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Analysis of the Mechanism Through Which the Provision of Grassroots Public Services Influences the Vitality of the Local Private Economy

Pu Ge[1,*]

[1] School of Economics and Management, Beijing University of Civil Engineering and Architecture, Beijing 102616, Beijing, China

SUMMARY: *This paper studies the influence mechanism of grassroots public service supply on local private economic vitality. Aiming at the problem that the existing research has a coarse description of the role path and insufficient utilization of unstructured governance data, this paper constructs a multi-source data system composed of public service statistical indicators, government affairs platform operation records and enterprise feedback texts, and combines text mining, feature fusion and interpretable machine learning methods to carry out mechanism identification. The research is based on 4576 valid samples from 286 districts and counties from 2021 to 2024. The results show that the local private economic vitality index rises from 0.418 to 0.641, the growth rate of new establishment of private enterprises rises from 4.9% to 12.3%, the enterprise survival rate rises from 71.6% to 84.7%, and the innovation input intensity rises from 2.8% to 5.0% when the level of grassroots public service supply rises from low to high. Among them, the impact of government service efficiency and digital public information service is more prominent, with the average contribution of 27.4% and 22.1% respectively. Research shows that the improvement of grassroots public services can continuously enhance the vitality of local private economy by reducing institutional transaction costs, enhancing information availability and stabilizing business expectations.*

KEYWORDS: *grassroots public service supply; Local private economic vitality; Mechanism identification; Explainable Machine Learning*

1 Introduction

Under the background of regional economic competition gradually shifting from resource scale competition to institutional environment optimization, governance efficiency improvement and factor allocation quality improvement, the supply of grassroots public services is no longer just a basic arrangement to ensure people's livelihood, but has gradually become an important external condition affecting the vitality of local private economy. With the continuous development of digital government construction, government platform integration, grid governance and intelligent service system, the public service supply mode is gradually shifting from decentralized, passive and experience-driven operation to a new form supported by data interconnection, process collaboration and algorithm assistance. The accessibility, stability and response efficiency of grassroots services such as education, medical care, social security, government examination and approval, credit services, industrial information release and enterprise-related demand response will affect the business decisions of private enterprises through multiple paths such as transaction cost changes, adjustment of

*gp15753058325@163.com
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operating expectations, allocation of innovation inputs and market entry intentions. Traditional research focuses more on the overall level of institutional environment or business environment. However, in the face of the multi-dimensional differences, temporal fluctuations and spatial heterogeneity existing in the supply of grassroots public services, it is difficult to accurately reveal the specific effect process on local private economic vitality by only relying on linear experience judgment. Therefore, it is necessary to introduce multi-source data processing, feature extraction and mechanism identification models. A more nuanced computational analysis of this problem is performed.

In recent years, the discussion on the relationship between the quality of government governance, the optimization of business environment, the construction of digital government and the entrepreneurial activity of enterprises has deepened. It has been generally pointed out that public governance capacity will directly affect the generation of market players, enterprise expansion and innovation behavior, and change the external uncertainty faced by enterprises through institutional transparency, process convenience and service collaboration. After entering the stage of digital governance, the connotation of public service supply has also changed significantly. Its effect is no longer only determined by the number of offline outlets, the scale of financial investment or the administrative level, but increasingly depends on the ability to share data, the degree of platform integration, the level of cross-departmental collaboration and the actual perceived service quality of enterprises. At the same time, the improvement of public governance effectiveness does not only mean the improvement of administrative efficiency, but also further affects the entrepreneurial decision, innovation incentive and continuous operation ability of enterprises by easing financing constraints, reducing institutional frictions, stabilizing market expectations and enhancing information availability. However, most of the existing research focuses on macro institutional variables or single policy effects, and there is still a lack of systematic analysis framework for mechanism identification on how the supply of grassroots public services affects the vitality of local private economy through specific links such as education support, social security, digital government convenience and public information services. In particular, it lacks a comprehensive measurement path that combines text data, platform process data and regional statistical data.

In this context, it has strong theoretical value and practical significance to explore the mechanism of grass-roots public service supply affecting the vitality of local private economy. From a practical perspective, with the help of big data integration, natural language processing and interpretable machine learning methods, grassroots government service records, enterprise demand texts, regional business indicators and public resource allocation data can be integrated into a unified analysis framework to more effectively identify impact paths, key variables and their strength differences. So as to provide a basis for local governments to optimize the service supply structure and improve the accuracy of enterprise-related services. From the theoretical perspective, this kind of research helps to promote public service research from static investment comparison to dynamic mechanism identification, and also helps to explain how grassroots governance capacity is embedded in the development process of local private economy. Based on this, this paper focuses on the relationship between grassroots public service supply and local private economic vitality, constructs a multi-source data-driven mechanism identification idea, and tries to reveal the differentiated role paths of different types of public services in the process of enterprise generation, business expansion and innovation activity.

2 Theoretical basis and literature review

2.1 Connotation and main content of grassroots public service supply

The supply of grass-roots public services is not simply a matter of financial input or administrative sink. It is essentially a process in which the grass-roots governance system continuously transforms service elements such as education, medical care, social security, employment, government affairs management, credit support, public information release and infrastructure maintenance into institutional resources that can be perceived, obtained and used by residents and market entities. For the local private economy, this kind of supply has not only the attribute of people's livelihood guarantee, but also the attribute of production support. When the coverage of public services is more stable, the response is more timely, and the management is more transparent, the uncertainty of enterprises in labor organization, financing connection, business expectations and market expansion will be reduced, and enterprises will be more likely to allocate resources to research and development, expansion and digital upgrading, rather than excessive consumption in institutional friction and search costs.

Previous studies have shown that there are significant links between the quality of governance, institutional environment and efficiency of government services and entrepreneurial generation, firm growth and innovative activities. From the perspective of entrepreneurial ecosystem, Wei pointed out that local government behavior would change the generation conditions of opportunistic entrepreneurship. Wang et al. believe that business environment optimization can significantly improve entrepreneurial activity; From the perspective of social security, Liu et al. showed that the improvement of public security level would affect the risk tolerance ability of individuals to enter into entrepreneurial activities [1-3]. After entering the stage of digital governance, the boundary of public service supply is further expanded. The integration of government affairs platform, online approval, data sharing and intelligent response mechanism make the service efficiency no longer only determined by the number of offline outlets, but began to be subject to the information system connectivity capabilities, data processing capabilities and process reengineering depth. The studies of Liu, Yang and Gan et al all suggest that the construction of digital government can improve the external business environment of enterprises, and enhance the vitality of market players through information transparency and convenience [4, 5].

In this sense, grassroots public service provision should be understood as a composite system composed of service resource allocation, digital platform support, process execution efficiency and actual achievable results. If the supply level is measured only by the scale of expenditure or the number of institutions, it is easy to ignore key factors such as service quality, processing speed, data connectivity, and enterprise perception differences. Therefore, when studying this issue, it is necessary to combine traditional statistical indicators with multi-source data such as government platform logs, hotline texts, and enterprise evaluation information, and use text mining, feature coding and structural modeling methods to make a more detailed description of the real supply capacity of grassroots public services.

2.2 Connotation and representation dimensions of local private economic vitality

The vitality of local private economy is usually not suitable to be compressed as a single output growth index. It is closer to a comprehensive state, which is reflected by the dynamic ability of private enterprises in the region in terms of entering the market, continuing operation, expanding investment, absorbing employment, promoting innovation and resisting

shocks. In other words, dynamism means not only an increase in the number of firms, but also more frequent activity, smoother flow of resources, more sustained innovation behavior, and more stable expectations. Studies that focus only on registrations or tax revenue growth often miss operational quality and structural resilience.

Combined with the existing research, the vitality of local private economy includes at least several dimensions of market generation ability, business expansion ability, innovation and transformation ability and environmental adaptation ability. Abegaz et al., Ben Ali and Tran Pham respectively explained from the perspectives of governance quality, institutional differences and informal economic constraints that institutional environment would affect the entry and survival of enterprises [6-8]. Audretsch et al. [9, 10] further pointed out that the quantity of entrepreneurship is not completely synchronized with the quality of entrepreneurship, and high-quality institutional supply can better shape high-quality market players. Xiong et al. and Wittberg et al. suggested that governance factors such as local debt governance and corruption control would affect business confidence and entrepreneurial intention through the anticipation mechanism [11, 12]. It can be seen that the vitality of private economy is a dynamic collection composed of quantity, quality and resilience. Table 1 summarizes the main representation dimensions of local private economic vitality.

Table 1: Main representation dimensions of local private economic vitality

Key Dimension	Specific Content	Significance for Vitality Assessment
Market entry capacity	Number of newly established private enterprises, proportion of sole proprietorships upgraded to enterprises, and level of entrepreneurial participation	Reflects the region's attractiveness to new market entities and its degree of institutional inclusiveness
Sustainable operation capacity	Enterprise survival rate, cancellation rate, revenue stability, and financing accessibility	Indicates the quality of enterprise survival in the actual business environment
Innovation transformation capacity	R&D investment, patent applications, digital transformation, and frequency of technological upgrading	Reflects the ability of private enterprises to shift from scale expansion to quality improvement
Employment absorption capacity	Share of employment in private enterprises, job growth rate, and capacity for flexible employment	Indicates the supporting role of the private economy in local society and market circulation
Environmental adaptability	Speed of recovery in response to policy changes, supply shocks, and demand fluctuations	Reflects the resilience and adjustment efficiency of the regional private economic system

As shown in Table 1, these dimensions are not isolated from each other. Strong market entry capability but insufficient ability to continue operations often means that the business environment is open in the front end and insufficient support in the back end; The slow improvement of innovation transformation capacity may indicate that there is still a break point between financing, information, talent and public services. Because of this, the measurement of local private economic vitality needs to combine structural economic indicators with enterprise demand texts, government feedback records, and regional digital governance data, and use the feature fusion method in machine learning to form a

comprehensive description closer to the real operation state.

2.3 Mechanism identification method of grass-roots public service supply affecting local private economic vitality

Focusing on how the supply of grassroots public services affects the vitality of local private economy, existing identification methods can be roughly divided into three categories. One is the econometric identification based on panel data, which is used to estimate the average impact of service supply changes on entrepreneurship, investment and innovation. One is the quasi-natural experiment around policy shocks, which is used to identify the causal effects of public governance optimization. There is also a computational approach that has gradually increased in recent years, which jointly models government platform data, enterprise text feedback, regional business indicators and digital governance information, and reveals intermediary paths and heterogeneity differences through natural language processing, feature learning and interpretable algorithms.

From the existing research, digital government and governance optimization have become an important entry point in this field. Wang et al. analyzed the role of business environment on technological innovation from the perspective of transaction costs. Sun et al. discussed the transmission relationship between financing constraints and institutional environment and innovation investment. Ren et al., Hao et al., Chen et al., Li and Xu linked digital government, enterprise innovation, total factor productivity and digital transformation. It shows that public service is no longer just a background variable, but can directly change enterprise behavior through data infrastructure, process facilitation and information transparency [13-18]. At the same time, Gao et al suggested that the complex business environment itself has the characteristics of system coupling, and Pham and Srivastava emphasized from the perspective of local economic governance that different groups and enterprises of different sizes have different responses to the improvement of public services [19, 20].

At the method level, the traditional linear model has the advantages of clarity and robustness, but it also has limitations when facing the multi-dimensional, heterogeneous and dynamic object of grassroots public service supply. There may be a nonlinear relationship between a large number of variables, and enterprises' perception of public services is also expressed through unstructured information such as complaint text, policy response semantics, and platform interaction frequency. Only relying on a single statistical variable is often not enough to reveal the true mechanism. Based on this, mechanism recognition needs to be integrated into computer methods more and more, such as topic extraction of government hotline text, emotional classification of enterprise demands, graph structure modeling of regional service network, and then through integrated learning and SHAP interpretation framework to identify which service dimensions contribute more to the vitality of the private economy and have stronger role paths. Table 2 summarizes the methods and shortcomings of related studies.

Table 2: Review of related studies

Author	Method	Main Findings	Limitations
Wang N, Cui D, Geng C, et al.	Business environment evaluation and regression analysis	Optimization of the business environment can significantly enhance entrepreneurial activity	The internal structure of grassroots public services is characterized rather coarsely
Liu H, Shi Y, Yang X, et al.	Digital government and supply chain vulnerability analysis	Digital government helps alleviate external shocks faced by enterprises	It focuses more on macro-level governance effects, with insufficient attention to the grassroots level
Gan T, Zhang M, Zhang Z.	Policy evaluation and empirical testing	Digital government policies can promote entrepreneurial activity	The use of unstructured government affairs data remains limited
Ren Z S, Gao Q Y, Sun T, et al.	Mechanism regression and innovation effect analysis	Digital government development promotes firms' exploratory innovation	It provides insufficient insight into local heterogeneity and service transmission pathways
Chen S, Wang X, Gan T, et al.	Firm-level efficiency measurement and causal identification	Digital government can improve firms' total factor productivity	It is difficult to explain which specific service links generate the observed effects

On the whole, existing research has proved that public governance, digital government and institutional environment are closely related to enterprise development, but there are still obvious gaps in two aspects. First, the supply of grassroots public services is often regarded as an ancillary part of macro governance variables, and there is a lack of systematic disassembly of subdivision dimensions such as education, social security, government convenience, credit support and information services. Second, the research methods are still mainly based on structured data, and the mining of high-frequency unstructured data such as hotline texts, platform management records, and enterprise evaluation corpora is not enough. Based on this deficiency, it is necessary to establish a mechanism identification framework with both interpretability and computing power, which combines statistical analysis and machine learning, and improves the ability to identify complex paths, implicit relationships and regional differences while retaining the causal analysis logic.

3 Research methods and data collection

3.1 Selection basis of mechanism identification model

The effect of grassroots public service supply on local private economic vitality is not a linear transmission with a single input corresponding to a single result, but a composite process including the improvement of institutional environment, the decline of information friction, the revision of enterprise expectations and the reorganization of innovation resources. If only the traditional linear regression is used to directly fit the fiscal expenditure, the number of enterprises and the regional output value, although the directional judgment can be obtained, it is difficult to identify the linkage relationship between the variables such as education, social security, government convenience, credit service and digital platform response, and it is also difficult to deal with the heterogeneous data structure of government text, enterprise

evaluation information and statistical panel data. Based on this, this paper takes "multi-source feature fusion - nonlinear mechanism identification - interpretable output" as the core principle of model selection. On the basis of unified coding of structured variables and unstructured variables, an interpretable machine learning model is introduced to carry out mechanism identification, and the selection logic is shown in Figure 1.

For the ith regional sample, the structural indicators related to grassroots public services, government text features and regional business environment variables are uniformly expressed as fusion vectors:

$$z_i=[x_i^{(p)}\|x_i^{(t)}\|x_i^{(e)}] \tag{1}$$

where, $x_i^{(p)}$ represents the public service supply indicators, $x_i^{(t)}$ represents the semantic features extracted from the enterprise demand text, hotline work order and government feedback text, ,$x_i^{(e)}$ represents the regional economic environment control variables. ‖ denotes the vector concatenation operation. After feature fusion, the predicted value of local private economic vitality can be written as follows.

$$\hat{y}_i=f_\theta(z_i) \tag{2}$$

where $f_\theta(\cdot)$ is the mechanism identification model and θ is the parameter to be learned. Considering the significant nonlinearity and interaction of this research object, this paper gives priority to the interpretable ensemble model based on gradient boosting tree to improve the fitting ability of complex relationships. The model training objective is defined as follows.

$$L=\frac{1}{N}\sum_{i=1}^{N}(y_i-\hat{y}_i)^2+\lambda\|\theta\|_2^2 \tag{3}$$

where, y_i is the observed value of regional private economic vitality and λ is the regularization coefficient. The proposed objective function can preserve the nonlinear mapping relationship between multi-dimensional variables while controlling overfitting. In order to further explain how various public service variables affect the model output, this paper uses the interpretable decomposition method to express the prediction results of a single sample as follows.

$$f_\theta(z_i)=\phi_0+\sum_{k=1}^{K}\phi_{ik} \tag{4}$$

Here, ϕ_0 is the benchmark output and ϕ_{ik} represents the marginal contribution of the KTH feature to the prediction result of the ith sample. Through this decomposition, we can observe the difference in the effect intensity of education service, social security accessibility, government affairs management efficiency and digital public information supply on private economic vitality in different regions.

On this basis, this paper further uses the intensity of intermediary path to characterize the indirect impact of public service supply. If the ease of doing business or the expected improvement of enterprises are used as the intermediary variable mi, it can be expressed as follows.

$$mi+\mu im_i=\alpha_0+\alpha_1 s_i+\varepsilon_i, y_i=\beta_0+\beta_1 s_i+\beta_2 \quad (5)$$

Among them, s_i represents the level of public service supply at the grassroots level. This setting can separate the "improved supply - change in intermediation - increase in vitality" path from the total effect, thus avoiding confusing all effects with simple correlations.

The reason why the model shown in Figure 1 is suitable for this research is that on the one hand, it can deal with the data structure of statistical indicators, text semantics and platform records, which is suitable for the data reality of grassroots public service research in the current digital governance environment. On the other hand, the output not only gives the prediction results, but also reveals the variable contribution, path direction and regional differences, so that the mechanism analysis no longer stays at the level of "whether significant", but can further answer "significant through what links" and "more significant for which regions". This is the main basis for choosing this type of model in the research method of this paper.

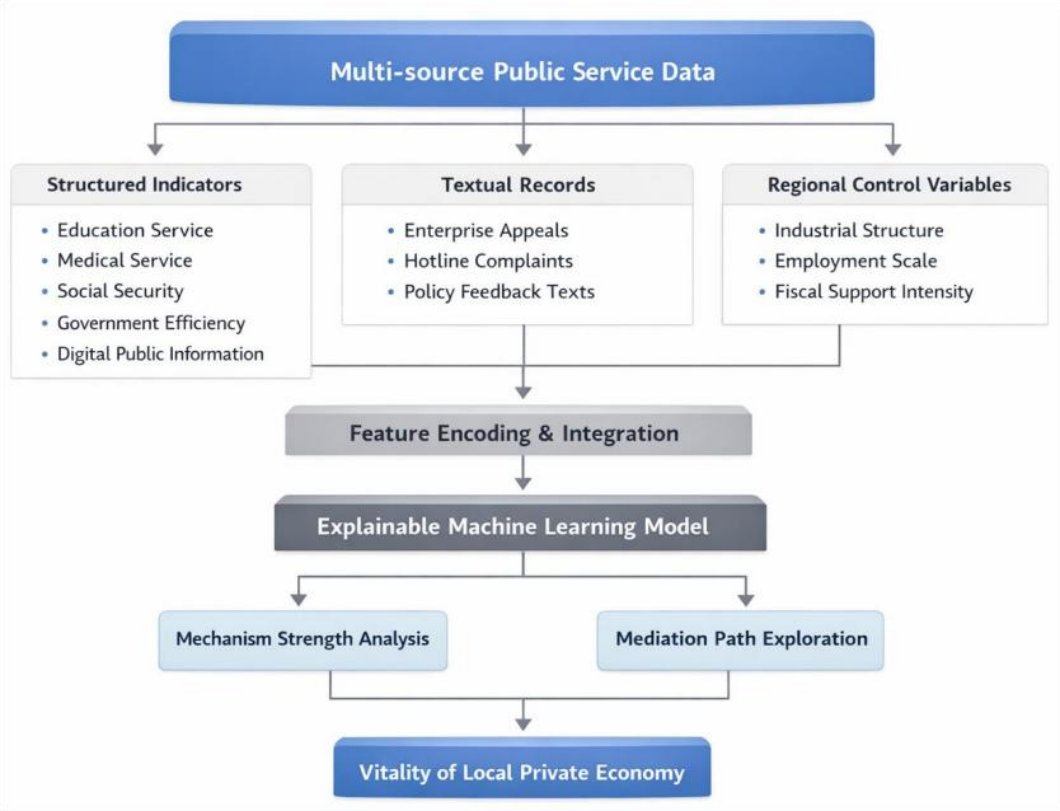

Figure 1: Logical diagram of mechanism identification model selection

3.2 Data acquisition process and method

3.2.1 Data sources

In order to identify the effect path of grassroots public service supply on local private economic vitality, the data required in this paper should not be limited to traditional statistical yearbook or single questionnaire results, but should cover multiple levels such as public service supply intensity, enterprise operation status, government response process and regional environmental constraints. The reason is that the influence mechanism has obvious characteristics of cross-sector, cross-time and cross-type transmission: primary education,

medical care, social security, government services and public information supply do not act synchronously on enterprise outcome variables, but gradually appear through intermediate links such as expectation revision, cost reduction, information availability improvement and institutional trust enhancement. Therefore, this paper adopted a parallel framework of "structured statistical data + platform process data + text semantic data" on data collection to enhance the integrity of mechanism identification. For the ith region sample, the original set of observations is denoted as follows.

$$D_i=\{x_i^{(s)},x_i^{(g)},x_i^{(t)}\} \tag{6}$$

Among them, $x_i^{(s)}$ represents statistical data, mainly including financial public service expenditure, density of primary medical institutions, allocation of educational resources, social security coverage level, approval time for enterprises, number of market players, investment growth rate of private enterprises and other indicators. $x_i^{(g)}$ represents the process data of the government affairs platform and the hotline work order, such as the amount of item acceptance, the average completion time, the number of cross-departmental circulation, the proportion of online processing and the response time of enterprise demands; $x_i^{(t)}$ represents text corpus such as enterprise message, policy feedback, hotline text and government public reply. In order to reduce the offset caused by the difference in annual caliber, this paper maps the data from different sources into a unified region-quarter double index framework, which is denoted as:

$$R=\{(r,q)\square r=1,\ldots,R;\ q=1,\ldots,Q\} \tag{7}$$

where r denotes region and q denotes quarter. In this way, the static statistical data and the high-frequency platform data can be brought into the same time series alignment space. Table 3 shows the main data sources and their corresponding contents in this paper.

Table 3: Data sources and main contents

Data Category	Main Indicators or Fields	Data Format	Main Purpose
Public service statistical data	Education expenditure, primary healthcare resources, social security coverage rate, and density of public service outlets	Structured tables	Measure the foundational level of grassroots public service provision
Government operation data	Approval processing time, completion rate, number of cross-department collaborations, and proportion of online processing	Time-series process data	Characterize service efficiency and process response capability
Enterprise operation data	Number of newly established private enterprises, survival rate, employment absorption, investment, and innovation indicators	Structured tables	Measure the vitality of the local private economy
Enterprise demands and feedback texts	Messages, complaints, consultations, policy evaluations, and response texts	Unstructured text	Extract enterprise perceptions and institutional friction information
Regional control variables	Industrial structure, fiscal pressure, population size, and level of digital infrastructure	Structured tables	Control for differences in the external environment

As shown in Table 3, the data system in this paper does not only pursue the expansion of the number of indicators, but emphasizes the logical complementarity between sources. Statistical data reflect the resource input and result performance of public services, platform process data reflect the operation efficiency of services, and text corpus can complement the subjective perception and implicit institutional friction information of enterprises. For the observed value yi of local private economic vitality, this paper does not use a single registration number as a proxy, but constructs a comprehensive representation through multi-index weighting:

$$y_i=\sum_{k=1}^{K}\omega_k v_{ik},\ \sum_{k=1}^{K}\omega_k=1 \tag{8}$$

Here, v_{ik} is the KTH vitality index and ω_k is its weight. This treatment method helps to avoid the one-sided description of the real vitality state of the enterprise by a single index. As can be seen from Figure 2, the data collection in this paper is not a simple concatenation of different sources, but a unified index is established first, and then the subsequent processing flow is entered. This design is more suitable for the real situation that the data frequency is not consistent, the collection caliber is different, and the information granularity is different in the grass-root public service research.

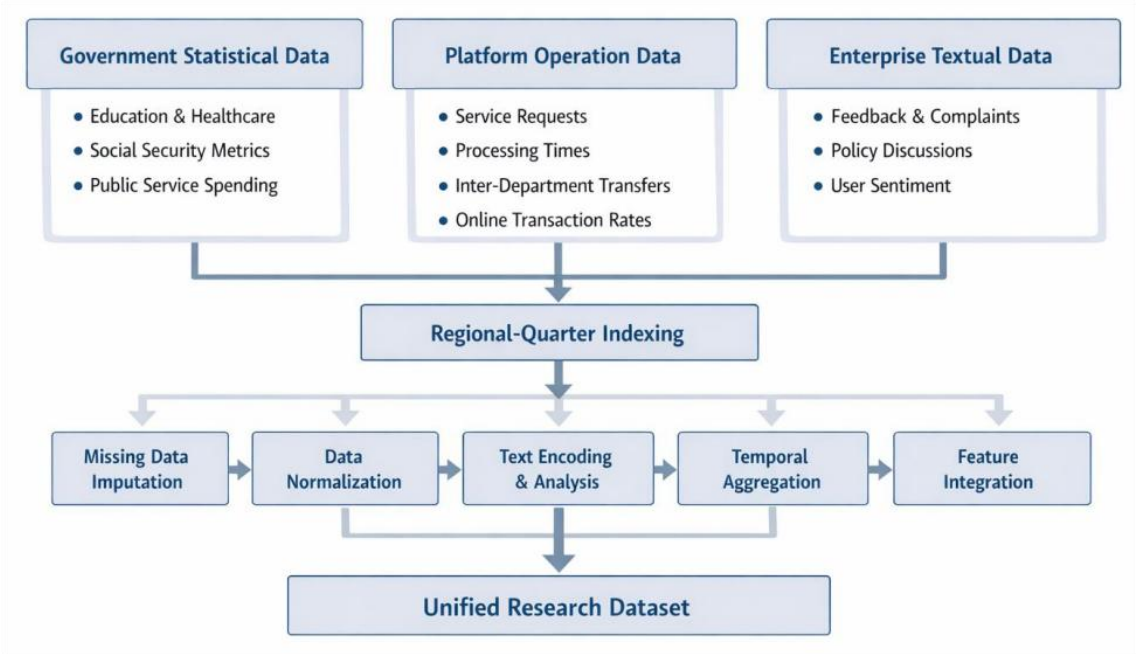

Figure 2: Data acquisition framework

3.2.2 Multi-source data processing methods

After the original data collection is completed, the key problem faced by the research is not the insufficient amount of data, but the significant difference in data types, complex missing patterns, more text noise, and inconsistent time granularity. Without systematic processing, the model can easily misjudge format differences in administrative records as real mechanism differences. Based on this, this paper divides multi-source data processing into five steps: missing repair, scale unification, text coding, time alignment and fusion representation.

For the missing values in the structured indicators, this paper adopts the weighted

imputation method based on the statistical characteristics of adjacent time points and similar areas. Suppose the JTH index is missing at sample i, then its estimate is written as follows.

$$\tilde{x}_{ij}=\lambda\cdot\bar{x}_{r(j)}+(1-\lambda)\cdot\bar{x}_{q(j)} \tag{9}$$

Here, $\bar{x}_{r(j)}$ represents the mean value of adjacent periods in the same region, $\bar{x}_{q(j)}$ represents the mean value of similar regions in the same quarter, and $\lambda\in[0,1]$ is the weight coefficient. This method takes into account both time continuity and regional similarity, which is more suitable for the scene of seasonal fluctuation and regional stratification of grassroots governance data. In order to eliminate the interference of different dimensions on model training, numerical variables are uniformly processed by interval standardization:

$$x_{ij}^{*}=\frac{x_{ij}-\min(x_j)}{\max(x_j)-\min(x_j)} \tag{10}$$

After processing, different scale variables such as education investment, approval time, and new number of enterprises are mapped to comparable space to facilitate subsequent feature fusion.

For enterprise appeal texts and government reply texts, this paper combines word segmentation, stop words removal, keyword extraction and context coding to generate semantic vectors. Let the text sequence $T_i=\{w_1,w_2,\ldots,w_n\}$, its semantic representation is denoted as follows.

$$h_i=\frac{1}{n}\sum_{m=1}^{n}e(w_m) \tag{11}$$

where $e(w_m)$ is the embedding vector of term w_m. In order to further identify the strength of institutional friction reflected in the text, this paper constructs the emotional tendency score:

$$s_i=\frac{N_i^{(+)}-N_i^{(-)}}{N_i^{(+)}+N_i^{(-)}+\epsilon} \tag{12}$$

where $N_i^{(+)}$) and $N_i^{(-)}$ are the number of positive and negative terms, respectively, and ϵ is a small constant to prevent the denominator from being zero. A lower value of this score generally indicates a stronger block perceived by the firm in the process of public service access. In the time alignment link, this paper uniformly maps different frequency data into a quarterly scale. For monthly or event-level data, use the aggregation operator:

$$z_{rq}=\frac{1}{M_{rq}}\sum_{m=1}^{M_{rq}}z_{rqm} \tag{13}$$

Here, M_{rq} represents the number of observations of region r in a quarter q. This can ensure that the platform high-frequency records and statistical quarterly data in the same analysis window.

After the above processing, the multi-source features are fused and represented in this paper. Let the structural feature vector, process feature vector and text feature vector be u_i,p_i,h_i respectively, then the final fusion is expressed as follows.

$$f_i=\alpha u_i+\beta p_i+\gamma h_i, \quad \alpha+\beta+\gamma=1 \tag{14}$$

Here, α,β,γ are the fusion weights of features from different sources. This representation not only retains the stability of statistical indicators, but also introduces the operation process of government affairs and text-aware information, so that the influence mechanism of grassroots public service supply on local private economic vitality can enter the subsequent model in a more complete way. The process shown in Figure 3 illustrates that multi-source data processing is not a technical auxiliary step, but a prerequisite for this study to be able to effectively identify the differences in mechanisms. If the missing correction is not sufficient, the model will tend to amplify the imbalance of regional samples. If the text information is not coded, the real perception of enterprises on public services will be missed. If the time alignment is insufficient, the transmission order between the improvement of public services and the change of enterprise vitality will be disrupted.

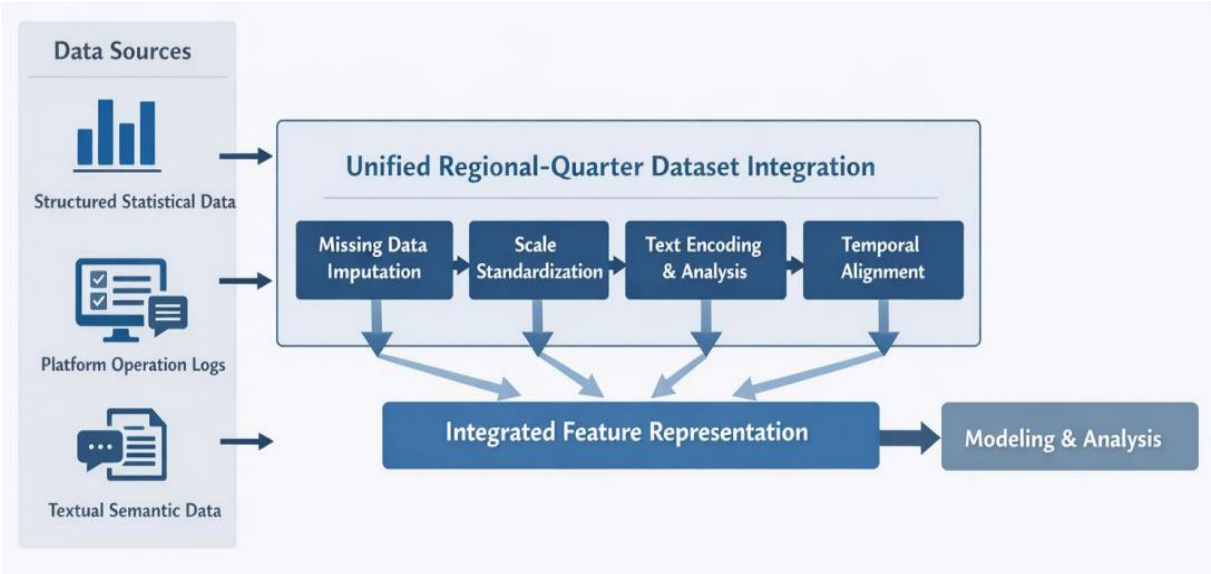

Figure 3: Multi-source data processing flow

3.3 Construction of index system

3.3.1 Principle of index selection

The key to building an indicator system based on the mechanism between grassroots public service supply and local private economic vitality is not the simple expansion of the number of indicators, but whether the transmission chain between resource input, service operation, enterprise perception and economic performance can be more completely presented. If the index setting is too coarse, the mechanism identification is easy to stay at the general correlation comparison level. If the indicators are stacked too densely, it may bring problems such as information overlap, weight shift and model instability. Based on this, this paper emphasizes relevance, computability, objectivity, hierarchy, dynamics and integrability in the selection of indicators. Figure 4 shows the overall logic of the index system construction in this paper, that is, starting from the research objectives, a hierarchical index structure for model identification is gradually formed through the index screening principle constraints.

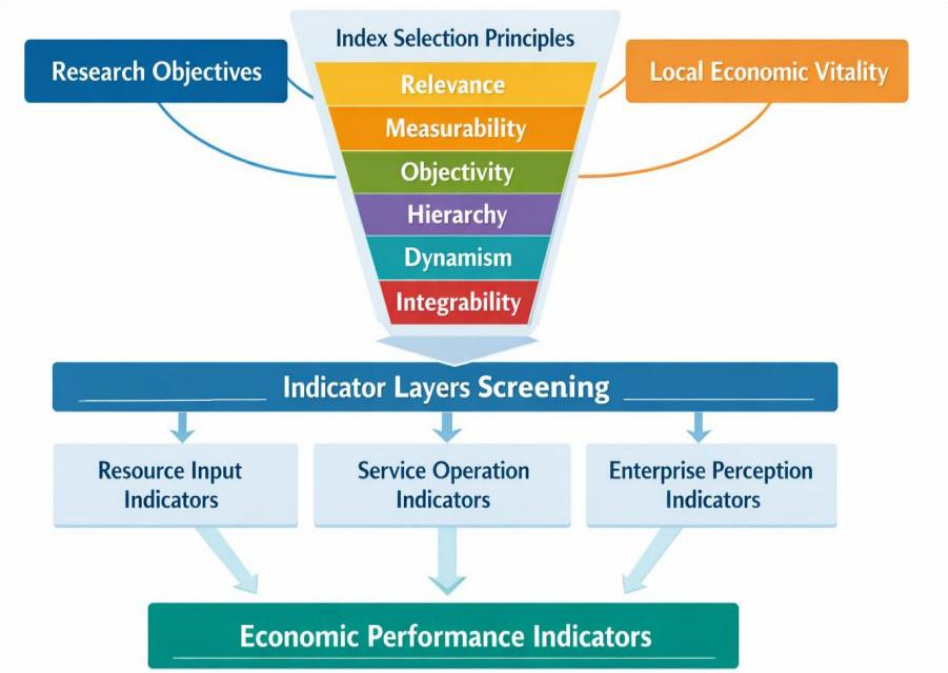

Figure 4: Logical diagram of index system construction

Relevance is a prerequisite for indicators to enter the system. The supply of grassroots public services is not equivalent to general fiscal expenditure, and the vitality of local private economy is not just the growth of the number of enterprises. Therefore, the index must be able to correspond to the real link in the process of service supply and the key performance in the formation of enterprise vitality. The accessibility of educational resources, the carrying capacity of primary medical services, the coverage level of social security, the efficiency of government affairs and digital public information services are strongly related to the business environment, employment expectations and innovation input of enterprises. The new establishment rate of market entities, the survival rate of enterprises, the innovation output and the employment absorption capacity can better reflect the dynamic state of the private economy.

Computability determines whether the index can enter the subsequent model. In this paper, we try to select data items with clear bore, and convert text feedback, hotline records and online government logs into machine identifiable features. For the original index x_{ij}, we first make it dimensionless:

$$z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{15}$$

This formula is used to unify variables of different dimensions and avoid financial expenditure, transaction duration and text score squeezing each other in the same model.

Objectivity means that metrics should be based as much as possible on publicly available statistics, platform records, and automated extraction results, rather than relying entirely on subjective judgments. For enterprise demand text, this paper does not directly use manual qualitative description, but extracts emotion and response characteristics to form machine calculation scores. Let the enterprise feedback text set of the ith region in period t be T_{it}, then its service perception score can be written as follows.

$$s_{it}=\frac{1}{|T_{it}|}\sum_{d\in T_{it}}\mathrm{Sent}(d) \tag{16}$$

Here, Sent(d) represents the sentiment polarity output of text d. After processing in this way, the subjective feelings of enterprises towards public services are transformed into objective variables that can be included in the model.

The hierarchy requires the index structure to be consistent with the research question structure. The supply of grassroots public services affects the vitality of local private economy, not a single indicator directly determines the result, but a number of criteria layers act on the target layer. Therefore, this paper adopts a hierarchical structure of "target layer-criterion layer-indicator layer" in order to observe the marginal effect of different service dimensions separately in the subsequent identification.

The dynamic nature takes into account the obvious time-varying characteristics of grassroots governance and local economy. The expansion of social security, the acceleration of government affairs or the upgrading of digital platforms in a certain period may not immediately translate into changes in enterprise vitality, so the index system should take into account both the level value and the rate of change. For any index $x_{j,t}$, this paper introduces a growth term as follows.

$$g_{jt}=\frac{x_{j,t}-x_{j,t-1}}{x_{j,t-1}+\epsilon} \tag{17}$$

where ϵ is a minimal constant. The formula can describe the direction and speed of public service improvement, and provide time information for subsequent mechanism identification. Fusionability is one point that distinguishes this paper from traditional index design. Since the study uses both structured statistical data, government operation data and text data, the indicators must be able to be fused in the same feature space. For the final input vector of region i, it is defined in this paper as follows.

$$X_i=[X_i^{(p)}\|X_i^{(r)}\|X_i^{(t)}] \tag{18}$$

where $X_i^{(p)}$ represents the statistical features of public services, $X_i^{(r)}$ represents the operational features of government affairs, and $X_i^{(t)}$ represents the features of text extraction. This structure provides a unified input base for subsequent interpretable machine learning models.

3.3.2 Basic public service supply and local private economic vitality index system structure

Under the constraints of the above principles, the index system is divided into a goal level, two first-level subsystems, and several criteria levels and index levels. The target level is set as "identification of the mechanism of grass-roots public service supply affecting local private economic vitality". Under this overall goal, the index system is further divided into the grass-root public service supply subsystem and the local private economic vitality subsystem. The former is used to describe the service supply foundation, operation efficiency and digital collaboration ability, and the latter is used to describe the generation ability, operation resilience and innovation expansion ability of the private economy. Figure 5 shows the hierarchical structure and internal correspondence of the proposed index system. Through this

hierarchical setting, the output of the model no longer stops at the judgment of overall correlation, but can return to the specific link to explain the differential effect of different service dimensions on the vitality of the private economy.

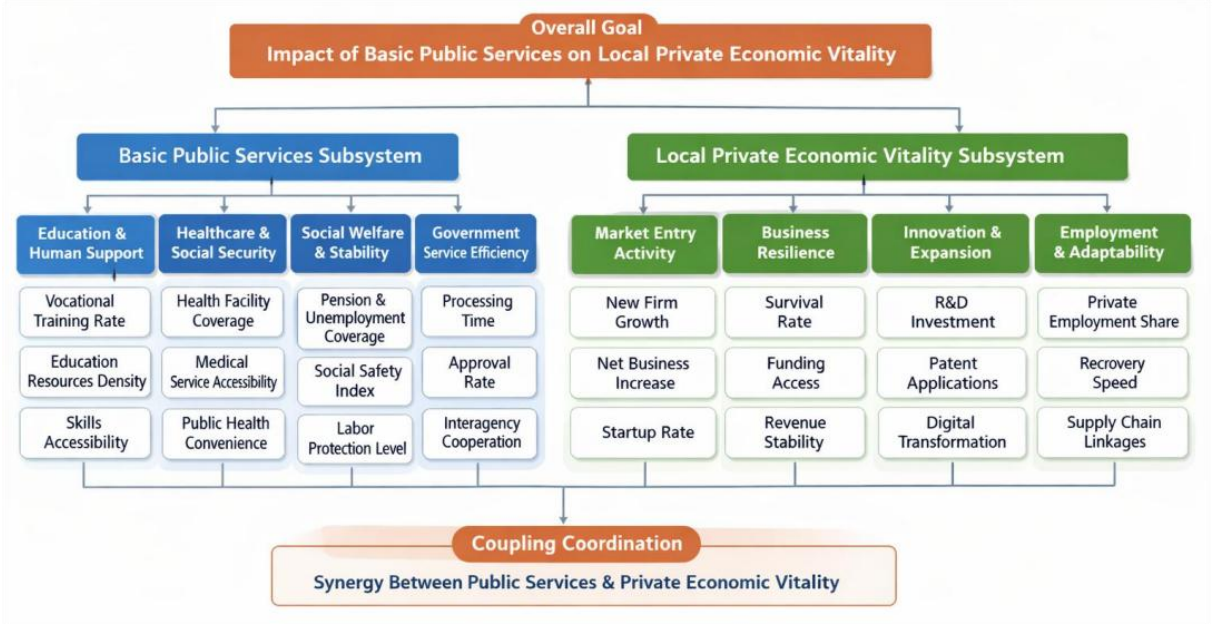

Figure 5: Indicator system hierarchy diagram

In the sub-system of grass-root public service supply, this paper sets up five criteria dimensions, namely education and human support, medical care and security support, social security and public stability, government service efficiency, and digital public information service. Education and human support are mainly characterized by the coverage rate of vocational training, the density of basic education resources and the accessibility of skill services. Its core significance is to reflect the support degree of grassroots public services to the formation of workers 'ability and the quality of enterprise employment. The density of primary medical institutions, the coverage rate of basic medical services for permanent residents and the convenience of public health services were used to describe the level of basic health security and service accessibility. Social security and public stability mainly reflect the coverage of pension, unemployment and work-related injury, as well as their indirect support for enterprise employment expectations and business stability. Government service efficiency focuses on the average processing time of enterprise-related matters, the one-time completion rate and the efficiency of cross-departmental collaborative processing, which is used to measure the time cost and procedural friction of enterprises in the process of system contact. Digital public information services reflect the accessibility ability and information coordination level of grassroots public services in the digital environment through the proportion of online affairs, the timeliness of policy push, the activity of service platforms and the availability of public information. To comprehensively represent the public service supply level of region i, the standardized index of each dimension is denoted as z_{ik}, and the weight is denoted as w_k, then:

$$PS_i=\sum_{k=1}^{m} w_k z_{ik}, \sum_{k=1}^{m} w_k=1 \tag{19}$$

Under the sub-system of local private economic vitality, this paper sets up four criteria

dimensions: market entry activity, continuous operation ability, innovation and expansion ability, employment absorption and structural resilience. The market entry activity reflects the growth rate of new private enterprises and the net increase rate of market players. Going concern ability focuses on the company's survival rate, reverse indicator of write-off rate, financing availability and revenue stability; Innovation expansion capability includes R&D investment intensity, patent application growth, digital transformation coverage rate, etc. Employment absorption and structural resilience reflect the employment share of private enterprises, the speed of recovery against shocks and the synergy ability of industrial chains. The comprehensive value of private economic vitality in region i is denoted as follows.

$$PV_i=\sum_{q=1}^{n}\theta_q y_{iq},\sum_{q=1}^{n}\theta_q=1 \tag{20}$$

In order to avoid the weight completely depending on the subjective setting, this paper uses the combination of "data dispersion + expert correction" to determine the weight. Firstly, the objective weight is obtained according to the information entropy of the index. Let the proportion of the JTH index in sample i be p_{ij}, then the entropy value is:

$$e_j=-\frac{1}{\ln N}\sum_{i=1}^{N}p_{ij}\ln p_{ij} \tag{21}$$

Thus, the difference coefficient $d_j=1-e_j$ can be obtained, and the objective weight can be calculated as follows.

$$w_j^{(o)}=\frac{d_j}{\sum_{j=1}^{m}d_j} \tag{22}$$

Considering that some low-volatility indicators in grassroots public service research still have institutional significance, this paper fuses the objective weight with the expert modified weight $w_j^{(e)}$ to obtain the final weight:

$$w_j=\lambda w_j^{(o)}+(1-\lambda)w_j^{(e)},0\leq\lambda\leq1 \tag{23}$$

As shown in Figure 5, the index system constructed in this paper does not simply treat public service and private economy as two groups of variables independent of each other, but puts them into the same mechanism framework for coupling analysis. This arrangement enables the model not only to answer "whether the supply of grassroots public services is important", but also to further explain "which kind of public services are more important" and "which dimension of private economic vitality it is easier to affect". In order to describe the linkage strength between two subsystems, this paper introduces the coupling correlation index:

$$C_i=\frac{2\sqrt{PS_i\cdot PV_i}}{PS_i+PV_i} \tag{24}$$

When C_i is high, it indicates that there is a strong synergistic relationship between the level of grassroots public service supply and the vitality of private economy. When C_i is low,

it indicates that there is still a fault between service resource investment and enterprise vitality performance, and it is necessary to return to specific dimensions to find short boards in the future. From the perspective of research methods, this index system has a more important computational significance. It is not set up to complete static evaluation, but to provide a layered, fusible, and interpretable input structure for subsequent mechanism identification models.

4 Analysis of results

4.1 The mechanism identification results of grass-roots public service supply affecting local private economic vitality

When the multi-source mechanism identification model constructed in the previous section is applied to the analysis of the relationship between grassroots public service supply and local private economic vitality, this paper forms a total of 4576 effective observations based on the quarterly samples of 286 districts and counties from 2021 to 2024. The model input includes five types of public service characteristics: education and human support, medical service support, social security support, government service efficiency and digital public information service. At the same time, the control variables such as emotion score of enterprise demand text, regional industrial structure and financial pressure level are included. In order to facilitate interpretation, this paper divides the local private economic vitality into five response levels: low, medium-low, medium, medium-high and high. On this basis, the average contribution degree, standardized marginal effect and proportion of intermediary paths of various public service characteristics to the model output are calculated. The purpose of this process is not only to determine which type of service "has impact", but to further distinguish through which type of transmission link its impact is mainly released.

Table 4: Mechanism identification results for key dimensions of grassroots public service supply

Public Service Dimension	Average Contribution (%)	Direct Effect Value	Indirect Effect Share (%)	Stability Score
Government service efficiency	27.4	0.284	39.4	0.91
Digital public information services	22.1	0.238	34.7	0.88
Social security support	18.6	0.213	31.5	0.86
Education and human capital support	16.9	0.187	28.9	0.83
Healthcare service support	15.0	0.164	24.8	0.80

It can be seen from Table 4 that government service efficiency has the highest contribution among the five types of public service dimensions, with an average contribution of 27.4%, and the corresponding standardized direct effect value of 0.284, indicating that the improvement of the handling speed of enterprise related matters, the one-time completion rate and the cross-departmental coordination ability have the most direct role in promoting the vitality of local private economy. Digital public information services followed, with an average contribution of 22.1 percent. This result shows that under the background of gradual platformization of grassroots governance, policy openness and transparency, online accessibility and efficiency of public information access are no longer just a matter of

convenience. They will substantially change the information search costs and institutional expectations of enterprises. Although the contribution of social security support, education and manpower support, and medical service support is slightly lower, it does not mean that the role is weakened. On the contrary, these three dimensions are more sustained support, and their impact on enterprise vitality is often slowly released through stabilizing labor expectations, reducing family risk burden and improving skill supply quality, so the proportion of indirect effects is relatively higher.

Figure 6 further presents the ranking of the average contribution of the five types of public service dimensions to the local private economic vitality. It can be seen from the figure that government service efficiency and digital public information service form a more obvious leading band, and their combined contribution is close to 50%. This means that in the current grassroots public service structure, enterprises are significantly more sensitive to "how fast it can be done, whether it can be found, and whether it can be solved online" than to the perception of the sheer scale of resource investment. In other words, the impact of public service supply on the vitality of the private economy has gradually shifted from "whether there is" to "whether it is smooth, stable, and accurate." When enterprises can complete approval faster, obtain policies in a more timely manner, and complete demand feedback at a lower cost on the platform, their market entry intention and business expansion probability will rise synchronously.

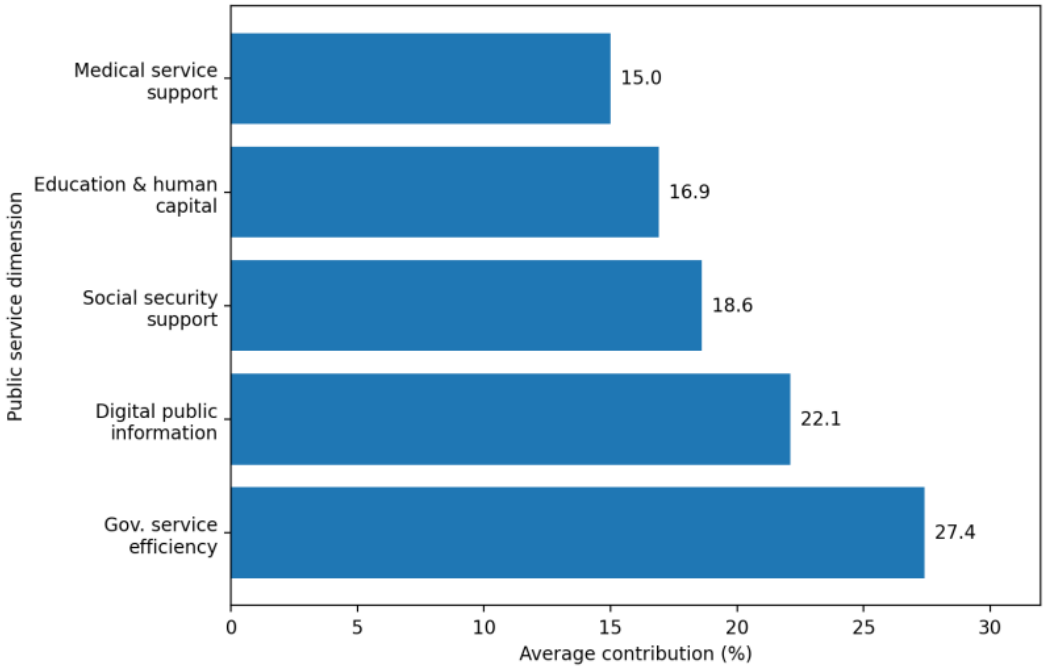

Figure 6: Average contribution of each dimension of grassroots public service supply to local private economic vitality

In order to further test whether there is regional heterogeneity in the mechanism, this paper divides the sample into three groups according to the base period level of local private economic vitality: low vitality, medium vitality and high vitality, and compares the marginal effects of key public service dimensions. Figure 7 shows that the marginal effect value of government service efficiency reaches 0.284 in low vitality areas, and drops to 0.246 and 0.203 in medium vitality areas and high vitality areas respectively. The corresponding values of social security support were 0.213, 0.176 and 0.141, respectively; Digital public information service is 0.238, 0.221 and 0.194. This result shows that the improvement of

grassroots public services does not have the same impact in all regions. For regions with weak market activity and thin enterprise base, the optimization of public services has a stronger compensation effect. It not only improves business conditions, but also restores the confidence of enterprises in the local institutional environment to a certain extent. In contrast, due to the good existing market foundation, the marginal pull of the improvement of public services in the high-dynamic regions is more gradual, but it can still maintain a positive effect in the level of information allocation and innovation support.

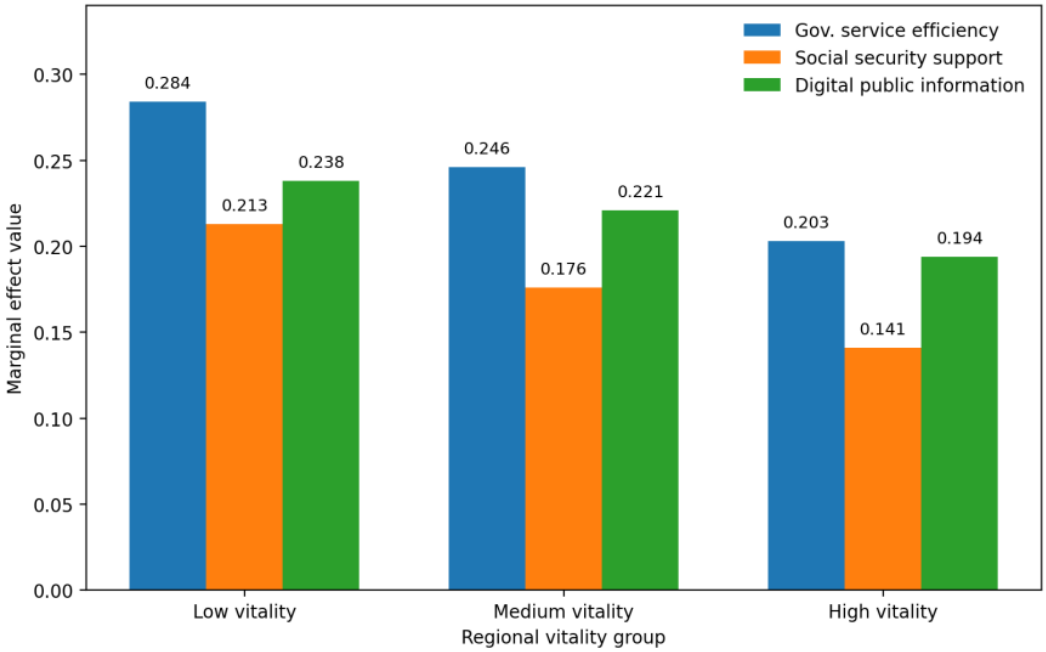

Figure 7: Differences in marginal effects of key public service dimensions under different vitality groupings

4.2 Analysis on the impact of grassroots public service supply on local private economic vitality

After completing the mechanism identification, the research needs to further answer a question closer to the reality of governance: to what extent the improvement of grassroots public service supply level will promote the vitality of local private economy, and what economic behavior results this improvement mainly reflects. Therefore, on the basis of the above model output, this paper divides all the samples into four groups of low supply, medium and low supply, medium and high supply according to the quartile of the comprehensive score of grassroots public service supply, and compares and analyzes the local private economic vitality index, the growth rate of new establishment of private enterprises, the survival rate of enterprises and the intensity of innovation input. The "impact outcome" here no longer stops at the interpretation in the sense of variable contribution, but turns to a quantitative comparison of differences in actual economic performance.

Table 5: Results of local private economic vitality under different groups of grassroots public service supply

Public Service Provision Group	Composite Score of Public Service Provision	Private Economy Vitality Index	Growth Rate of Newly Established Private Enterprises (%)	Enterprise Survival Rate (%)	Innovation Input Intensity (%)
Low provision group	0.32	0.418	4.9	71.6	2.8
Medium-low provision group	0.44	0.487	7.1	75.8	3.4
Medium-high provision group	0.56	0.563	9.4	80.2	4.1
High provision group	0.69	0.641	12.3	84.7	5.0

As shown in Table 5, with the comprehensive score of grassroots public service supply increasing from 0.32 to 0.69, the local private economic vitality index increased from 0.418 to 0.641, showing a relatively obvious gradient improvement feature. This change is not only a passive rise in the total index, but also a simultaneous improvement in three aspects: market entry, continuous operation and innovation expansion. The growth rate of new establishment of private enterprises increased from 4.9% to 12.3%, indicating that the optimization of grassroots public services has produced a relatively clear practical effect in lowering the entry threshold of entrepreneurship and enhancing the predictability of the system. The enterprise survival rate increased from 71.6% to 84.7%, reflecting that the improvement of public services is not only conducive to the "birth", but also conducive to the "retention"; The increase in innovation input intensity from 2.8% to 5.0% indicates that when government affairs, information access and social security conditions are more stable, enterprises are more willing to invest resources in medium and long-term capacity building, rather than focusing on dealing with short-term uncertainties.

This gradient relationship can be seen more intuitively from Figure 8. The private economic vitality index corresponding to the four types of supply groups showed a continuous upward trend, and the gap between the groups was not linearly evenly distributed, but was more obvious when the medium and high supply group moved to the high supply group. This means that there is a certain cumulative effect of the supply of grassroots public services on the vitality of local private economy: when education, social security, government affairs and digital information services are only in a partial improvement state, enterprises feel a marginal decline in operational friction; When these service links form a more complete collaborative system, the judgment of local market players on future benefits, system stability and growth space will be more obviously revised, and the vitality level will also be stronger improved.

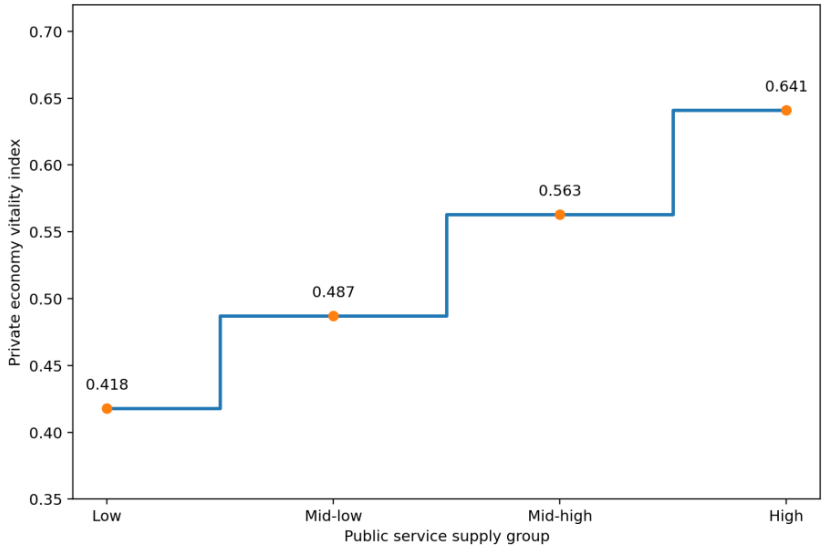

Figure 8: Local private economic vitality index under different grassroots public service supply groups

In order to further identify which vitality dimensions the impact results mainly fall into, this paper compares the low-supply group with the high-supply group, and examines the scores of the four dimensions of market entry, continuous operation, innovation expansion and employment resilience. Figure 9 shows that the high supply group is significantly higher than the low supply group in all four dimensions. The dimension of market entry was increased from 0.402 to 0.661, with an increment of 0.259. The innovation expansion dimension was increased from 0.358 to 0.612, with an increment of 0.254; The dimension of continuing operations increased from 0.436 to 0.648; The employment resilience dimension increased from 0.477 to 0.643. It can be seen that the improvement of grassroots public service supply is not evenly distributed to the private economy, and its impact on "whether enterprises dare to enter" and "whether enterprises are willing to expand investment" is more prominent, while the impact on employment resilience is also obvious, but the pace is relatively slow.

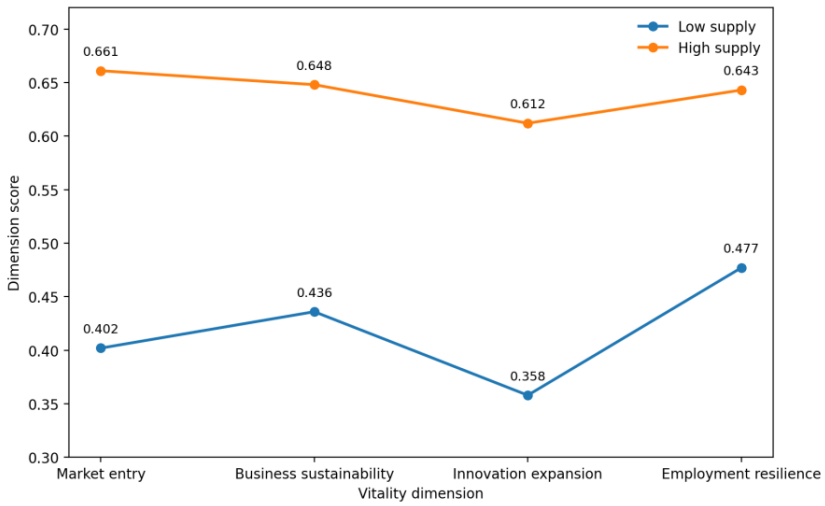

Figure 9: Comparison of scores between the low supply group and the high supply group on different vitality dimensions

This result forms a good echo with the previous mechanism identification section. The higher contribution of government service efficiency and digital public information service in mechanism identification is indeed easier to translate into the improvement of enterprise entry and innovation expansion at the level of impact results. The reason is that the expedited handling of enterprise-related matters, the openness and transparency of policy information and the enhanced accessibility of online services will directly shorten the time cost of enterprise establishment, filing, reporting and obtaining support resources, thus having an immediate impact on market entry behavior. The effects of social security support, education and manpower support, and medical service support are more reflected in the operational stability and employment absorption capacity, which are not as rapid as the efficiency of government affairs, but the improvement of enterprise survival rate and organizational resilience indicators is more sustained.

4.3 Discussion

To assess the explanatory power and methodological value of our findings, it is necessary to contrast them with existing studies on doing business, digital government, and entrepreneurial activity. From the existing results, most studies have proved that the quality of public governance can affect the entry, innovation input and business expectations of enterprises, but many of the analysis still stays at the level of macro institutional variables or single policy impact, and the difference between education support, social security stability, government efficiency and digital information service within the supply of grassroots public services is insufficiently revealed. The results of this paper show that, after splitting grassroots public services into computable multi-dimensional indicators and incorporating them into the unified model with enterprise demand texts, platform operation logs and regional operation data, the marginal contributions and transmission paths of different service dimensions can be more clearly identified, which has the advantage of fine-grained interpretation compared with the traditional regression framework.

An important finding of this paper is that the efficiency of government service and digital public information service show strong influence in the mechanism identification and result analysis, indicating that the improvement of local private economic vitality depends more and more on the public service to shift from "resource supply" to "process collaboration" and "data connectivity". This is not exactly the same as some studies that only emphasize the scale of financial input or the intensity of administrative support. With the help of text mining, feature fusion and interpretable machine learning methods, this paper not only identifies whether the improvement of public services is effective, but also further reveals the link through which the effectiveness is released, thus enhancing the operability of the research conclusions.

At the same time, the results of this paper also suggest that the promotion of grassroots public services to private economic vitality does not occur evenly. The marginal response of low vitality regions is more obvious, while high vitality regions are more characterized by stability optimization and structural upgrading. This means that the follow-up governance should not adopt a single promotion mode, but should combine the regional basic conditions, continuously update the index system and model parameters, and dynamically track the platform data and enterprise feedback. In this way, the supply of grassroots public services can be truly transformed from a general security mechanism to an intelligent governance tool that supports the sustainable growth of local private economy.

5 Conclusion

This paper focuses on the effect process of grassroots public service supply on local private economic vitality, and integrates education, medical care, social security, government efficiency and digital public information services into a unified analysis framework. Combined with regional statistical data, government platform records and enterprise feedback texts, a multi-source computing model for mechanism identification is constructed. The results show that grassroots public service is not just a background variable to ensure people's livelihood. It will continue to affect the entry activity, survival ability and innovation expansion level of the local private economy by reducing institutional transaction costs, improving enterprise expectations, enhancing information availability and stabilizing the labor environment. Among them, government service efficiency and digital public information service show stronger direct promotion effect, while social security and education support show more obvious long-term support characteristics. The value of this paper is that the research on public service is promoted from the general investment comparison to the interpretable and hierarchical mechanism identification, and the idea of text mining and feature fusion is introduced in the method, which improves the ability to describe the complex influence path. However, the research is still constrained by the sample coverage, the data integrity of some grassroots platforms, and the semantic deviation of text. In the future, based on the expansion of regional samples, more high-frequency dynamic monitoring data and more elaborate time series modeling methods can be introduced to improve the robustness and generalization of the conclusions.

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