

## Research Article

# The Growth Model of Industrial Internet Platform in Industrial 4.0

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The development of industrial Internet platform is an important carrier to realize the innovation of Industry 4.0. This paper analyzes the development mechanism of Chinese industrial Internet platforms from three aspects of motivation, incentives, and constraints, summarizes the influencing factors of platform development, and establishes a growth model of industrial Internet platform, to select representative factual data as observation variables to verify the effect of each factor. In the end, this paper puts forward relevant suggestions for the government, platform companies, and other related parties to drive the realization of Industry 4.0.

## 1. Introduction

As the forerunner of the fourth industrial revolution, the industrial Internet which integrates IT and OT has become a new engine for the high-quality development of China's industry. Industrial enterprises rely on the industrial Internet to complete the storage, management, and in-depth application of industrial data [1]. The industrial Internet platform as the core of industrial Internet promotes the realization of Industry 4.0 through vertical integration, end-to-end integration, and horizontal integration of enterprises. Developed countries have built a number of industrial Internet platforms with comprehensive strength, such as Siemens' mind sphere, GE's Predix, and Dassault's 3dexpress. Although a number of cross-industry and cross-field platforms such as Haier COSMO platform, Ali Super Et, and Yonyou cloud have been formed in China, compared with the platforms of developed countries, the core technology of industrial Internet platform construction is still short board. Moreover, the current platform development situation is still difficult to appear a platform with the ability to solve all industry problems, and the existing comprehensive platform has gradually turned to mining their own good industry field. Therefore, the development of industry-level

industrial Internet platform is the only way to guide the construction of industrial Internet platform.

This paper analyzes the influencing factors of the development of industry platforms from the three aspects, summarizes the influencing effects between various influencing factors, and establishes the growth model of industrial Internet platforms. It is hoped that this paper can enrich the theoretical research on the industrial Internet platforms and provide new thinking directions and some suggestions for the development of platforms to promote the development of Industry 4.0.

## 2. Literature Reviews

At present, there are three main research contents about the development of industrial Internet platform. The first is to discuss the construction and governance of the platform from the perspective of technology development or strategic management. Scholars have selected the business models of GE and Siemens as representatives to study the value cocreation growth model of industrial Internet platform enterprises [2]. Li et al. [3] proposed practical value of the reference architecture and assessment framework of IIP to evaluate the usage of IIP from three aspects of foundation, key capability, value, and

benefit and verified it by an industry practice. Menon et al. [4] analyze the perceived impact of platform openness from the perspective of industrial Internet platform providers and end users, helping managers make better decisions from all sides. Dos Santos et al. [5] visualize several links between the technologies of Industry 4.0 to reach distinct industrial performance goals to assist managers in the planning and execution of technology networks for Industry 4.0.

The second is to discuss the economic role of platform enterprises, including the regulation of bilateral markets, the cross-border network effects, and the access and pricing of platforms. Zhang and Yu [6] built an industrial Internet platform for the collaborative management and control of the supply chain and proved that the platform has a significant effect on improving the efficiency of supply chain management from the economic benefit forecast.

The third is the research on the innovation management of industrial platforms. Y. Zhang et al. [7] analyzed the collaboration mechanism between distributed participants to solve the manufacturing service collaboration problem under a blockchain-based industrial Internet platform, so as to promote the wide application of IIP. Menon et al. [8] analyzed and understood the potential role of industrial Internet platforms in the management of product lifecycle-related D-I-K as well as presented in detail managerial implications toward long-term and sustainable selection of industrial Internet platform. Eisenmann [9] summarizes the results of a multiyear research project on platform strategies to guide the development of the platform from different perspectives.

However, in terms of research content, the existing studies consider the development of industrial Internet platform from a single perspective, resulting in one-sided findings. The theoretical research on the development mechanism of the industrial Internet platform is insufficient, and there is a few literature on the macroplatform development proposal. In terms of analytical methods, there is a lack of research that combines both qualitative and quantitative approaches; much of the literature analyzes the influencing factors of the platform growth through only one method. In response to research gaps and the inadequacy of the existing analytical methods, this paper proposes the following innovations:

- (1) This paper constructs a growth model of industrial Internet platform and analyzes the platform development from the four aspects of supply, demand, support, and constraints. It effectively avoids drawing one-sided theoretical conclusions based on a single perspective of platform enterprises
- (2) This paper uses qualitative and quantitative methods to analyze and verify the influencing factors of platform growth, which can provide theoretical guidance for the development of industrial Internet and the implementation of Industry 4.0

### 3. Method

*3.1. Qualitative Analysis on the Development Mechanism of Industrial Internet Platform.* This paper selects advanced

and demonstrative industrial Internet platforms in the four industries of bearings, auto parts, molds, and textiles and uses grounded theory to design interview content, obtain research materials, code research materials, and sort out logical relationships. On the basis of 30 research materials, 5 main areas affecting the development of the platform were obtained, namely, the growth ability of platform enterprises, the market demand of industrial enterprises, the support and encouragement of policy environment, the technology ecology of platform construction, and the cloud environment for enterprises to go to the cloud, which were divided into three aspects: power mechanism, incentive mechanism, and constraint mechanism. Finally, the final coding content of the 4 prereserved interview materials was compared with the coding content obtained above, and it was found that there was no new encoding, which proved that the previous code is reasonable and the factor extraction was effective.

#### 3.1.1. Dynamic Mechanism Analysis

##### (1) The Driving Force of Platform Enterprises.

- (i) The Driving Force of Platform Enterprise Profitability. The role of profitability in promoting enterprise growth has been proved by scholars for a long time. The projects of platform enterprises need to estimate the cloud transformation time according to the degree of digitalization of industrial enterprises, and the long payback time will make the early-stage companies face greater financial pressure. The development level of industrial Internet platform service providers directly reflects the development of industrial Internet platform. The growth ability of platform enterprises is the endogenous driving force of platform development, and the profitability of the enterprises is the direct driving force of platform development.
- (ii) The Driving Force of Talent Team in Platform Enterprises. Talent is one of the important factors of long-term stable economic growth. Talents drive innovation and successful output of application; they are the backbone of the platform development. With the transformation of manufacturing industry and the advancement of industrial digitization, the demand for digital talents in the industrial economy will continue to expand. However, the existing digital talents in China cannot meet the huge market demand. Enterprises must pay attention to the construction of talent teams and build their own talent-training model to avoid the dilemma of talent-constraining development.
- (iii) The Driving Force of Technological Innovation Ability. Technological innovation capability is another important factor in ensuring long-term stable economic growth. The platform ecosystems rely on complementors who enhance the value of platforms by creating complementary technologies [10]. The industrial Internet platform is a deeply integrated application of various high and new technologies,

and the technological innovation is the main supporting component in the process of platform construction. The technological innovation ability of enterprises directly determines the function realization and reliability of the platform. Industrial enterprises with stronger technical strength have higher operability for accessing process data, and the companies in the same industry will spread to the cloud faster. The speed and magnitude of the platform's diffusion largely determine the survival and success of all the stakeholders in the value chain [11]. Openness to applications directly influences the participation intention of application developers as well as the user base of the platform. From the perspective of user scale, an increased user base leads to the enhanced participation intention of application developers through indirect network effects [12].

### (2) *The Driving Force of Industrial Enterprises.*

- (i) *The Pulling Force of Market Competition of Industrial Enterprises.* Market turbulence and competition jointly influence the direction and strength of the performance effect of firm innovativeness [13]. The more industrial enterprises in the same industry, the fiercer market competition will be. During the past two decades, many advanced manufacturing models and technologies have been proposed to realize TQCSEFK for manufacturing enterprise [14]. Now, competitive pressure still promotes the digital transformation of industrial enterprises, increases the demand of enterprise cloud platform, enables industrial enterprises to actively understand the functions of industrial Internet platform, and also promotes the platform to develop targeted function which meets the requirements of industrial production and can be applied quickly.
- (ii) *The Pulling Force of Transformation and Upgrading of Manufacturing Industry.* High production efficiency promotes the development of enterprises. The application of new technologies can help companies save resources and improve production efficiency and profits. Under the background of the transformation of manufacturing industry and the high-quality development of the economy, the industrial enterprises that uses traditional manufacturing mode have a demand for digital transformation and upgrading, which stimulates the pace of enterprise cloud, excavates huge market potential for the development of the industrial Internet platform, and promotes the development of the platform.

*3.1.2. Incentive Mechanism Analysis.* Favorable policy environment has a good incentive effect on the development of the platform. Facing platform enterprises, Chinese government issued various training policies and established a special working group of industrial Internet, which accurately assisted with industrial Internet development and the integration applications and opened up a way for the develop-

ment of platform enterprises. For industrial enterprises, the government has launched enterprise cloud programs, cloud benchmarking subsidies, and other policies, which reduces the financial pressure of industrial enterprise cloud, help enterprises to recognize the trend of industrial economic transformation, and put forward more viable solutions for the long-term development of enterprises [15]. The platform support policy and enterprise cloud policy released by government can effectively push the scale development of platform, promote the platform side to expand their user scale and the industrial enterprise side to study the digital production management mode, and create a good supply and demand policy environment for both sides.

In addition, the intermediary agencies in the external environment also have a certain incentive effect on the development of the platform. Intermediary agencies mainly include financial institutions, research institutions in various fields, think tanks, industry associations, and industry alliances. With the support and promotion of the government, financial institutions issue preferential financing policies for platform construction and users to promote the development of the industry. By publishing the latest industry trends and jointly promoting the formation of technical standards, research institutions effectively promoted the healthy and orderly growth of industrial Internet platform.

### *3.1.3. Constraint Mechanism Analysis*

*(1) Constraints of Platform Construction Technology Ecology.* The construction technology of industrial Internet platform is still in continuous exploration, and the bottleneck of platform technology development has emerged. Analyzing according to the architecture of the platform, in terms of information infrastructure layer, firstly, the network environment of the platform still needs to be further improved, the industrial 5G network has not been covered in some counties and townships, and the problem of transmission delay in industrial network also needs to be solved; secondly, there are difficulties in data collection, analysis, and transmission; and thirdly, the edge computing ability still needs to be strengthened. In the platform layer, the lack of sharing mechanism between microservice components and industrial database leads to the repeated development of common modules on many platforms, resulting in resource waste and development lag. In the aspect of application layer, the supply of industrial software is short of variety and supply capacity, which cannot effectively meet the needs of enterprise users, and most industrial software lacks independent innovation, which cannot resist the risk of technology monopoly. The imperfection of technology ecology reduces the development speed of industrial Internet platform, which is not conducive to the long-term healthy development of the platform.

*(2) Constraints of Cloud Environment for Enterprises.* Environmental factors include laws and regulations, market competition, or societal factors [16–19]. Enterprise cloud environment is still in the embryonic stage. As the market supply is not perfect, the cross-regional service capability

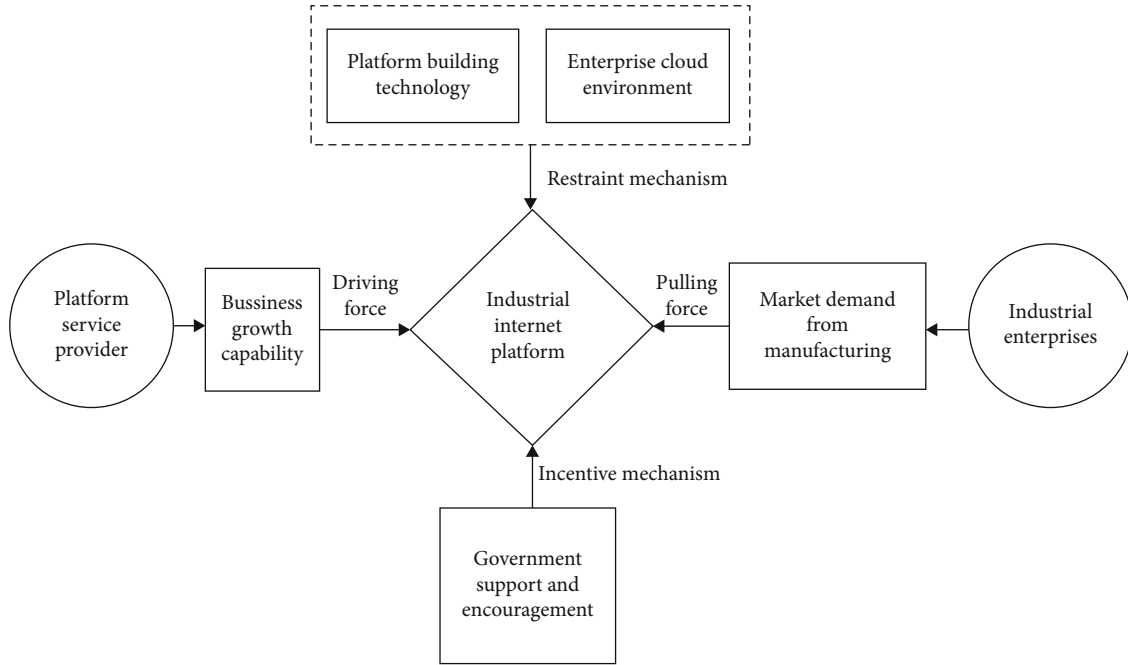


FIGURE 1: Schematic diagram of the impact mechanism of industrial Internet platform development.

of the platform is not enough, the choice of industrial enterprise cloud is relatively narrow, and the cost of enterprise cloud, including equipment transformation costs, software and hardware purchase costs, and platform service costs, is often high, as well as the latter use of the platform needs to be equipped with personnel and system maintenance costs, which all hinder the process of going to the cloud [20]. What is more, there are certain risks associated with the monitoring and security functions of the platform, which can cause immeasurable damage to industrial enterprises, and the security and stability of the cloud environment still need to be improved. The digital level of enterprises before going to the cloud and the cost of going to and using the cloud are both deterrents to the willingness to use the platform. Besides, the legal environment regarding intellectual property rights, data transactions, and other issues of responsibility and rights with the cloud is not yet perfect, and the risks of using the cloud cannot be fully controlled. These concerns also form a constraint mechanism for platform development.

To sum up, this paper argues that the dynamic mechanism of industrial Internet platform development is formed by the joint action of the driving force of platform enterprises and the pulling force of industrial enterprises. Profitability, talent team strength, and technological innovation ability constitute the growth ability of platform enterprises to drive the development of the platform. Competitive pressure and the demand for transformation and upgrading of manufacturing industry constitute the market demand of industrial enterprises to pull the development of the platform. Government, financial institutions, and other intermediaries stimulate the development of the platform. The technical ecology of platform construction and the environment for enterprises to use the cloud constitute the constraint mechanism, which limits the speed of plat-

form development. The specific dynamic mechanism is shown in Figure 1.

### 3.2. Quantitative Analysis on the Development Mechanism of Industrial Internet Platform

**3.2.1. Indicator Selection.** The growth model of the industrial Internet platform has been constructed, and the five major influencing factors have been qualitatively analyzed. In order to objectively verify the effect of the influence of each influencing factor, this paper takes these five factors as the independent variable and the platform development as the dependent variable and selects the corresponding measurement indicators to represent the connotation of each variable to verify the correlation between the variables.

This paper selects the development of industrial Internet platforms in various provinces and cities nationwide as the research object and verifies the comprehensive effect of influencing the development of the platform with cross-sectional data such as the development of the digital economy, the R&D investment of industrial enterprises, and the promotion of platform projects in various provinces and cities in China in 2019. This paper selects the number of platforms and projects publicly promoted by the Ministry of Industry and Information Technology as of September 2020 as the output data to measure the development level of industrial Internet platforms in various regions. The indicators reflecting the influencing factors come from the “2019 China Science and Technology Statistical Yearbook,” “2019 National Statistical Yearbook,” “China New Infrastructure Competitiveness Index White Paper,” “China Digital Economy Index 2019 Report,” and “Big Data City Cyber Security Index Report,” with a total of 13 indicators. The 13 indicators are shown in Table 1.

TABLE 1: Influence factors on the development of industrial Internet platforms.

(a)

Categories	Enterprise growth ability in high technology industries			Cloud demand of manufacturing enterprises of standard-sized industrial enterprises			
Influence factors	R&D personnel full-time equivalent	Internal expenditure on R&D	Number of valid invention patents	Revenue	External expenditure on R&D	Internal expenditure on R&D	Enterprise funds in R&D internal expenditure sources

(b)

Categories	Government policy support		Platform construction technology ecology		Cloud environment for enterprises	
Influence factors	Expenditure on science and technology	Funds in R&D internal expenditure sources	New infrastructure competitiveness index	Digital economy index	Innovation capability ranking	City corporate cybersecurity index

**3.2.2. Data Analysis.** According to the measurement indicators selected, this paper statistically forms 12 index data of 31 provinces and cities across the country. We used SPSS software to analyze the quantitative relationship of each influencing factor. It is observed that the indicators differ significantly in the size of the values and the range of numerical changes is large. So first of all, the data should be standardized, and then, the linear correlation between the indicators and the number of industrial Internet platforms (projects) should be analyzed for each index after standardization. The correlation results in Table 2 show that the number of industrial Internet platforms (projects) in various provinces and cities in China has the highest correlation coefficients in the three variables of “innovation ability ranking,” “new infrastructure competitiveness index,” and “digital economy index,” which are 0.820, 0.763, and 0.732, respectively, and the variables related to the full-time equivalent of R&D personnel in high-tech enterprises are excluded.

On the basis of verifying the correlation, the regression model was used to study the relationship between the influencing factors and the construction of industrial Internet platforms in various provinces of China. Using the least squares method to calculate the regression equation parameters, it is found that the multicollinear influence of the economic index data is high, and the variance expansion coefficient of more than 5 factors in the regression results is greater than 10, so the regression results cannot be used as a strong proof of the effect of each factor. Looking at the numerical law of various indicators, it is found that the data from the statistical yearbook reflect similar gaps between provinces and cities, resulting in a significant multicollinearity. Therefore, the stepwise regression method is adopted to eliminate the indexes with the coefficient of variance expansion greater than 10 and obtain the five indicators of new infrastructure competitiveness index, high-tech industry R&D internal expenditure, government funds in the internal expenditure source of industrial enterprise R&D, industrial enterprise R&D internal expenditure, and urban enterprise network security index, using the least

squares method to regress these five remaining indicators. Finally, the valid data indicators and regression effects are shown in Table 3.

## 4. Discussion

In the regression result obtained by the least squares method, it was found that the variance expansion coefficient of each indicator is less than 10, which proves the rationality of the final result. According to Table 2, although the coefficient significance of each variable is not high, it meets the significant level of 0.05, which verifies the influence of the above factors. The standardized impact coefficients show that the New Infrastructure Competitiveness Index has the most significant effect, with a standardized coefficient of 0.538, followed by Industrial Enterprise R&D Internal Expenditure and High Technology Industry R&D Internal Expenditure, with standardized coefficients of 0.452 and 0.440, respectively, and the Urban Enterprise Cybersecurity Index and Government Funding in Industrial Enterprise R&D Internal Expenditure Sources also have a certain impact on the number of industrial Internet platform projects in the final region. According to the corresponding influencing factors of each variable, the influence of each factor on the development of local industrial Internet platforms can be concluded from a macroperspective. The technology ecology has the greatest impact on the development of the industrial Internet platform and the willingness of industrial enterprises to go to the cloud, and the technical level of the platform enterprises themselves also plays a higher weight of influence. In addition, policy support has also played a role in promoting the development of local industrial Internet platforms.

The correlation test and result analysis can provide some suggestions for the development of industrial Internet platforms:

- (1) The technological innovation capability of the platform construction is an important reference indicator for the development of the platform and the

TABLE 2: Correlation of variables.

	High-tech industry R&D personnel full-time equivalent	Internal expenditure on R&D in high technology industries	Number of valid invention patents in high technology industries	High technology industry revenue	External expenditure on R&D by standard-sized industrial enterprises	Internal expenditure on R&D by standard-sized industrial enterprises	Enterprise funds in R&D internal expenditure sources of standard-sized industrial enterprises	Government expenditure on science and technology	Government funds in R&D internal expenditure sources of standard-sized industrial enterprises	New infrastructure competitiveness index	Digital economy index	Innovation capability ranking	City corporate cybersecurity index	Number of industrial Internet platforms and projects
High-tech industry R&D personnel full-time equivalent	1	.995**	.962**	.977**	.956**	.867**	.867**	.909**	.742**	.433*	.759**	.754**	0.287	0.393
Internal expenditure on R&D in high technology industries		1	.963**	.984**	.960**	.876**	.875**	.923**	.771**	.466*	.782**	.783**	0.311	.425*
Number of valid invention patents in high technology industries			1	.944**	.964**	.735**	.733**	.889**	.733**	0.340	.683**	.717**	0.190	.412*
High technology industry revenue				1	.926**	.870**	.869**	.911**	.752**	.470*	.771**	.789**	0.328	.415*
External expenditure on R&D by standard-sized industrial enterprises					1	.824**	.822**	.917**	.789**	.427*	.767**	.761**	0.295	.441*
Internal expenditure on R&D by standard-sized industrial enterprises						1	1.000**	.826**	.701**	.593**	.821**	.756**	.476*	.404*
Enterprise funds in R&D internal expenditure sources of standard-sized industrial enterprises							1	.823**	.689**	.589**	.816**	.751**	.474*	.399*
Government expenditure on science and technology								1	.798**	.659**	.885**	.916**	.444*	.644**
Government funds in R&D internal expenditure sources of standard-sized industrial enterprises									1	.503*	.762**	.753**	0.304	.421*



TABLE 3: Regression analysis results.

	Unstandardized factor <i>B</i>	Standard errors	Standardized factor Beta	<i>t</i>	Significance	Tolerance	Collinearity statistics VIF
(Constant)	1.34E-15	0.134		0	1		
New infrastructure competitiveness index	0.53	0.057	0.538	9.395	0.003	0.313	3.191
Internal expenditure on R&D in high technology industries	0.54	0.078	0.44	5.627	0.01	0.17	5.874
Government funding from internal R&D expenditure sources in industrial enterprises	0.137	0.065	0.137	2.113	0.047	0.372	2.685
Internal R&D expenditure of industrial enterprises	0.552	0.067	0.452	6.714	0.012	0.181	5.531
City corporate cybersecurity index	0.153	0.071	0.153	2.159	0.039	0.378	2.646

enterprises' access to the cloud. The technological innovation capability of platform enterprises is the endogenous driving force of the platform and is an important reflection of the growth capability of high-tech industries. Innovation can reduce cost and improve performance and product quality; thus, the competitiveness of industrial enterprises will enhance. The technological innovation capability directly determines its empowering effect and is the driving force for platform users to go to the cloud

- (2) The demand for industrial enterprises to go to the cloud is the main pulling force for the development of the platform. Users are the main source of profit for the platform and the basis for the platform to survive. After accumulating a certain scale of users, the platform will basically get stable development under the influence of network effect. Therefore, the demand for industrial enterprises to go to the cloud is the direct driving force for the platform to accumulate the scale of users, pulling the rapid development of the platform
- (3) The support of the policy environment plays an important guiding and supporting effect on platform development. The government worked from both the supply and demand sides to promote and support industrial Internet platform service providers on the one hand and to enact subsidy policies for cloud-based enterprises on the other hand. Financial and research institutions and other intermediaries have contributed to easing the financial pressure on enterprises to go to the cloud, guiding the movement of platform development, and advancing the formation of technical standards. They provide a good policy support environment for the development of industrial Internet platforms together
- (4) The technical ecology of the platform construction is an important constraint mechanism for the development of the platform. The maturity of the deployment of the basic environment, including the construction of local basic information and the digitization of the economy, constrains the development of the platform

enterprise up; the integrity of the technical ecology, including the security of enterprise data, the stability of the production process, and the soundness of laws and regulations, is also an important factor that hinders users from using the cloud platform

- (5) Enterprise cloud environment is another constraint force for the development of industry platform

## 5. Conclusion

This paper analyzes the influencing factors of industrial Internet platform construction in China from three aspects and establishes a model of platform development influencing mechanism with the growth ability of platform enterprises as the driving force, the market demand of industrial enterprises as the pulling force, the support and encouragement of policy environment as the incentive mechanism, and the technical ecology of platform construction and the cloud environment of enterprise as the constraining mechanism. And this paper constructs a regression analysis model through data statistics to analyze the influencing factors; the correlation test and result analysis were conducted to conclude that the main factor affecting the construction of the industrial Internet platform is the technical ecology of the platform construction, followed by the willingness of industrial enterprises to go to the cloud and the technical level and then policy support.

However, in terms of data statistical analysis, due to the relatively short period of time for the construction of Chinese industrial Internet platform, the relevant data cannot be compared over the years, which leads to instability in the analysis results. And the cross-sectional macrodata can only reflect the macroimpact but cannot deeply explore the development impact mechanism of specific platform enterprises.

## Data Availability

The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.



## Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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