environment is essential in strategic management as it is in physics. Learning how executives interpret external events is important since the perception of threats and opportunities will lead to different behaviours [79]. Also, managers should have the proper capabilities in order to enhance entropy. Resources should be allocated to obtain extensive information concerning target markets and to develop important relationships with distributors and consumers.

In our study we build upon the heuristic-systematic processing model to develop the theoretical connections between entropy and organizational actions, and find that the link between entropy and corporate entrepreneurship is contingent upon organizational capabilities. Our study contributes to the limited number of empirical research on entropy in an organization setting by highlighting the boundary conditions of the impact by examining the moderating effect of firms' organizational capabilities and also to the development of Econophysics as a fast growing area of interdisciplinary science [38].

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Appendix A

Table A1. Measurement items and validity assessment.

	Item	Reliability	Loadings
Corporate entrepreneurship	Extent of changes occurred during the past one year	0.72	-
	Change of competitive approach (strategy) for each business units		0.75
	Reorganized operations to ensure better coordination among business units		0.82
	Initiation of programs to improve the productivity of business units		0.76
	Entering new industries		0.85
	Establishment of new ventures		0.74
	Development of advanced research (R&D) facilities		0.76
	Expenditure on R&D		0.71
	Pioneering the development of revolutionary innovations in industry		0.64
	Introduction of large number of new products to the market		0.73

Appendix B

Table A2. Measurement items and validity assessment.

Item		Reliability	Loadings
Threat	Label the change negatively.	0.63	0.72
	Feel that there is a high probability of losing a great deal.		0.71
	Label the change as a potential loss.		0.74
	Label the change as having negative implications for the future.		0.66
Opportunity	Perceive that benefits will come from the business environment	0.70	0.67
	Feel the future will be better because of the business environment		0.76
	Label the change as a potential gain.		0.77
	Label the change as having positive implications for the future.		0.76
	Label the change positively.		0.77
Organizational capabilities	Managerial capabilities	0.86	0.87
	Technology capabilities		0.86
	Marketing capabilities		0.84
Entrepreneurial orientation	Top managers favour a strong emphasis on R&D, technological leadership, and innovations	0.74	0.84
	Marketed numerous new lines of products/services		0.80
	Dramatic change in in product/service lines		0.75
	Company typically initiates actions which competitors than respond to		0.84
	Company is very often the first business to introduce new products/series, management techniques, operating technologies etc.		0.67
	Company typically adopts a very competitive, undo-the-competitors posture		0.75
	Top managers have a strong proclivity for high-risk projects		0.72
	Top managers believe that owing to the nature of the environment wide-ranging acts are necessary to achieve the firm's objectives		0.81
	When confronted with decision-making situations involving uncertainty, company adopts a aggressive posture in order to maximize the probability of exploiting potential opportunities		0.76
Financial slack	The firm's retained earnings for market expansion	0.86	0.70
	Financial resources that can be used on a discretionary basis		0.87
HR slack	Skilled labour	0.68	0.85
	Managerial talent		0.62
Environmental uncertainty	The rate of products/services become obsolete in the industry	0.78	0.80
	Unpredictable demand and customer tastes		0.79

Note: based on a 10-point Likert scale, 1 = not at all, 10 = great extent.

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