Research on the Influence Path of Organizational Resilience on Innovation Performance of Start-up Enterprises Based on Machine Learning Algorithm

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Abstract: Under the impact of the epidemic on the economy, start-ups are facing enormous pressure and challenges. Based on machine learning algorithm, this study obtains business indicators such as registration time, registered capital, number of employees, operating income and R&D investment of start-up enterprises through data mining to construct a Bayesian network model. The purpose of this study is to explore the impact of organizational resilience on innovation performance of start-up enterprises before and after the impact, so as to help start-up enterprises achieve transformation and upgrading and reduce innovation costs. The results show that organizational resistance factors (executive compensation, number of employees, ownership concentration, etc.) have no significant impact on innovation performance, while organizational resilience factors (operating revenue, operating profit, asset-liability ratio, etc.) have a significant impact on innovation performance.

Keywords: Organizational resilience, innovation performance, start-up enterprises, Bayesion network, machine learning algorithm

1 Introduction

With the rapid development of information technology, innovation has become the key factor for the development of modern enterprises. Start-ups are facing huge challenges due to the economic impact of the pandemic. In recent years, the word "resilience" has become a hot topic in academic research. Many scholars use "resilience" to measure the resistance and resilience of economic system in the face of external shocks. With the development of China's economy, science and technology has become the core element of national strategic development, and scientific and technological innovation has become the driving force of development. As an important driving force for economic development, scientific and technological innovation can enhance organizational resilience through efficient innovation input, which is worthy of further study. In addition, driven by information technology, the application and promotion of new technologies such as 3D printing, industrial Internet, open source hardware and software, and mobile Internet have driven the development of entrepreneurial enterprises. The rise of digitisation has given new impetus to start-ups. Under the impact of the epidemic, how to make use of information technology to innovate and quickly restore productivity has become an urgent problem for start-up enterprises to solve.

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2 Literature Review

The term Resilience originated from engineering, mainly manifested in engineering resilience, and later developed to ecological resilience and evolutionary resilience.Its main emphasis is that when a system is subjected to impact or interference, the system can adjust from one equilibrium state to another [1]. In recent years, the word "resilience" has attracted much attention in the academic world. Its main view is that resilience refers to the ability of a system to adapt and change when it is stimulated by shocks or disturbances. The characteristics of resilience include: buffering, adaptability, resilience and evolution [2][3][4]. Therefore, organizational resilience refers to the degree to which an organization can actively cope with the turbulence of the external environment and the degree to which it can self-adjust and resume operation when faced with internal and external shocks [5]. The academic research on organizational toughness mainly reflects the research on the pre-variable of organizational toughness, while the research on the post-variable of organizational toughness is relatively lacking. Ortiz put forward the measurement method of organizational resilience, which is mainly measured quantitatively from the two dimensions of enterprise performance growth and financial fluctuation[6]. In existing studies, researchers believe that organizational resilience is closely related to an organization's sense of social responsibility, and employees, shareholders and social reputation have an impact on organizational resilience [7]. Hua and Chen took high-tech enterprises in the Pearl River Delta as the research object, and concluded that financial focus and scientific and technological innovation affected economic resilience, financial focus could reduce R&D costs and integrate resources, while scientific and technological innovation promoted economic resilience and improved the efficiency of innovation [8]. Liu et al believed that in the process of enterprise innovation, Digital empowerment is a key factor in enterprise innovation.Information technology, data mining, algorithms and cloud computing all affect the innovation performance of enterprises [9]. Therefore, in the face of economic shocks, start-up enterprises can use information technology, digital transformation and other ways to strengthen their innovation efficiency and reduce innovation costs.And through self-learning and timely adjustment to restore the original path and make new breakthroughs, so that the enterprise can quickly achieve transformation and stable financial capacity.

3 Study Design

3.1 Source of data

Based on python's random module, this study randomly sampled 342 start-ups registered on the 2018-2022 innovation and entrepreneurship platform to obtain the information of 200 start-ups.

Random sampling method:

```
import random
   nNowCount=0
foutRandom_data = open(train_data, 'w')
```

```
for line in open(strFeatureMatNormal):
    if listSerial[nNowCount]==1:
            fout Random_data.write(line)
    nNowCount+=1
print "Random_data is OK"
```

3.2 Processing of data

In this study, the standard process of machine learning was adopted for data processing.Firstly, the underlying original information is obtained from the platform database and log files. In view of the sparsity of the online learning data, the enterprises with less enterprise information are first cleaned out, and the data is processed and transformed to obtain higher level indicators. The obtained data is divided into test set and training set, the training set is used to train the model, and the test set is used to evaluate the model. And optimize the model according to the feedback.

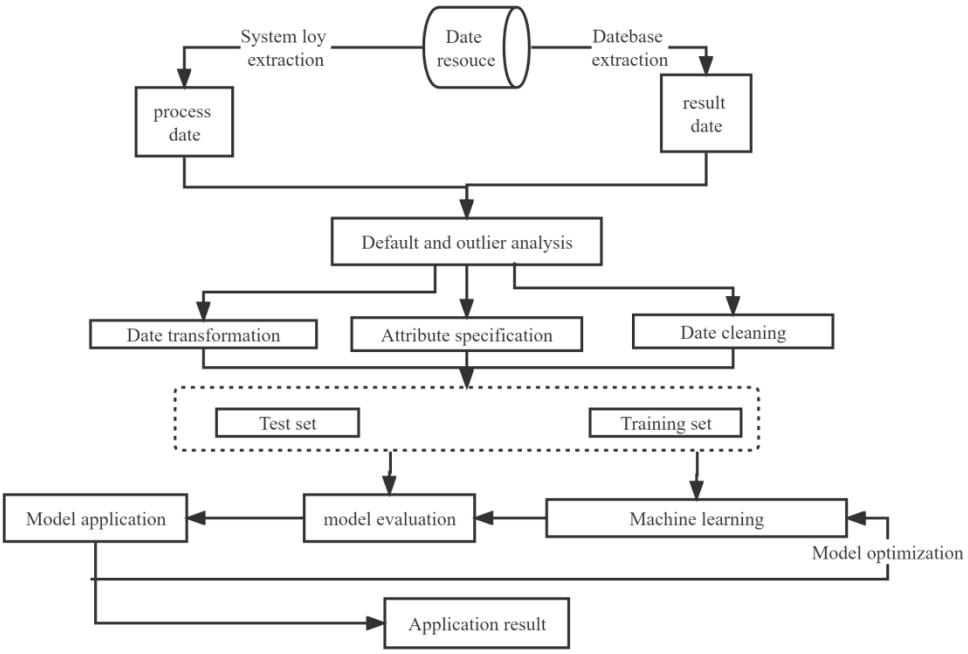

Fig. 1. Flow of the trained model.

3.3. Machine learning algorithm

3.3.1 Regression model

In this study, Ridge regression was used to construct regression models. Normalization methods vary among different machine learning methods. In Ridge regression, the normalization term is the sum of the squares of all the coefficients. The model requires 11 parameters (see **Table 1.**), of which, there are 9 explanatory variables and 2 explained variables, and the regression model is shown below (see Formula (1) (2)).

$$Y = \alpha + \chi_1\beta_1 + \chi_2\beta_2 + \ldots\ldots + \chi_9\beta_9 + \delta \tag{1}$$

$$\min\left\{\sum_{i=1}^{n}\left(Y_i - \hat{\beta}_o - \sum_{a=1}^{s}\hat{\beta}_k X_{ai}\right)^2 + \lambda\sum_{a=1}^{s}\hat{\beta}_a{}^2\right\} \tag{2}$$

Where: α represents the intercept; χ1, χ2..., χ9 is the related variable of organizational resilience and innovation performance, β_1, β_2, ...β_9 is the parameter, and δ is the error term.

Table 1. Variable index

Classification	Dimension	Indicators	Variable
Business attributes		Age of business	Age
		Number of employees	Employees
		Registered capital	RC
Organizational toughness	Resilience	Asset-liability ratio	OR
		Operating income	EC
		Operating margin	OP
		Ownership concentration	ALR
	Resistance	Board size	OC
		Executive compensation	BS
Innovation performance		R&d investment	RI
		New products	NP

3.3.2 Bayesian network

This article refers to Heckerman et al. and Tsamardinos et al. 's approach to construct a Bayesian network [10][11]. Bayesian network algorithm has three kinds: constraint, fraction and mixed algorithm. The basic idea is to create a directed acyclic graph according to the probability or causal dependence between a group of random variables. The collection of parent and child nodes forms the Bayesian network, which is called the directed acyclic graph (DAG). Based on the fractional algorithm, this study assumes that the factor variable affecting the organizational resilience and innovation performance of start-ups is set A={A1, A2,...AP,A_{p+1}}, B=A_{p+1}, Construct a Bayesian network D. Let D = (G, A), where G is that all nodes in the network are sets; A is the set of all connected nodes in the network. Let the parameter of the global distribution of the set of variables be γ, and then by calculating a network score reflecting its goodness of fit, a spatial search is conducted from a network structure without arcs, adding, deleting or reversing one arc at a time, until the score cannot be improved. The calculation formula is as follows (see **formula (3) (4)**).

$$\Pr（\mathrm{A}\,|\,\mathrm{G}）=\Pr（\mathrm{D}，\ \delta\,|\,\mathrm{G}）=\Pr(D\,|\,G)\times\Pr(\delta\,|\,D,G) \tag{3}$$

$$\mathrm{BIC}（\mathrm{G},\mathrm{A}）=\sum_{n=1}^{p+1}\left[\log\left(\Pr(A_n\,|\,\prod_{A_n})-\frac{|\delta_{A_n}|}{2}\log N\right)\right] \tag{4}$$

Where, BIC is the network score value, $\prod_{A_n}$ is A_n of the parent node set, δ is the parameter level, and N is the sample size.

4 Analysis of data

4.1 Data distribution test

In this study, the normal distribution of variables was tested by univariate normal distribution test. Therefore, the mean vector and covariance (see formula (5) and (6)) were firstly calculated, and the kurtosis coefficient (see formula (7)) and skewness coefficient (see formula (8))of the observed variation were analyzed to make the data obey the normal distribution. The calculation formula is as follows:

$$Y_a=\frac{1}{n}\sum_{b=1}^{n}Y_{ab} \tag{5}$$

$$M_{ac}=\frac{1}{n-1}\sum_{a=1}^{j}\sum_{b=1}^{j}\sum_{c=1}^{n}(Y_{ab}-Y_a)(Y_{cb}-Y_c） \tag{6}$$

$$K_{1,\ j}=\frac{1}{n^2}\sum_{a=1}^{j}j\sum_{b=1}^{j}\sum_{c=1}^{j}((Y_{ab}-Y_a)M_{ac}^{-1}(Y_{cb}-Y_c))^2 \tag{7}$$

$$K_{2,\ j}=\frac{1}{n^2}\sum_{a=1}^{j}j\sum_{b=1}^{j}\sum_{c=1}^{j}((Y_{ab}-Y_a)M_{ac}^{-1}(Y_{cb}-Y_c))^3 \tag{8}$$

Where, Y_{ab} represents the observed value of the variable (a=1,.... j ; b=1, ... n), M_{ac} represents the sample variance covariance matrix; $K_{1,\ j}$, $K_{2.j}$ represent kurtosis and skewness.

According to the data in **Table 2**, the skewness and kurtosis are distributed between (-1.96 and 1.96), indicating that the distribution of each item is reasonable and the data results are normally distributed.

Table 2. Descriptive statistical analysis.

Var.	Skewness	Kurtosis
Age	- .524	- .602
En	- .400	- .460
RC	-. 414	- .603

OR	- .499	-. 663
EC	- .205	- .740
OP	.102	-. 866
ALR	- .076	- .561
OC	- .050	- .656
BS	- .319	- .626
RI	- .341	- .158
NP	- .199	- .338

4.2 Sequencing analysis of influencing factors

After standardizing the variables in this study, Ridge regression was used to rank the importance of the variables.In this way, we can understand the most important factors affecting organizational resilience in start-up enterprises (See **Table 3**.).

Table 3. Factor sequencing analysis.

Sorting	Variable	Regression coefficient
5	Age of business	Age
7	Number of employees	EN
6	Registered capital	RC
3	Operating revenue	OR
9	Executive compensation	EC
1	Operating margin	OP
2	Asset-liability ratio	ALR
4	Ownership concentration	OC
8	Board scale	BS

According to **Table 3.** show that the three factors that have the greatest impact on organizational resilience of start-ups are operating profit rate, asset-liability ratio and operating income. The smallest three factors are the number of employees, the number of board of directors and executive compensation.

4.3 Bayesian network

In this study, the variables were sorted according to the Ridge regression method, and the Bayesian network was constructed (see **Fig. 2**).

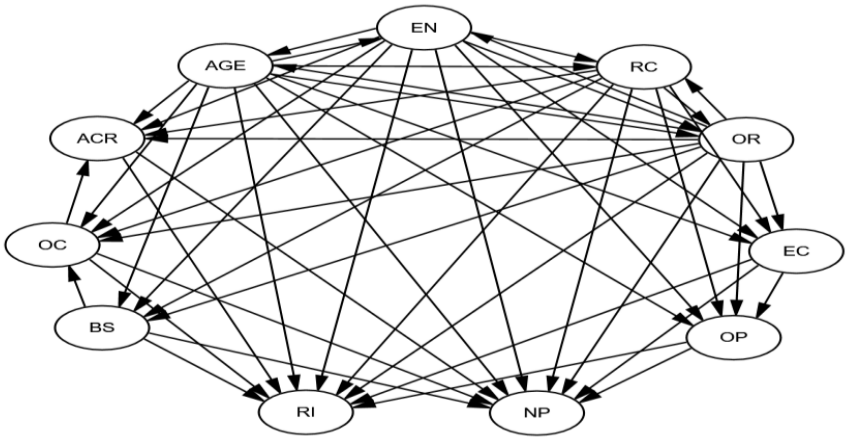

Fig.2. Bayesian network.

Table 4. Verification results of direct path.

Path			Estimate
OP	→	RI	-45763.32
ALP	→	RI	-5305.87
OR	→	RI	-643.12
OC	→	RI	-5.88
OP	→	NP	-3724.12
ALP	→	NP	-657.09
OR	→	NP	-94.23
OC	→	NP	-5.96

According to **Table 4**, three of the six factors affecting organizational resilience have direct transmission paths with innovation performance. Among them, innovation performance is highly dependent on OP, which once again verifies that operating margin plays a decisive role in the innovation performance of start-ups. At the same time, the absolute arc strength of the direct path of ALP and OR on innovation performance is also large. This conclusion is consistent with the importance ranking of variable factors, indicating that maintaining a moderate asset-liability ratio plays an important role in improving the innovation performance of enterprises. In addition, the results also confirm that the direct transmission effect of the number of employees, executive compensation and board size on innovation performance is significantly low.

5 Conclusion

This study built a Bayesian network model based on machine learning algorithm to explore the influencing factors of organizational resilience of start-up enterprises on innovation performance. The results show that organizational resilience has a partial impact on innovation performance, in which the factors representing organizational resistance, such as board size, executive compensation and equity concentration, have no significant relationship with

innovation performance, while the factors of organizational resilience, such as operating revenue, operating profit and asset-liability ratio, can effectively promote organizational innovation performance. The possible reason is that when an organization receives external impact, its resistance is manifested in its financial capacity and industrial structure, and these factors cannot directly affect innovation performance. Organizational resilience is reflected in organizational innovation and strategic adjustment, which directly affect the innovation performance of enterprises. In the face of external impact, start-up enterprises timely adjust their strategies, carry out information transformation, reduce innovation costs, and provide innovative performance. Therefore, in the face of the impact of the epidemic, start-up enterprises can fully combine information technology to transform and upgrade their enterprises, reduce the cost of innovation through information technology, and enable the rapid development of enterprises.

Due to the limitation of time, this study still has some shortcomings, such as insufficient sample size and single research methods. In the follow-up research, this study will further expand the research content and research methods, especially for other types of organizations.

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