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A Neutrosophic Genetic Algebraic Model for Financial Risk Evaluation in Technology Innovation Enterprises

Yushan Zhou*

School of Economics and Management, SouthWest University of Science and Technology, Mianyang, 621010, China

*Corresponding author, E-mail: 15982843049@163.com

Abstract: This paper introduces a new mathematical model called Neutrosophic Genetic Evolution Algebra (NGEA) to assess financial risk in technology innovation enterprises. Inspired by concepts in neutrosophic genetics, the model uses algebraic structures to represent and evaluate business changes, market dynamics, and outcome uncertainty. Each financial decision such as launching a new product or entering a new market is treated like a genetic mutation, which may result in business growth, stability, or failure. These outcomes are expressed using neutrosophic triplets (T: truth, I: indeterminacy, F: falsehood). We develop multiple equations to capture the evolution of financial states over time and apply the model to real-world innovation cases. The results show that NGEA provides a more flexible and realistic tool for managing risk under uncertainty.

Keywords: Neutrosophic Algebra, Financial Risk, Technology Enterprises, Innovation, Uncertainty Modeling, Decision Evaluation.

1. Introduction

In today's fast-paced technology markets, innovation plays a central role in the success or failure of enterprises. However, innovation is also tightly linked to financial risk, especially in uncertain or volatile environments. Traditional financial models often struggle to account for the many layers of ambiguity that surround new technology ventures [1].

Florentin Smarandache introduced Neutrosophy in 1998 as a new branch of philosophy that focuses on reasoning under uncertainty. At the core of neutrosophy is the idea of a triadic structure, represented as a triple: $(\langle A\rangle, \langle \text{neut A}\rangle, \langle \text{antiA} \rangle)$. In this structure, $\langle A\rangle$ is any concept, idea, or proposition, while $\langle \text{antiA} \rangle$ is its direct opposite, and $\langle \text{neutA} \rangle$ stands for the neutral or indeterminate part that exists between the two. This framework allows us to consider partial truth, uncertainty, and contradiction all at the same time.

Neutrosophy provides a powerful base for further mathematical and applied models, such as neutrosophic sets, logic, and algebra, which are especially useful in fields dealing with vague, incomplete, or conflicting information [2].

Smarandache was the first to introduce the concept of Neutrosophic Genetics in 2021 he proposed a new mathematical framework that combines principles of genetics with neutrosophic logic [3]. This innovative approach models genetic behavior using three components: truth, indeterminacy, and falsehood allowing for a more flexible and realistic understanding of mutation, inheritance, and evolution under uncertainty. Smarandache's work laid the foundation for further studies in applying neutrosophic thinking to biological, technological, and decision-making processes involving complex and uncertain systems [4].

This paper introduces a new approach for analyzing such risks, based on NGEA. The model adapts concepts from neutrosophic genetics originally developed to describe biological mutation, speciation, and coevolution using neutrosophic logic and applies them to the financial dynamics of technology-driven companies.

In neutrosophic genetics, a mutation is not simply good or bad. It can also be neutral or uncertain. Similarly, in business, a strategic innovation like launching a new product or entering a new market can result in growth, failure, or an unclear outcome. Each of these results can be described using neutrosophic values: truth (T), indeterminacy (I), and falsehood (F).

By modeling financial decisions as mutations, and business outcomes as speciation (growth), continuation (neutrality), or extinction (collapse), NGEA allows us to evaluate risk using structured algebraic expressions. This leads to a richer, more flexible framework for understanding how technology enterprises evolve under pressure, compete in dynamic environments, and manage uncertainty over time.

The following sections will develop this algebraic model in detail, present its equations and logic, and apply it to real-world decision-making scenarios for technology innovation enterprises.

2. The Neutrosophic Genetic Evolution Algebra (NGEA) Model

This section introduces the main structure of the model we use in this paper. The goal is to measure and understand the financial risk that comes with innovation in technology enterprises.

We treat every business decision such as creating a new product, changing strategy, or entering a new market as a kind of genetic mutation. In real life, this mutation might help the business grow, keep it stable, or cause it to fail. Because outcomes are rarely black and white, we describe each one using neutrosophic values:
T (Truth): How much the outcome is expected to be successful
I (Indeterminacy): How uncertain or unclear the outcome is
F (Falsehood): How likely the outcome is to fail
We also think of the business as something that evolves. A company might grow into something new (speciation), stay the same (neutral), or disappear (collapse). Its interaction with the market may also vary: it can cooperate, compete, or remain unaffected.

To measure all this, we use a new algebra called Neutrosophic Genetic Evolution Algebra (NGEA). This algebra lets us create equations that combine:

a) the type of decision made (mutation),
b) the environment (market),
c) and the possible results.

In the next section, we will write the mathematical formulas that describe this model and show how to calculate risk in different conditions.

3. Mathematical Foundation

3.1. Neutrosophic Mutation Triplet

Each business decision (like investing in R&D, launching a new product, or pivoting to a new market) is defined as a mutation:

$$M = (T_m, I_m, F_m)$$

Where:
$T_m \in [0,1]$ represents the expected financial truth or benefit (e.g., success rate),
$I_m \in [0,1]$ represents the indeterminacy, uncertainty or unpredictability of the outcome,
$F_m \in [0,1]$ represents the falsehood, or potential loss/failure risk.

These three values form a Neutrosophic Mutation Triplet, and they do not have to sum to 1, allowing the model to represent real-world financial complexity.

3.2. Market Environment Triplet

To reflect external conditions, we define a second triplet:

$$E = (T_e, I_e, F_e)$$

Where:
T_e : Market readiness or openness to the innovation,

I_e : Market uncertainty or volatility,

F_e : Competitive pressure or external threats.

This triplet represents the financial ecosystem in which the company operates.

3.3. Neutrosophic Speciation Equation (Financial Growth Potential)

The speciation equation evaluates how a mutation may evolve into business growth under neutrosophic uncertainty:

$$S = \alpha \cdot T_m - \beta \cdot F_m + \gamma \cdot (1 - I_m)$$

Where:

S : Growth potential (higher = better),

α, β, γ : positive weights reflecting importance of benefit, risk, and stability.

Example 1

A company launches a green energy platform:

$T_m = 0.8, I_m = 0.1, F_m = 0.2$

$\alpha = 1.0, \beta = 0.9, \gamma = 1.1$

$S = 1.0 \cdot 0.8 - 0.9 \cdot 0.2 + 1.1 \cdot (1 - 0.1) = 0.8 - 0.18 + 0.99 = 1.61$

This suggests strong growth potential.

3.4. Collapse Risk Equation

We define the collapse risk score:

$$C = \lambda_1 \cdot F_m + \lambda_2 \cdot I_m$$

Where:

C : Financial collapse risk,

λ_1, λ_2 : weights for how much risk and uncertainty affect failure.

Example 2

Using the previous values:

$F_m = 0.2, I_m = 0.1, \lambda_1 = 1.0, \lambda_2 = 0.7$

$C = 1.0 \cdot 0.2 + 0.7 \cdot 0.1 = 0.2 + 0.07 = 0.27$

A moderate collapse risk score.

3.5. Coevolution Interaction Equation

We measure alignment between internal decisions and external conditions:

$$E_c = T_m \cdot T_e - F_m \cdot F_e - |I_m - I_e|$$

Where:

E_c : Coevolution fitness score (positive = aligned, negative = mismatch).

Example 3

$T_e = 0.6, I_e = 0.2, F_e = 0.3$

$E_c = 0.8 \cdot 0.6 - 0.2 \cdot 0.3 - |0.1 - 0.2| = 0.48 - 0.06 - 0.1 = 0.32$

A positive value implies moderate alignment.

3.6. Neutrosophic Evolution Function

To capture the full dynamic nature of financial evolution over time:

$$EV(t) = w_1 \cdot S(t) - w_2 \cdot C(t) + w_3 \cdot E_c(t)$$

Where:

$EV(t)$: Evolution Score at time t, $S(t), C(t), E_c(t)$: the dynamic versions of the above metrics, w_1, w_2, w_3 : time-sensitive weights.

This equation can help simulate how financial position changes over time.

4. Application

This section shows how we can use the Neutrosophic Genetic Evolution Algebra model to analyze real business cases. The examples here focus on technology companies making risky but important innovation decisions. These decisions can lead to growth, failure, or uncertain results.

We use the equations defined earlier to compute three key outcomes:

a) Speciation Score (S): How likely the company will grow.
b) Collapse Risk (C): How much risk the company faces.
c) Coevolution Score (E_a): How well the company's decision fits with the market.

Case 1: Startup Launching a Smart Wearable

A new company is planning to launch a smart wearable for health monitoring. The decision is risky but could bring big rewards.

Internal neutrosophic values (Mutation):

$$T_m = 0.7, I_m = 0.2, F_m = 0.1$$

Market conditions (Environment):

$$T_e = 0.6, I_e = 0.3, F_e = 0.1$$

Step 1: Compute Speciation Score

$$S = \alpha \cdot T_m - \beta \cdot F_m + \gamma \cdot (1 - I_m)$$

Let $\alpha = 1.0, \beta = 0.9, \gamma = 1.1$

$$S = 1.0 \cdot 0.7 - 0.9 \cdot 0.1 + 1.1 \cdot (1 - 0.2) = 0.7 - 0.09 + 0.88 = 1.49$$

The high score 1.49 shows strong business growth potential.

Step 2: Compute Collapse Risk

$$C = \lambda_1 \cdot F_m + \lambda_2 \cdot I_m$$

Let $\lambda_1 = 1.0, \lambda_2 = 0.8$

$$C = 1.0 \cdot 0.1 + 0.8 \cdot 0.2 = 0.1 + 0.16 = 0.26$$

A moderate risk of failure 0.26, acceptable in innovation.

Step 3: Compute Coevolution Score

$$E_c = T_m \cdot T_e - F_m \cdot F_e - |I_m - I_e|$$

$E_c = 0.7 \cdot 0.6 - 0.1 \cdot 0.1 - |0.2 - 0.3| = 0.42 - 0.01 - 0.1 = 0.31$

A positive score shows decent alignment with the market.

Case 2: Mid-size Tech Firm Adopting Blockchain

Another company plans to switch its internal systems to blockchain.

Internal (Mutation):

$$T_m = 0.6, I_m = 0.3, F_m = 0.2$$

Market (Environment):

$$T_e = 0.7, I_e = 0.2, F_e = 0.1$$

Let the same weights apply.

Speciation

$S = 1.0 \cdot 0.6 - 0.9 \cdot 0.2 + 1.1 \cdot (1 - 0.3) = 0.6 - 0.18 + 0.77 = 1.19$

Collapse

$C = 1.0 \cdot 0.2 + 0.8 \cdot 0.3 = 0.2 + 0.24 = 0.44$

Coevolution

$E_c = 0.6 \cdot 0.7 - 0.2 \cdot 0.1 - |0.3 - 0.2| = 0.42 - 0.02 - 0.1 = 0.30$

This means lower growth potential and higher risk, but decent market fit as illustrated in Table 1.

Table 1. Summary of two cases

Case	Growth (S)	Risk (C)	Market Fit (E_a)	Decision
1	1.49	0.26	0.31	Launch smart wearable
2	1.19	0.44	0.30	Adopt blockchain infrastructure

5. Results

The NGEA model helps us break down each business decision into three parts: how likely it is to succeed, how uncertain the result is, and how much risk is involved. By separating these parts, the model gives a more realistic picture of financial outcomes.

In the first case (smart wearable), the company had a strong chance of growing with low risk. The numbers showed that this decision was well-aligned with the market and had stable support. It was a smart and safe move for the business.

In the second case (blockchain adoption), the company faced more uncertainty and higher risk. Even though the market seemed open, the company's internal challenges made the move less promising. The model clearly showed that this choice needed more caution.

These results prove that NGEA can explain why one decision may be better than another, not just with one score, but with multiple useful indicators. This makes it easier for business teams to see the full picture before they act.

NGEA is not just about scores it is about understanding decisions in a deeper, more flexible way.

6. Conclusion

This paper introduced a new method called Neutrosophic Genetic Evolution Algebra (NGEA) to understand financial risk in technology innovation companies. The model uses a unique way of thinking: it treats business decisions like genetic changes that can lead to success, failure, or unclear outcomes.

We used neutrosophic values truth, indeterminacy, and falsehood to describe each decision and its environment. With the help of clear formulas, we measured how much a company might grow, how much danger it faces, and how well it fits the market.

Our examples showed that this model gives a more detailed picture of risk than regular tools. It helps business leaders choose better paths, especially when dealing with innovation, where things are never fully certain.

This approach can be adapted to other fields too any place where decisions are risky and outcomes are not black and white.

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