Holistic Innovation, Market Structure, and Performance—Research on a Computer Decision-Making Method

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ABSTRACT Unlike the traditional SCP (Structure-Conduct-Performance) model, several Holistic Innovation (HI) policies formulated by policymakers under strategic guidance can optimize the market structure and performance. Owing to the value and difficulties of issues, controversies (especially those from abroad) abound. Few scholars have conducted interdisciplinary research in this domain using IT technology. This study begins with a simple firm theory model, extends the Cournot duopoly model, then constructs a theoretical model referring to HI, the market structure, and performance. Results of this study revise the traditional view that “firms/enterprises with market advantages (monopoly firms and oligarchs) are harmful to the market structure and its performance and reveal the boundary conditions for monopoly and oligopoly firms harming the market structure and performance.” In this study, we design the research model as an application software (with obtained patents). Through data calculation, we conclude that “if no more than eight oligarchs exist, then the market structure and performance will not be hurt.” Using firms’ data, the application software can accurately calculate and measure the market structure and performance in the context of HI, thereby helping firms and policymakers make precise strategic decisions. This study contributes to research on HI as well as on the market structure and performance. Moreover, this study expands the academic understanding on the tripartite relationship. The traditional SCP model regards the market structure as a difficult construct to change, and by merely conforming to it, innovation can influence improved performance. By contrast, this study argues that when HI becomes increasingly crucial and shared in the future, the market structure can be influenced and will demonstrate spectacular market performance.

INDEX TERMS Holistic innovation, market structure, market performance, assessment model, simulation decision.

I. INTRODUCTION Economists believe that the essence of economic development lies in innovation. Nonetheless, a monopoly is a primary source of technological innovation under the capitalist financial system. For example, Schumpeter (1939) emphasized the importance of entrepreneurs and innovators and introduced “new combinations” to new products or processes [1]. Innovation generates excess profits in the short term. However, such gains will disappear eventually, in the long run, owing to imitation. Additionally, Samuelson and Anthony (2007) spoke highly of Schumpeter’s innovation viewpoint and presented the issue of “the relationship between innovation and market power” [2]. The scholars believed that firms’ viability in an incomplete competition involves the power of pricing and the development of new products, technologies, and markets to generate future profits. From the perspective of most strategists, firms are consistently trying to adapt to the market to survive and promote their performance (Porter, 2010) [3]. However, Waldman and Jensen (2013) argued that a highly complex relationship should exist between innovation and market power [4]. For instance, in some specific scenarios,
government or firm strategies often combine or reshape innovation resources, thereby changing the market structure and performance. Successful examples include the miracle of Silicon Valley, which was created by the “Information Highway” plan proposed by the Reagan administration, “Toyota City” (Aichi-ken) in Japan under an automobile industry strategy, and the recent Trump administration “Quantum Initiative” launch. Undoubtedly, innovation combination, especially under strategic guidance (by policymakers or firms), can lead to changes in the market structure and performance. Accordingly, scholars presented the concept of Holistic Innovation (HI),¹ which represents a combination of innovations guided by strategic vision. Chen et al. (2018) defined HI as a total and collaborative innovation driven by a strategic vision in an era of strategic innovation, which aims for a sustainable and competitive advantage [5]. Furthermore, HI is a new innovation paradigm being complex of strategic innovation, collaborative innovation, total innovation, and open innovation. Subsequently, “open” as one of the four core elements contains innovation performance. Plus, according to the theoretical framework of HI, there is a social part including market results (also including market structure) (see Chen et al., 2018) [5]. Therefore, the concept of HI has a strong impact on innovation performance and market structure.

The existing literature discusses the issue of market structures (Loury, 1979; Kamien & Schwartz, 1975) [6], [7], but rarely presents academic arguments on this concept (Phillip, 1971; MacLeod, 1987; Jefferson & Xu, 1991) [8]–[10]. In essence, the market structure is generally regarded as the connections and characteristics of different elements in the market. In this study, the market structure refers expressly to the domain of industrial organization theory, therefore can be expressed as the characteristics and forms of market relations among firms, reflecting market competition and a monopoly status, such as a complete competition, an oligopoly, or a complete monopoly. Performance generally refers to the overall work achievement of an organization (including individuals; Cheng et al., 2012) [11]. Previous studies habitually equate market performance with several economic performance indicators of organizations (or firms) in the market, such as quantity, price, profit, and so on (Calantone et al., 2002; Ciftci & Cready, 2011; Li & Yan, 2020) [12]–[14]. However, from the perspective of organizational (government, firm, and individual) decision making, we should consider indicators at the microeconomic level and symbols of social (or organizational) efficiency, including total industrial capacity, consumer surplus, producer surplus, and overall social surplus.

Theoretically, abundant literature exists on the relations between innovation combination, the market structure, and market performance (Liu & Zheng, 2018; Kou & Gao, 2013; Li & Zhang, 2011; Chen et al., 2008) [15]–[18]. Nevertheless, most methodologies generally follow the traditional SCP method. Regarding the market structure, Charles (1971) argued that “The structure of the American industry has approximately changed surprisingly little since the turn of the century” [8]. By contrast, HI has a particular impact on the traditional SCP model, and the extension of HI confirms the assumption of Waldman and Jensen (2013), Norton et al. (2015) [4], [19]. Additionally, scholars conducted numerous empirical studies on the relationship between various innovation activities (including HI) and the market structure. However, owing to the complexity of the calculation process or omission of essential variables leading to coefficient deviation, drawing improper conclusions and presenting unreliable results are possible (Carlton et al., 1999) [20]. A crucial aspect is that most studies seem restricted by specific industries and exhibit considerably different results (Liu & Yang, 2020; Jing et al., 2019; Li & Zhang, 2011; Liu & Liu, 2010) [17], [21]–[23], which confuses firms and policymakers. Furthermore, the result inspires a profound reflection on the specific conditions of innovation. Contemporary research pays attention to the requirements of HI, such as market demands (Dong & Shi, 2019) [24], technology opportunities (Wang & Huang, 2013) [25], and diversion conditions. Although empirical data and research results prove that these factors are exceedingly significant, substantial work to be done remains (Charles, 2014) [26]. Accordingly, how HI can change the market structure and performance has become an exciting and valuable topic and is the motivation and direction of this study.

Computer simulation technology involves converting theoretical models into programs for computers (Zhang, 2005) [27]. By employing historical data, such programs can calculate data indicators that can help policymakers and business managers make decisions. This method is considered as a highly effective experimental technique and popular in social research (Yu et al., 2008) [28]. How HI affects the market structure and performance can be determined by this experimental method. The advantages of this method lie in three aspects. First, this method can make tedious theoretical analysis and argumentation applicable and straightforward by using information engineering technology. For instance, policymakers and managers need only to input the exogenous parameters of their organization into the system, which can provide the corresponding reports (Cohen & Levin, 1980) [29].

However, considering the performance of the market structure as the primary goal, this method can scientifically calculate market power according to the theoretical model (under the principle of social welfare maximization and the law of equilibrium between consumer and producer surplus; Zhang, 2005) [30]. Fundamentally, the results of the computer calculations are highly accurate and can provide quantitative evidence for the reasons behind the economy (Mankiw, 2009) [31]. Such reasons include social welfare

¹Firms’ HI has been paid more attention in recent years, is based on new combinations of the production factors and production conditions of the Schumpeterian innovation concept.
loss caused by unreasonable resource profit taxes due to a monopoly and its underlying issues, market standardization, innovation promotion, excess profits from the rational acquisition of resources, etc. Another example is how much excess profit surplus firms can gain through innovation and whether they should surrender their monopoly position.

Therefore, this study aims to solve these problems by establishing several models and developing an application software.

1) From changes in price elements and the marginal cost of an oligopoly game model caused by HI to a quantitative demonstration, this study will determine “whether the market structure and performance will change as HI changes.” Generally, after the assumption of HI promoting the market structure to become reasonable, market efficiency can improve. In other words, theoretically, the view that “a monopoly or oligopoly with market forces will make market outcomes inefficient” is remedied to a certain extent.

2) Free from the conceptual issues and problems in interpreting the classic SCP theory, if this research encounters bottlenecks in linking with mainstream economics at the academic level, in that case, a clear explanation of different empirical phenomena is provided from a general theoretical level.

3) The analysis model is used to examine market structure change and market efficiency improvement due to innovation to conduct an empirical regression analysis.

4) This study determines whether the theoretical model and decision-making software can provide a corresponding policy basis for policymakers.

II. BACKGROUNDS AND FUNDAMENTAL MODEL
A. GAME THEORY FRAMEWORK OF FIRMS AND ISSUE OF COMPETITION

Our theoretical model is established based on existing research, following repeated steps such as discovering laws → seeking clues → analyzing → modeling → correcting the model → calculating the data. Despite a variety of power promoting technological innovation, the effect produced by the combination of innovation can be gained from the formulas in Table 1 and Table 2 and reflected in the data in Table 4.

Before the impact of HI on the market structure and performance can be obtained through scientific calculation, a systematic indicator evaluation system must first be established. A market structure indicator system and market performance evaluation system are built, in which the market structure involves three evaluation methods, that is, a comparison between assessment indicators such as CR, the Herfindahl–Hirschman Index (HHI), and the Lerner index (Sun, 2002) [32]. The market performance evaluation system includes total quantity (Q), price (P), profits (π), consumer surplus (CS), producer surplus (PS), and total social surplus (TS; Sun, 2002) [32].

According to the Cournot (oligopoly) model (Hopkins & Woodward, 1965; Huck et al., 1999) [33], [34], n (n > 4) symmetrical companies with product homogeneity (or heterogeneity) are assumed, and their cost functions are C(qc) = cqi (c is the unit marginal cost and q is the output; i = 1, 2, . . . . . . ; n) without considering the fixed costs of firms (in the short term, fixed costs do not change with production,
TABLE 2. Evaluation index Table of market performance.

| Performance Indicators | Numbers of firms engaging in innovation N(∈[0,n]) |  |
|------------------------|-----------------------------------------------|---|
|                        | N=0                                           | N=g,g∈[1,n-1] | N=n |
| Non-innovative firms yields (Qn) | $q_{in} = \frac{a-c}{b(n+1)}$ | $q_{in} = \frac{a-c-g\Delta c}{b(n+1)}$ | $q_{in} = \frac{a-c-\Delta c}{b(n+1)}$ |
| Innovative firms yields (Qi)      | 0                                              | $q_{i} = \frac{a-c+(n-g+1)\Delta c}{b(n+1)}$ | $q_{i} = \frac{a+c+\Delta c}{b(n+1)}$ |
| Total Yields (Q)       | $n\left(\frac{a-c}{n+1}\right)^2$             | $\frac{n(a-c)+N\Delta c}{b(n+1)}$ | $rac{n(a-c-\Delta c)^2}{b(n+1)^2}$ |
| Price (P)              | $a + n\Delta c$                               | $\frac{a + n\Delta c - N\Delta c}{n+1}$ | $rac{n(a-c-\Delta c)^2}{b(n+1)^2}$ |
| Profit (π)             | $\frac{n(a-c)^2}{b(n+1)^2}$                   | $\frac{n(a-c-\Delta c)^2}{b(n+1)^2}$ |  |
| Consumers’ Surplus (CS) | $\frac{(a-c)^2}{2b(n+1)^2}$                   | $\frac{(a-c)^2+2c}{b(n+1)^2}$ |  |
| Producer Surplus (PS)  | $\frac{n(a-c)^2}{b(n+1)^2}$                   | $\frac{(a-c)^2+2c}{b(n+1)^2}$ |  |
| Total Social Surplus (TS) | $\frac{(a-c)^2+2a}{2b(n+1)^2}$               | $\frac{(a-c)^2+2a+2n+\Delta c}{2b(n+1)^2}$ |  |

Note: $a$ represents the price variable constant, $b$ represents the yield variable constant, $c$ represents the unit marginal cost, $n$ represents the number of industrial firms, $N$ and $g$ represent the number of innovative firms ($N \in [0, n]$, $g \in [1, n-1]$), $m$ and $j$ represent the ranking of the innovative firms, $k$ and $i$ represent the ranking of the non-innovative firms, $\Delta C$ represents the change value of the marginal cost, and $t=\Delta C/(a-c)$ represents overall exogenous variable conditions.

fixed costs do not affect the choice and thus are ignored). The anti-demand function of the market is $p = a - bQ$ ($P$ is the price, $a$ is the price variable constant, and $b$ is the output quantity variable constant; $Q = q_1 + q_2 + \ldots + q_n$). Several phosphorus chemical firms (in the oligopoly scenario) in China engaged in HI are taken as an example (marginal cost changes ultimately reflect the impact of these behaviors). They make business units reduce the marginal cost $\Delta C$, that is, the marginal cost after innovation is $C’=C-\Delta C$. To simplify the problem, we assume that the innovation and implementation costs of such firms are ignored; thus, they can yield high profits relative to the unit marginal cost reduction. $n$ companies are set, and the absence of impact from the new firms entering or exiting is assumed. No firms are engaging in innovation in $n$ companies, whereas $g$ ($g \in [1, n-1]$) firms and $n$ firms are conducting innovation. The number of firms and changes causing the quantity of a single firm in the industry, the equilibrium price, the market concentration, the $HHI$, the $LI$ change comparison reflection, $CS$, $PS$, and $TS$ can be considered with $HI$. To facilitate the analysis, the production of all the firms is assumed to be solvable, but in business or several other firms, it must meet the following conditions: $\Delta C/(a-c) = t$, $n-1 < (a-c)/\Delta C$ is assumed, then $n < (1/t + 1)(t$ is the general exogenous variable condition).

In the oligopoly market structure, two homogeneous (or heterogeneous) companies are in the Cournot competition; thus, the model’s conclusion is applied to $n$ manufacturers. The balanced quantity for each vendor is $1/(n+1)$ of the most massive market demand, and the total quantity is $n/(n+1)$ of the maximum demand in the market. To facilitate discussion and description, only the quantitative impact from the systematic and collaborative innovation behavior is considered, that is, innovation marginal cost $C’=C-\Delta C$. The measured innovation portfolio is omitted, such as R&D investments, patents, advertising investments, and so on. The number of innovations in firms with HI from the three cases is illustrated: 0 firm innovation in $n$ firms in the industry, $g$ ($g \in [1, n-1]$) innovation firms, and $n$ innovation firms. They are assumed to be the same in terms of innovation, and the impact on the market structure and performance after innovation is summarized in table 1 and table 2.

1) Zero innovation firms. When no firm is engaging in innovation in $n$ firms, the profit objective function of $n$ firms owing to symmetric $n$ firms is

$$\pi_i = \left[a-b(q_1+\ldots+q_i+\ldots+q_n)\right]q_i-cq_i, \quad i \in [1, n]$$ (1)

where $i$ represents the firm type, $c$ is the unit marginal cost, and $q$ is the yield.
TABLE 3. Market structure and market performance under holistic innovation.

| Market structure and performance Indicators | Numbers of firms engaging in innovation N(N∈[0,n]) |
|--------------------------------------------|--------------------------------------------------|
| Non-innovative firms output quantity       |                                                   |
| \( q_{g1} = \frac{a-c}{b(n+1)} \)         | \( q_{gk} = \frac{a-c-g\Delta c}{(n+1)b} \)     | \( q_{gj} = \frac{a-c-n\Delta c}{(n+1)b} \) |
| Innovative firms output quantity          |                                                   |
| \( q_{gm} = \frac{a-c+(n-g+1)\Delta c}{(n+1)b} \) | \( q_{gu} = \frac{a-c+\Delta c}{b(n+1)} \)     |
| Market concentration \( C_{Nm} \)         |                                                   |
| \( \frac{4}{n} \)                         | \( \frac{4 + gt(n-3)}{n + gt} \)              | \( \frac{4}{n} \) |
| Herfindahl index \( H_N \)                | \( \frac{1}{n} \)                              | \( -\frac{(n+2)N^2}{(n+N)^2} + \left( t^2n^2 + 2t^2n + t^2 + 2t \right)N + n \) |
| Lerner Index \( L_N \)                    | \( \frac{a-c}{a+nc} \)                         | \( \frac{a-c + (n-N+1)\Delta c}{a+nc-N\Delta c} \) |
| Total yields \( Q_N \)                    | \( \frac{n(a-c)}{b(n+1)} \)                    | \( \frac{na-nc+N\Delta c}{(n+1)b} \) |
| price \( P_N \)                           | \( \frac{a+nc}{n+1} \)                         | \( \frac{a+nc-N\Delta c}{n+1} \) |
| Profit \( \pi_N \)                        | \( \frac{n(a-c)^2}{b(n+1)^2} \)               | \( \frac{n(a-c-N\Delta c)^2}{b(n+1)^2} \) |
| Consumers’ Surplus \( CS_N \)             | \( \frac{(na-nc)^2}{2(n+1)^2b} \)             | \( \frac{(na-nc+N\Delta c)^2}{2(n+1)^2b} \) |
| Producer Surplus \( PS_N \)               | \( \frac{n(a-c)^2}{b(n+1)^2} \)               | \( \frac{(a-c)^2[-(n+2)N^2 + (t^2n^2 + 2t^2n + t^2 + 2t)N + n]}{(n+1)^2b} \) |
| Total Social Surplus \( TS_N \)           | \( \frac{(a-c)^2(2n+2t)}{2(n+1)^2b} \)        | \( \frac{(a-c)^2[-2nt - 3t^2] + 2t^2 + 4t + 2t + 4t]}{(n+1)b} \) |

2) \( g \) firms engaging in innovation. When \( g(\in [1,n-1], \) a positive integer) out of \( n \) firms implement innovation, the marginal cost of the unit is reduced to \( c - \Delta c \), and the profit objective function of \( n \) firms is

\[
\begin{align*}
\pi_{gm} &= [ab(q_{g1} + q_{g2} + \ldots + q_{g1} + \ldots + q_{gm})] \\
\pi_{gm} &= (c-\Delta c)q_{g1}, m \in [1,g] \\
\pi_{uk} &= [ab(qu1 + qu2 + \ldots + qu1 + \ldots + qu_m)] \\
\pi_{uk} &= cq_{ku}, k \in [g+1,n] \\
\pi_n &= \pi_{gm} + \pi_{uk} 
\end{align*}
\]

where \( g \) and \( u \) denote the number of firms with and without innovation; \( m \) and \( k \) represent the firm type; \( c \) is the unit marginal cost; \( \Delta c \) represents the change values of the unit cost and \( q \) is the yield.

3) \( n \) innovative firms. When all \( n \) firms are involved in innovation, the profit objective function of the \( n \) firms is

\[
\begin{align*}
\pi_n &= [ab(q_j + \ldots + q_j + \ldots + q_n)] \\
q_j &= (c-\Delta c)q_j, j \in [1,n] 
\end{align*}
\]
innovative combination and multiple-firm innovative combination on the market structure and performance.

**B. DATA CALCULATION ON HI, MARKET STRUCTURE, AND PERFORMANCE**

According to our analysis model, we conduct a statistical survey on the data of 150 phosphorous chemical industry firms from 2004 to 2016. The relevant indicators are calculated by the equations in Table 4, and the results are presented in Table 4 after the summary. Table 4 shows the market structure and performance data, reflecting changes in the number of firms’ HI, from 0 to 8, in the phosphorous chemical industry.

The parameters \(a, b, c, n, g, k, \Delta C\) of different industries differ. Although the data in the table above are only the characterization of the chemical industry enterprises, they reflect the essential law hidden behind the data. The primary conclusions are as follows. The HI of oligarchic competing firms is positively correlated with the market mechanism and performance. In other words, the more flexible the market mechanism, the more efficient the market. The correlation is illustrated by the fact that the HI of firms leads to the alteration of the gaming model of oligarchic competition, which goes a step further, resulting in changes in the external variables, which can all be judged by quantity. The conduct mechanism through which the HI among firms affects market mechanisms and the evaluation of the market mechanisms’ performance form a positive correlation, which would make a fundamental difference, thereby promoting the general development of the entire industry.

**C. QUANTITY ANALYSIS**

1) **PRICE AND PROFIT EFFECT WITH HI**

\[ a: \text{COMPARATIVE ANALYSIS OF OUTPUT QUANTITY OF INNOVATIVE FIRMS} \]

Table 3 shows that \(g\) out of \(n\) firms in the industry are involved in innovation, and the analytical results can be concluded as follows (Figure 1). (1) The output quantity of the innovative firms is larger than that of the firms in the industry without innovation, that is, \(q_{gm} > q_{oi}(m \in [1, g])\), where \(q_{oi}\) is the unit output quantity of one firm without innovation. (2) The output quantity of the firms without innovation is smaller than that of the firms before innovation, that is, \(q_{gk} < q_{oi}(k \in [g + 1, n])\). (3) When all the firms are engaging in innovation, the quantity remains more massive than that without innovation, that is, \(q_{nj} < q_{gm}(j \in [1, n], g = n)\). Therefore, it can be seen that under the same other conditions, only considering the impact of innovation, the innovation of firms in the industry will cause changes in the current output of firms, including that of innovative firms and firms without innovation. In the conditions mentioned above, the quantity of the innovative firms will increase, whereas that of the firms without innovation will decrease. Moreover, the quantity of all the firms will appear balanced when they are participating in innovation. \(CR_g\) is the optimum number of oligarchic competing firms. As the number of firms in an industry (all innovative) increases, the firms’ quantity decreases progressively.
**b: COMPARATIVE ANALYSIS OF THE GLOBAL QUANTITY**

The comparison in Table 3 shows that under the aforementioned supposed conditions, among the $n$ firms in the industry, $g$ firms have implemented innovation, and their global quantity is larger than that of all the firms before innovation, that is, $Q_{gm} > Q_{oi}(m \in [1, g])$, where $Q_{oi}$ is the global quantity of the $n$ firms before innovation. With the expansion of innovation in the industry, and after all, every firm engages in innovation, the quantity of an individual firm will likely decrease according to the points of the curve in the figure. The reason for this outcome is unknown, which also indicates that the global quantity will increase continuously (the middle curve in Figure 2).

![Figure 2](image2.png)

**FIGURE 2.** The trend of Profit, Quantity, and Price. Notes: The upper line represents the Profit, the middle line represents the Quantity, and the under-laid line represents the Price.

**c: COMPARATIVE ANALYSIS OF PRICE ($P$)**

The comparison in Table 3 demonstrates that under the aforementioned supposed conditions, $g$ firms engage in innovation, and their prices ($P$) are smaller than those all the firms before innovation, that is, $P_{gm} < P_{oi}(m \in [1, g])$, where $P_{oi}$ is the prices of $n$ firms before innovation. As innovation in the industry expands, the balanced prices will decrease continuously (the under-laid curve in Figure 2), thereby proving Schumpeter’s theory.

**d: COMPARATIVE ANALYSIS OF PROFIT ($\pi$)**

The comparison in Table 3 indicates that $g$ firms engage in innovation, and their profit($\pi$) is more substantial than that of the firms without innovation, that is, $\pi_{gm} > \pi_{oi}(m \in [1, g])$. Suppose that all $n$ firms engage in innovation. Their profit is smaller than that of $g$ firms with innovation, that is, $\pi_{nj} < \pi_{qm}(j \in [1, n])$, and innovative benefits would appear balanced (the upper curve in Figure 2), thereby proving Schumpeter’s theory.

2) **EFFECT OF MARKET STRUCTURE WITH HI**

**a: MARKET CENTRALITY OF THE FIRST FOUR FIRMS ($CR_4$)**

Based on the assumption of $n > 4$, it can be seen from Table 3 that under the above conditions, when there are four enterprises innovating at the same time, the market concentration ratio $CR_4$ reaches the maximum (the upper curve in Figure 3). When $n$ firms are engaged in the same innovation, the market concentration rate is $CR_{na} = CR_{qa} = 4/n$, and the innovation has no effect on the market concentration rate of $CR_4$.

![Figure 3](image3.png)

**FIGURE 3.** The trend of CR, HHI, and LI. Notes: The upper line represents the CR, the middle line represents the HHI, and the under-laid line represents the LI.

**b: HHI**

It can be seen from table 3 that under the above premise conditions, $g$ firms in the industry have implemented innovation, and the $HHI$ is greater than that of no enterprise in the industry innovates, that is, $HHI_{gm} > H_{oi}(m \in [1, g])$. As innovation in the industry expands, the $HHI$ will increase then decrease, during which a maximum point lying above $N^* = n/(t + 2)$ or nearby exists (the middle curve in Figure 3).

**c: LI**

As shown in Table 3, in the other presupposition, within $n$ firms in the same industry, $g$ firms implement innovation, whose $LI$ is higher than that of the firms without innovation, that is, $LI_{gm} > LI_{oi}(m \in [1, g])$. When all $n$ firms implement innovation, $LI_{gm} < LI_{oi}$ tends to decrease (the curve at the bottom of Figure 3). The degree of the market power in the competitive market and monopoly market tends to compete.

3) **EFFECT OF MARKET PERFORMANCE WITH HI**

**a: COMPARATIVE ANALYSIS OF CONSUMER SURPLUS (CS)**

Table 3 shows that in the presupposition mentioned above, $g$ out of $n$ firms in the same industry implement innovation, and their $CS$ is higher than that of the firms without innovation, that is, $CS_{gm} > CS_{oi}(m \in [1, g])$. As innovation in the industry expands, consumer surplus continues to increase (the middle curve in Figure 4).

**b: COMPARISON OF PRODUCER SURPLUS (PS)**

As indicated in Table 3, in the other presupposition, $g$ out of $n$ firms in the same industry implement innovation, and their producer surplus is higher than that of the firms without innovation, that is, $PS_{gm} > PS_{oi}(m \in [1, g])$ (the curve at the bottom of Figure 4). With the increase of firms innovation behavior, producer surplus will continue to increase to the maximum point, and then gradually decrease.
Although an oligopoly hopes to become a cartel to earn excess monopoly profits, this progress is generally impossible. The anti-monopoly law considers the prohibition of a disclosure agreement among oligopolies as the focus of public policy. Hence, occasionally, owing to the carving up of profits, battles among oligopoly members make a deal impossible. From the results of all the communication oligopolies in China, products and services seem to reach a certain equilibrium. Equilibrium can be inferred from several oligopolies, ultimately not making different decisions that benefit people. In other words, several interactive economic bodies assume that the others have established a strategy and thus select their optimal strategy. Hence, the Nash equilibrium emerges.

The example of the communication oligopolies illustrates the conflict between cooperation and self-regard. The results of the collaboration and achievement of monopolies can improve the situation of oligopolies. However, as they pursue their self-interest, they cannot accomplish a merger or maximize their share of profits. Oligopolies cannot resist the temptation to expand production and grab a large market share. When every oligopoly tries to do so, an invisible hand will increase the total quantity, and prices will drop.

Meanwhile, self-benefiting does not mean market competition. Oligarchs, similar to monopolists, realize that the more products they produce, the lower their prices. Therefore, they do not follow the rules of competitive firms (products are produced at marginal cost). Overall, oligarchs choose the best quantity, which is larger than the competitive quantity and smaller than the monopolistic quantity, thereby maximizing profit. The oligopoly price is lower than the monopolistic price but higher than the competitive price (marginal cost).

D. FURTHER DISCUSSIONS

The innovation portfolio of oligopoly firms positively correlates with its effect on the market structure and performance, which can be referred to as the innovative market structure effect. The competitive market structure verifies Joseph Schumpeter’s views from Samuelson’s research. Those views state that the more rational the market structure, the more effective the market. This effect is realized by changes in endogenous variable parameters, which are affected by changes in the exogenous variable parameters in the competitive oligarch model, and the innovation portfolio of a firm causes these exchanges. These changes and effects can be studied and determined through quantitative analyses. The chain of causation (the transmission mechanism from the innovation portfolio of a firm to the market structure positively correlates with the market structure and performance relations) would fundamentally affect the evolution of an industrial organization, thereby promoting the development of the entire industrial organization. The conclusions are analyzed, as follows:

1) The extension of a firm’s innovation portfolio would affect market concentration, which varies regularly toward the balance between a monopoly and a competition to improve the allocation of resources. In light of the
invariability of other conditions, if the firms in the industry have the same initial cost function and the cost function varies accordingly after the same (single) innovation, then market concentration will never change.

2) In light of the invariability of other conditions, if at least two firms in a market have exogenous sunk costs, then the price requested varies between a monopolistic price and a competitive price.

3) Similar to the $HHI$, the market concentration rate index ($CRN$) does not vary, but a positive correlation is reflected between concentration level and price. The market concentration rate is the endogenous variable determined by industry characteristics (pricing, advertising, research, and development costs). Therefore, the determination of the $CRN$ to the market structure should be considered. Overall, market size varies accordingly, with the concentration rate in a market having exogenous sunk costs. The market size has a negative correlation with the concentration rate in all the industries except for the most competitive ones. As innovation portfolio firms increase, the variation in the two indices first increases then decreases market competition.

4) Similar to the market $CRN$ and $HHI$, the $LI$ does not vary under the same conditions, which means that the $LI$ is adequate to measure the market structure. As innovation portfolio firms increase, the variation in the $LI$, which first increases then declines, does the market competition right.

5) The extension of the innovation portfolio in the industry and its innovation intensity (asymptotic, mutant, and primary types) affect the market quantity, consumer surplus, producer surplus, total social surplus (social welfare), and profit. Under the assumed conditions, the market price will decline continuously as the number of innovation portfolio firms increases. Market quantity increases steadily and profit, consumer surplus, and total social surplus (social welfare) increase. Nevertheless, producer surplus first rises then declines. Changes in producer surplus correlate with demand functions, firm original cost functions, and the marginal costs of reduction caused by the innovation portfolio. Consumer surplus, producer surplus, total social surplus (social welfare), and profit are higher than those not affected by innovation portfolio extension and the social welfare maximization principle, and a new Nash equilibrium between consumer and producer surplus and market forces is realized, whereby alleviating the huge conflict between producers and society.

6) The prices of crude oil and other products from the China National Petroleum Corporation(CNPC) and China National Offshore Oil Corp (CNOOC) are consistent with international market prices, thereby creating enormous producer surplus. How the three corporations earn excess profits can explain the different observations, where foreign and domestic markets are involved. People believe that earning money from the global market on the condition that the domestic need is provided is fair, and the key point lies in whom the excess profits are given. As far as consumers are concerned, the better the quality of goods or the more considerate the service received, the better the same amount of money is paid. The same is valid in a perfect competition, a monopolistic competition, an oligopoly, and a monopoly.

7) Market structure conditions positively correlate with market performance conditions. Under the assumed conditions, when all the firms in an industry innovate, the market concentration rate and market forces have minimum values. However, consumer surplus and total social surplus (social welfare) have maximum benefits. In other words, as innovation portfolio firms increase, the market structure changes from concentration to separation, the market force declines accordingly. However, market performance improves continuously, and a producer gains innovative excess surplus from the aspects of consumer surplus and total social surplus (social welfare). Therefore, being affected by the innovation portfolio, $CRN$, $HHI$, and the $LI$ positively correlate with market performance.

8) Innovation portfolio firms exert pressure on non-innovation firms, whose quantity and profits are minimal. A competition mechanism is created, promoting non-innovation firms to change; thus, the behaviors of firms in this industry change accordingly. Moreover, corporate behavior within the industry will likewise change. The causal chain of firm innovation behaviors or actions affecting the market structure and market performance will lead to the development of the sector as an entire organization. This result is one of the main connotation goals longed for by an innovation-oriented country.

9) The state of the industrial organization should determine the perfect intensity of market forces under the maximization of social welfare and the homeostatic principles of consumer and producer surplus [14]. Otherwise, monopolies should be broken up to maintain the long-term equilibrium state. The principle involves achieving equalization among oligarchs, and the evolution of the number of oligarchs should proceed toward the direction of a monopolistic competition and perfect competition.

10) Innovative firms should pay the government excess surplus from innovation benefits generated by the government’s incentive policies. Nothing is wrong with firm performance, and governments consider the maximization of value as their goal. Firms pursuing profit maximization should be based on maintaining their hold on the market. To pursue interest maximization for ordinary people, governments should focus their functions on justice and stabilization.

11) The uniform conclusion and qualitative judgment of the four types of market structures, namely, a perfect competition, a monopolistic competition, an oligopoly, and a monopoly, and their performance can be described as follows. For consumers, among goods or services obtained at the same cost, high-quality products are better than standard products, which in turn are better than low-quality products. Low-quality products are better than adulterated products, which in turn are better than no-quality products. The pros and cons of a perfect competition, a monopolistic competition, an oligopoly, and a monopoly are similar. The combined effect of systematic collaborative innovation behavior from
HI can enable these four types of market structures and their performance to accelerate evolution to upgrade industries.

III. INTRODUCTION OF DECISION-MAKING SOFTWARE

A. SYSTEM OVERVIEW

1) System role and its significance. The assessment model can provide users with scientific and convenient means and a reference to economic indicators. The simulation evaluation system software developed through software engineering and information processing technology can calculate the results of the evaluation model and form research reports automatically once users input related parameters. Such a calculation model can solve (with a calculator, a spreadsheet software, and manually) a series of problems of existing research and analysis methods, such as computational complexity, duplication, inefficiency, unreliable conclusions, requirements for professionals to complete, and so on.

The application of this simulation software for analyzing and evaluating the state of an industrial organization can explore the economic and practical economic evaluation methods that non-economic experts employ, which can help promote the development of economic market structure and performance measurements and evaluations.

2) Range of application. This simulation evaluation system can provide a means for auxiliary calculations and analyses for economic research and teaching and scientific research and analyses and decision making for industry structure and performance measurement; generate a high level of efficiency; and provide a highly comprehensive evaluative index system, research data, and reports. It can also provide auxiliary calculations and means for scientific research, leading to fast and accurate research and decision making for individuals engaged in economic work or teaching research, corporate strategic planners, government macro- or microeconomic managers, or other economic and non-economic professionals.

3) Characteristics of the system software. This system software, which is easy to operate without special maintenance requirements, is a single-user stand-alone system with a C/S mode. It can be operated by anyone with a basic knowledge of computers. The software supports a variety of formats for research reports, and users can arbitrarily modify the form and content of a research report according to the software’s modification rules. Moreover, texts, figures, images, and multimedia objects can be embedded in research reports. The program is a green software that does not need unique configurations or to be installed. Furthermore, it can run on an ordinary PC with Windows XP and Word 2000 after it is copied directly to the computer’s hard disk or U disk.

B. SYSTEM FUNCTIONS AND PROCESSES

The system consists of five modules, that is, project management, data processing, report processing, dictionary management, and system management, with the market structure as the indicator model, market performance as the mathematical model, and the performance report templates of several industries. Users can create and modify a report template for their industry. The system operation process is as follows: log on and identity verification to start up the system → project management → data processing → figure display → report forming → data backup.

C. DATA PROCESSING MODULE

The data processing module contains three modules, that is, data input, data calculation, and figure display. The main interface of the data processing module is shown in Figure 5 and divided into left and right parts. The left part is used to display the calculation results (data tables and figures), and the right side consists of the control panel and data input box. The data table in Figure 5 demonstrates the market structure and performance data displayed by category.

The input indicator calculation variables are at the top right side of the control panel, such as the price variable constant (a), the quantity variable constant (b), marginal unit costs (c), the marginal cost of the change value (ΔC), innovative fixed costs (CFC), the total number of industries and firms (n), and the number of innovative firms (N). When inputting these data, the system has control over the input operation and can automatically determine the legitimacy and rationality of the input data. After the data are inputted, clicking the data calculating button will generate the data, as shown in figure 5. The bottom right side of the control panel (shown in Figure 6) contains three cards representing documents, data, and figures, which are used for saving and reading the calculation data and displaying them in the controlling data table (font size and line spacing), figure display mode, and content.

The social welfare indicator data are taken as an example to illustrate the use of the graphic operation. The figures include five display cards (the top of Figure 7) representing price profit indicators, social welfare indicators, quantity indicators, market structure indicators, and cost indicators. For the curves shown in each card, users can set the display position of the figure and decide whether to show the node data or only the specified curve. The displayed curves can also be zoomed, rotated three dimensions, displayed on a full screen, and moved in the horizontal direction of the abscissa axis or the vertical direction of the longitudinal axis. These curve display control functions are convenient for users for reading and analyzing, significantly when the curves and data increase. Many operations can be completed simply by ticking off corresponding indication positions.

1) Curve display setting. Users can set whether to display the data of the curve node. Users can also set the display position of the example figure and tick off the curve to be displayed.

2) Report processing module. The report processing module includes a browser report, a design report template, and report file generation. The operations of the browser report and design report template are completed with the aid (call) of the system’s external MS Word software. The system uses the Object Linking and Embedding (OLE) technology for the
request. After the variable data are inputted, a report can be generated. While a story is developing, the user is asked to input the file storage location and file name by selecting the reporting template file and report file options.

D. KEY TECHNOLOGIES

In the development process of the system software, OLE, object-oriented programming, component technology, 3D figure display technology, database technology, document templates, the WORD software domain, and many other techniques are adopted. These techniques are highly integrated, among which OLE technology is used for reporting the call of documents and the WORD software domain for reporting the generation of materials. The adoption of these techniques can help improve the system software’s expandability, programming efficiency, and flexibility.

Given that the system uses a small amount of numerical data and a large amount of file data, a free mini-database program (ACCESS) is used for the data storage of storage project attribute data and dictionary attribute data. In addition, a document file storage technology is employed for storing additional documents, such as image files, mathematical formulas, other files, and so on. Standard Structured Query Language (SQL) statements are used to access the database to facilitate the replacement and expansion of the database system in the future. This process can enhance the performance of the database and support the storage of large files and is conducive for supporting a variety of data formats, which can change demand and help in portability demanded by users and convenient system upgrades in the future.

IV. SUMMARY

A. MAIN CONCLUSIONS AND CONTRIBUTIONS

This study constructs a decision-making model and software based on primary game theory and conducts data experiments. The results reveal that the innovation system behavior of monopoly, oligopoly, and perfect competition firms has an interactive and positive correlation with the market structure and performance. In other words, the systematic practice of innovation is stimulated to form a competitive market
structure and performance. This study confirms Schumpeter’s view that the innovation system can make the market structure highly reasonable and improve market efficiency by reducing marginal cost. This type of influence is caused by the HI system, which leads to changes in the endogenous variable parameters in the oligopoly competition game model. These influences and modifications can be judged and determined quantitatively. When firms’ innovation behavior accumulates and the HI system chain forms, the “enterprise adaptive innovation system mode” gradually increases to a (regional) “industrial innovation system mode.” The transmission mechanism of its (CSP) influence will have a fundamental impact on the evolution of the industrial organization and promote the development of the entire industry.

This study has three main theoretical contributions. First, it explores the controversial issue of structure and behavior determinism from a new perspective. Ding (2012) [35] debated on the determinism of structure and behavior and believed that the relationship between the two is complicated and should be intertwined. Nonetheless, their fundamental relationship should be interactive. Through theoretical analysis, this study generally indicates that the intricate relationships between conduct, structure, and performance are commonly involved. However, their primary relationship is interactive. Our study responds to the review of market structure theory that the broad application prospect of game theory and the Chicago School reflects the main stream of the development of market structure theory, which nevertheless must be explored and verified (Qi, 1998) [36]. Moreover, our analysis of the game theory model partly proves the “conduct–performance” path. Additionally, this study responds to the viewpoint, that is, the new methodology and theoretical scope are expanded, thereby placing exploration on the impact of the systematic behavior of firms or HI on market structure and performance for academic research under the context of modern industrial organization theory (Hu, 2011) [37].

Second, this study presents the boundary of the influence of market structure on market performance in the Chinese context. Primarily, this study partly responds to Sun (2002) [38], holding that, from the perspective of the effect of China’s market structure and performance, a comparative perspective can be adopted. Specifically, for consumers, when paying the same price, the goods or services obtained should be superior to quality ones, which are better than inferior ones. Moreover, inferior products are better than no products regardless of the market structure, such as a perfect competition, a monopoly competition, and an oligopoly, which are the same. However, our conclusion supports the rationality of the viewpoint of Huai and Liu (2007) that “the relationship and influencing factors between market structure and performance is reasonable” (Huai & Liu) [39]. Accordingly, our research on the relationship between consumer surplus, producer surplus, and total social surplus in the performance analysis makes up for existing consumer behavior analyses under particular regulations.

Third, the relationship between HI and the market structure is expanded. In the article by Zhou (2013) titled “The relationship between market structure and enterprise innovation: a literature review,” the author points out that “most scholars usually assume the market structure as an exogenous variable not affected by enterprise technological innovation in static research on the impact of market structure on enterprise innovation behavior. In fact, the innovation behavior of enterprises in the industry has an important impact on the evolution of market structure Impact” [40]. Our analysis in this study illustrates that “the HI in the industry has an important impact on the evolution of the market structure” and complements the traditional SCP model. Additionally, this study expands the research of Li (2009), which stated that the relationship between technological innovation and the market structure challenges the neoclassical static equilibrium method and the belief that a perfectly competitive market structure can maximize efficiency [41].

Moreover, industrial organization theory based on neoclassical theory attempts to verify the Schumpeter hypothesis from the perspective of experience but does not obtain precise results. Thus, the results of this study are clear. Furthermore, though a large number of achievements have been confirmed in the analysis of firms’ innovation behavior and market structure by using the game theory method, these conclusions are formed under rigorous assumptions, which are highly sensitive to the assumptions and therefore lack generality,
and are difficult to verify empirically. This study solves the problem proposed by Li (2007) [42]. Experience can be verified directly by using the general “input index function group” as the hypothesis.

Briefly, this study solves the interactive process of the relationship between firms’ innovation and the market structure from the dynamic process of industrial development by HI using industrial development theory. In addition, this study presents the channel of the “research path between neoclassical mainstream economics and nonmainstream economics” in the existing domain and explains “mainstream research with a high general theoretical framework.”

B. POLICY IMPLICATIONS

The core of this research on the relationship between firms’ innovation and the market structure is to reveal the internal mechanism of the interaction between the characteristics of firms’ innovation and the market structure, which has substantial theoretical and practical value. We apply this theory to China’s industrial technology innovation system, which can differentiate the behavior of enterprises in the market, thereby solving two problems. First, the software system developed according to the model can provide a reference index for firms to find their position in the market structure to improve the design and implementation capability of corporation strategies or their market strategies to increase their product innovation. Second, as the HI data (firms’ output, price, and profit) is input, the software automatically deduces the changes of indicators through repeated iterative optimization calculation with the game theory, after that predicts the optimization level of market structure and performance. The results can provide a reliable basis for policymakers. More importantly, the software is exceedingly applicable to all kinds of industries. Here is a single example, if the government hopes to keep market performance/efficiency unharmed by its competition structure, to form an oligopoly status, it can adopt several subsidies or tax policies to achieve this goal. However, if the government wants to balance the competitive power of an industry, it can also use corresponding strategies to achieve this goal.

V. LIMITATIONS

This study differs from those on the traditional SCP model in emphasizing the concept of HI, containing the intentions of policymakers and strategy makers. Therefore, under this HI framework analysis, the entire market and performance will change inevitably. Undoubtedly, such an analysis framework can provide a new understanding and ideas for entrepreneurs, governments, and scholars. This study is challenging mainly because determining the value (how vital) and difficulty of the research (interdisciplinary research) will require a long time period. From the value aspect of this study, because HI is policy-driven (similar to the revival of the Keynesian non-mainstream schools), it contradicts the liberal school theory of mainstream economics, and mainstream economists may not recognize it as absolute risk. A problematic aspect of this study is that it is a cross-disciplinary combination; thus, it requires mathematical economics theories and computer (simulation) technology as well as other social sciences. Such combinatorial research (methodology) is extremely challenging. Specifically, the current economic game of large countries involves numerous unexpected aspects of the economy, which surprises many researchers to a certain extent, thereby leading to a limitation in the current scale of studies. We searched the recent literature but found no contributive research, thereby proving that this investigation is challenging. Furthermore, we believe that research on HI, the market structure, and performance has substantial research value, and in-depth analysis using information technology is highly advisable.

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