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ENGINEERING MATERIALS INNOVATION IN URBAN INFRASTRUCTURE AND ITS CONTRIBUTION TO ECONOMIC GROWTH: EVIDENCE FROM MAJOR CHINESE CITIES

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As large-scale infrastructure expansion has accelerated across China's leading cities, the construction sector has grown quickly and the engineering materials industry has shifted from a relatively weak base toward stronger capabilities. This study develops a structured theoretical framework to clarify how engineering materials innovation operates within the construction industry, and then links this mechanism to regional growth using insights from economic growth theory. Employing a threshold regression model, the paper examines the relationship between engineering materials innovation and GDP growth in major Chinese cities. The analysis finds that the sector currently faces two key challenges: a slowing industrial growth rate and declining fixed-asset investment. Meanwhile, innovation outputs are becoming more diversified—reflected in rising diversity and ubiquity indices—though their rate of increase is moderating. Threshold regression estimates suggest that each 1% increase in engineering materials innovation is associated with a 0.099%–0.112% rise in regional GDP. Overall, the study offers a broader explanation of innovation-led economic development through the lens of engineering materials, enriches the literature on regional growth, and provides practical implications for public policy and firm-level innovation strategy.

Index Terms — construction industry, engineering materials, technological innovation, threshold regression model, economic growth

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INTRODUCTION

Urban infrastructure is an essential component that supports the functioning of modern cities and the lives of their inhabitants, and its quality and efficiency are directly related to the sustainability of urban development. With the acceleration of urbanization and population growth, there is an urgent need for more efficient and sustainable solutions for urban infrastructure construction.

Innovative new materials and processes have become the key to improving the quality and efficiency of urban infrastructure construction. New materials not only have higher strength and durability, providing more reliable support for infrastructure, but their application significantly improves construction speed and efficiency [1, 2, 3]. As the high-speed period of large-scale rigid demand for infrastructure construction in China has passed, some of the high speeds of infrastructure and real estate development are no longer available. Therefore, the economic construction of building materials products to reduce the growth in demand, is bound to reduce the building materials industry investment in fixed assets, relying on the power of investment is no longer the building materials industry is looking forward to [4, 5, 6]. Building materials traditional growth model and the single pursuit of quantitative growth development approach is no longer suitable for the new development needs, the contradiction between supply and demand to bring most of the industry and most of the economic benefits of the enterprise is not stable [7, 8]. The innovation of engineering materials in the construction industry, promote China's manufacturing and China's creation at the same time opened up a new economic growth point, the industry shows a new look [9, 10, 11]. Science and technology is the first productive force, science and technology innovation in the building materials industry so that a large number of high-end technology to leap into the world's leading, and promote the building materials industry into a new era of China's manufacturing and China's creation and enter a new cross-border development period [12, 13, 14, 15]. Due to the enhancement of scientific and technological innovation, the development of new economic growth points of the dual role, so that in the serious overcapacity, business and efficiency decline in the building materials industry has ushered in its own spring, a number of industries, a large number of enterprises on the track of high-quality development [16, 17, 18, 19].

The innovation of the study is to investigate the impact of engineering materials innovation on regional economic growth from multiple perspectives, and to clarify the role of engineering materials industry factors and policy factors in the above relationship. The research design utilizes the theories of economic growth, industrial upgrading, technological innovation and sustainable development, and combines the relevant knowledge of econometrics. A threshold regression model is established with the regional economic growth index (GDP) as the explanatory variable, and engineering materials innovation (INN), policy subsidies (GOV), physical capital (PC), and industrial clustering (HTIC) as the explanatory variables, with the aim of revealing the role of engineering materials innovation in promoting economic growth, and making reasonable suggestions for the formulation of related policies.

ENGINEERING MATERIALS INNOVATION IN URBAN INFRASTRUCTURE DEVELOPMENT

Classification of new building materials

New construction materials are materials with entirely new physical, chemical or material properties that meet specific needs in various fields. The innovation and application of new materials in the construction of urban infrastructure is essential to improve the efficiency, quality and sustainability of infrastructure development. Depending on the nature and scope of application, new materials for municipal construction can be categorized as follows:

1. **High-performance concrete:** A common new material is high-performance concrete, which has excellent strength, durability and crack resistance properties and is widely used in urban infrastructure projects such as bridges, tunnels and underground structures. High-performance concrete is prepared through precise control of material composition and proportioning, and special processing techniques. It is capable of withstanding greater loads and deformations, extending the service life of infrastructure and reducing repair and maintenance costs.

2. **Recycled Building Materials:** Recycled building materials, is the use of waste or recycled materials manufactured. Recycled building materials not only reduce the consumption of resources, but also reduce environmental pollution, and are suitable for the walls, floors and roofs of buildings. Common recycled building materials include recycled concrete, recycled glass and recycled metals. These materials realize the effective use of resources and the development of a circular economy by recycling and reusing waste.

3. **Waterproof materials:** Used to protect buildings and infrastructure from water erosion and infiltration.

4. **Energy-saving materials:** Used to improve the energy efficiency of buildings and reduce energy consumption.

5. **Composite Materials:** Combined with materials of different properties, they have high strength, light weight, corrosion resistance and good anti-seismic properties, and are often used in the fields of bridges, pipelines and underground structures.

Organizational structure of the new building materials industry

Definition of the main body of engineering materials technology innovation

In urban infrastructure construction, the main bodies involved in technological innovation of engineering materials in the construction industry include the government, consumers, and construction industry enterprises.

1. **Government:** The government is the driving body of engineering material innovation in urban infrastructure construction. In order to realize the environmental and economic benefits, the government will promote the innovation and development of engineering materials technology in the construction industry through environmental regulation, so as to further realize the win-win situation of industrial economic growth and environmental protection. Therefore, this paper defines the government as the driving body of technological innovation.

2. **Consumption:** Consumers, i.e. the feedback subject of engineering material innovation. Consumer feedback on engineering material innovation is reflected in the process of consumer choice of construction products produced by technological innovation in the construction industry, and the degree of acceptance and diffusion of construction products produced by consumers of new technologies will directly affect the direction of the development of technological innovation and the direction of market promotion. Therefore, this paper defines the consumer, as the feedback subject of engineering materials innovation in the construction industry.

3. **Construction Industry Enterprises:** Construction industry enterprises are the implementation of engineering materials innovation, but also the dominant player in technological innovation, construction industry enterprises through the adoption of innovative ideas, research and development activities, so as to produce or accept new technologies, the formation of new production methods, and then produce new construction products, to open up new markets. Therefore, this paper regards construction enterprises

as the implementation body of engineering material innovation in the construction industry, and at the same time, based on the definition standard of construction enterprises in the Statistical Yearbook of China's Construction Industry, defines construction enterprises as all construction enterprises with qualification levels of general contracting and specialized contracting.

Reconfiguration of the value chain

The modular reconstruction of the value chain of China's building materials industry is shown in Figure 1. In this modular reconfiguration of the industrial value chain, enterprises can choose business combinations according to their own resource conditions, break through the limitations of departmental and geographical divisions, and seek the optimal allocation of resources. The modular organization formed can be divided into two categories: One is the module integration enterprise, which refers to the general contracting enterprise in the construction industry. The second is the module production enterprise, the construction industry refers to subcontracting enterprises and various types of specialized enterprises.

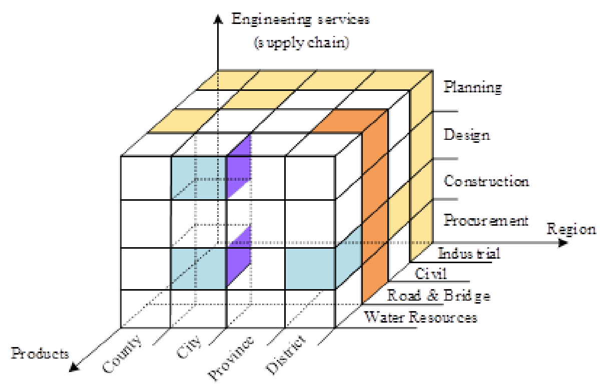

Figure 1: Modular reconstruction of value chain of Chinese construction industry.

Each link in the value chain gathers a number of firms, and an upstream module integration (general contracting) firm can face a number of downstream module manufacturing (subcontracting or specialization) firms at the same time. A downstream module manufacturing enterprise (subcontracting or specialization) can also face several upstream module integration (general contracting) enterprises at the same time. This makes the unidirectional contractual relationship in the original value chain broken, and a net-like contractual relationship is formed between enterprises, and the industrial value chain has also completed the evolution from a single vertical chain structure to a three-dimensional value structure.

Engineering Materials Innovation Model

The engineering material innovation model of the construction industry proposed in this paper is established based on the definition of the innovation subject and the reconstruction of the value chain, as shown in Figure 2. The construction industry engineering materials innovation is guided by the innovation goal and strategy at the enterprise level, which is the starting point of the enterprise's own innovation behavior, and actually occurs at the project level in the interaction process with the government and consumers. Eventually, through the diffusion of new technologies in the construction industry enterprises to realize the impact on the industry level, and the construction industry in the macro-external environment, in turn, affecting the goals and strategies of the construction industry enterprises, and thus the cycle repeats itself, realizing the construction industry's engineering materials innovation.

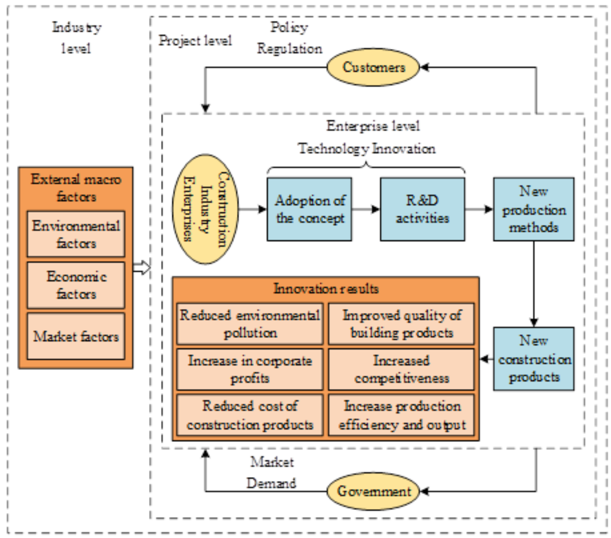

Figure 2: Theoretic model of technological innovation for construction industry.

RESEARCH DESIGN ON ENGINEERING MATERIALS INNOVATION AND REGIONAL ECONOMIC GROWTH

Economic growth process

Economic theory states that the process of sustained economic development is the process of constantly breaking through the primary factor constraints at a given stage of economic development. It is assumed that at a given point in time Δt, total output Y and total input I in the economic system are divided into corresponding shares according to the type of input factor:

$$Y = Y_L + Y_K + Y_T + Y_R + Y_S, \tag{1}$$

$$I = I_L + I_K + I_T + I_R + I_S, \tag{2}$$

where Y and I are total output and total inputs expressed in monetary terms during the Δt time period, respectively (or Y numerically equal to the GDP of a given year if Δt it is that year). L, K, T, R, S denote labor, capital, technological inputs, natural factors and social factors, respectively.

The total economic efficiency θ of the economic system at this point in time can then be defined as:

$$\theta = \frac{Y}{I \cdot \Delta t}. \tag{3}$$

Accordingly, the efficiency of the use of various factors of production is:

$$\theta_i = \frac{Y_i}{I_i} \cdot \Delta t, \tag{4}$$

where i is L, K, T, R, S respectively. Then there are:

$$Y = \sum \theta_i (I_i \cdot \Delta t), \tag{5}$$

$$\theta = \frac{\sum \theta_i I_i}{\sum I_i}. \tag{6}$$

That is, economic efficiency is the weighted average of the efficiencies in the use of various factors. Assuming that Δt is a unit of time, output Y is simply a function of factor inputs I_i and the efficiency of their use θ_i, and accordingly the problem of output maximization can be described as:

$$\max Y = \sum \theta_i I_i, \tag{7}$$

$$\text{s.t.} \quad \sum I_i = I. \tag{8}$$

According to the Lagrangian function:

$$L = \sum \theta_i I_i + \lambda \left(1 - \sum I_i\right), \tag{9}$$

where λ is the Lagrange multiplier and the first order condition is:

$$\frac{\partial L}{\partial I_i} = \theta_i - \lambda = 0. \tag{10}$$

This leads to the necessary condition for output Y to be maximized:

$$\theta_L = \theta_K = \theta_T = \theta_R = \theta_S. \tag{11}$$

The above equation shows that in a regional economic system there is always a certain factor that is used with the lowest efficiency, and this lowest efficiency limits the growth of output and is the efficiency bottleneck of the economic system. When one efficiency bottleneck is eliminated, a new efficiency bottleneck emerges, so the process of economic growth is a race for efficiency in which efficiency bottlenecks are constantly identified and eliminated.

Threshold regression model design and variable selection

Selection of variables

The main sources of data in this paper are the China Architecture Science and Technology Yearbook and China Statistical Yearbook of each year, as well as the statistical yearbooks and statistical bulletins of each province and city.

Explained variable: Regional economic growth indicator (lnGDP), using the gross domestic product of each city, with 2007 as the base period, and taking the logarithm after deflating according to the GDP deflator of each province.

Explanatory variables: Engineering material innovation (INN); Regional innovation network level (NET) including network size, openness, strength, and structural holes; Policy subsidies (GOV); Physical capital (PC) measured by fixed asset investment; Engineering material technology industry agglomeration (HTIC) measured by location entropy:

$$HTIC_{it}^{H} = \frac{x_{it}^{H}/x_{it}}{x_{t}^{H}/x_{t}}. \tag{12}$$

Infrastructure level (INF) measured by infrastructure implementation level; Digital development level (DIG) measured by total regional postal, telecommunication, and courier services.

Modeling

To test the impact of innovation in engineering materials (INN) on regional economic growth (GDP), the following fixed-threshold regression model was set up:

$$\ln GDP_{it} = \alpha + \beta_1 \ln INN_{it} + \beta_2 \ln NET_{it}. \tag{13}$$

where i and t are the region and year respectively, α, β are coefficients to be estimated, and ε_{it} is the random perturbation term.

In this paper, the engineering materials technology innovation variable is set to $t+1$ periods, reflecting a typical one-year lag between R&D and patent application.

STUDY ON THE MECHANISM OF ENGINEERING MATERIALS INNOVATION ON ECONOMIC GROWTH

Trends in the engineering materials industry and GDP

Slowdown in the growth of the engineering materials industry

China's GDP increased from 367.95 billion yuan in 1978 to 126.1 trillion yuan in 2023. The total output value of engineering materials industry rose from 18.684 billion yuan in 1980 to 153,395 billion yuan in 2023. From 2007–2023, influenced by GDP slowdown, the growth rate of value added of engineering materials industry also declined, with a major drop in 2015 (11.41% in 2014 to 7.12% in 2015). For most of 2012–2023, the engineering materials growth rate is higher than GDP growth, but it fell to 6.6% in 2017, indicating a need for deeper analysis.

Lower investment in fixed assets

Fixed asset investment continues to grow in total, but its growth rate declined from 30.13% in 2010 to 4.24% in 2023. More than 60% of fixed asset investment is used for engineering materials purchase and installation. The decline in growth rate reduces demand and brings external pressure, but also forces transformation toward high efficiency, low cost, and environmental protection.

Diversity and ubiquity of engineering material innovations

The diversity index (number of technology categories produced with comparative advantage) is:

$$DIVERSITY = K_{c,0} = \sum_{t}^{m} M_{c,t}, \tag{14}$$

where if region c can produce technology t with advantage $RCA_{c,t} \geq 1$, then $M_{c,t} = 1$, else 0.

The ubiquity index (number of regions able to produce a technology) is:

$$UBIQUITY = K_{t,0} = \sum_{c}^{n} M_{c,t}. \tag{15}$$

In 2007, Beijing and Shanghai produced the most diverse engineering material technologies with the lowest overall ubiquity, showing clear differentiation. In 2023, diversification paths diverged, and Chengdu, Tianjin, Chongqing, and Suzhou exceeded Beijing and Shanghai in diversification.

Impact of engineering materials innovation on economic growth

Descriptive and correlation analysis

Table 1 reports descriptive statistics and correlations. GDP is significantly positively correlated with INN, NET, GOV, PC, HTIC, and INF.

Table 1: Descriptive and correlation analysis of main variables.

Variable	N	Mean	SD	Min	Max
lnGDP	212	9.982	0.611	8.152	11.396
lnINN	212	15.051	1.035	12.341	17.009
lnNET	212	2.374	0.091	2.459	2.834
lnGOV	212	4.452	0.833	2.834	6.946
lnPC	212	7.694	0.576	7.351	6.924
lnHTIC	212	0.988	0.855	0.152	10.005
lnINF	212	9.972	0.809	8.351	17.038
lnTRA	212	2.771	0.351	0.175	6.011
lnDIG	212	0.533	0.181	0.203	0.919

Threshold effect identification and estimation

Threshold effect identification results (Table 2) show a single threshold effect of GOV at 10% level and a double threshold effect at 1% level.

Table 2: Identification of threshold effect (threshold variable GOV; explanatory variable INN).

	Single threshold	Double threshold	Triple threshold
F value	28.15*	38.72***	10.51
p value	0.068	0.000	0.112
BS	500	500	500

Threshold estimates and confidence intervals are shown in Table 3. First GOV threshold is 3.505 with CI [3.351, 3.505]; second threshold is 4.227 with CI [3.558, 6.833].

Table 3: Threshold estimation and confidence interval (GOV).

	First threshold value	Second threshold value
Threshold value	3.505	4.227
95% confidence interval	[3.351, 3.505]	[3.558, 6.833]

Threshold regression results

Results in Table 4 show that: when GOV < 3.505, each 1% increase in INN increases GDP by 0.109%; when $3.505 \leq$ GOV ≤ 4.227, GDP increases by 0.099%; when GOV > 4.227, GDP increases by 0.112%.

Table 4: Threshold estimation results.

Variable	Dependent variable (lnGDP)
lnINN (lnGOV < 3.505)	0.109*** (4.52)
lnINN ($3.505 \leq$ lnGOV ≤ 4.227)	0.099** (3.80)
lnINN (lnGOV > 4.227)	0.112*** (3.92)
lnNET	0.576*** (3.06)
lnPC	0.468*** (10.88)
lnHTIC	-0.051 (-2.34)
lnINF	0.248*** (11.59)
lnTRA	0.052** (1.61)
lnDIG	0.036 (0.89)
Constant	0.108 (0.28)
R^2	0.965
F-value	425.72***

The regression results show that the positive moderating effect of policy subsidies on the positive relationship between independent R&D innovation and regional economic growth gradually increases with the improvement of the level of the innovation network, reflecting that the innovation network can improve intra-regional knowledge flow, broaden its scope, enhance the “recognition label” of policy subsidies, facilitate external investment, reduce duplicated R&D costs, and accelerate dissemination of innovation achievements.

CONCLUSION

This paper establishes the theoretical analysis framework of engineering material innovation and regional economic growth from multiple perspectives, and reveals the influence mechanism of engineering material innovation on regional economic growth in a more in-depth way. There is a double threshold effect on the impact of engineering materials innovation on regional economic growth. That is, when the local regional government support is lower than 3.505, for every 1% growth in engineering materials innovation, GDP grows by 0.109%. For every 1% growth between 3.505 and 4.227, GDP grows by 0.099%. Greater than 4.227, GDP grows by 0.112% for every 1% growth. The results provide a new perspective and comprehensive explanation for the study of engineering materials innovation-driven economic development, enriching the theoretical study of regional economic growth, and at the same time can guide the innovation practice of construction engineering materials enterprises. Meanwhile, this paper mainly adopts the relevant data of statistical yearbook to explore the influence mechanism of engineering materials innovation on regional economic growth, which belongs to statistical information. Future research can strengthen the questionnaire survey and big data analysis to further validate the conclusions of this study, in order to increase the reliability of the conclusions and the richness of the research method.

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