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Research Article

Study on the Operation Efficiency of Toll Roads in China from the Perspective of Scale Economy

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Although China's toll highways are world-renowned, they suffer from indisputable operational inefficiencies. Operationally, China's toll highway sector is characterized by an administrative monopoly. In particular, governmental loan-repayment highways have such characteristics as franchising, monopoly, and "one highway by one company." Hence, this study concentrates on the relationship between economic performance, administrative monopoly, and scale efficiency with respect to toll highways, and explores how the China-specific administrative monopoly affects the transformation of toll highways from scale to efficiency. Using the globally referenced data envelopment analysis- (DEA-) Malmquist Index, this study first measures the operational efficiency of China's toll highway sector from 2010 to 2017. Based on provincial panel data, this paper then discusses the relationship between toll highway scale and economic performance through system-generalized method of moments estimation and verifies the status quo of the transformation of toll highways from scale to efficiency. From the provincial and industrial perspectives, this study further verifies how an administrative monopoly restricts the transformation from scale to total factor productivity and scale efficiency through the unique operation pattern in the toll highway sector. Finally, this study conducts an extended analysis of the relationship between operational efficiency and debt in the toll highway sector. The administrative monopoly is found to increase the debt burden of the toll highway sector and to have a negative impact on the long-term sustainability of the sector.

1. Introduction

According to the *Outline for Building China's Strength in Transportation* (dated September 2019), jointly released by the Central Committee of the Communist Party of China and the State Council, the transport sector should adjust its focus from speed and scale to quality and efficiency. This official document is likely to represent a milestone in the advance of China from a transport giant (specifically, the scales of China's expressways and high-speed railways rank first globally) to a transport power (characterized by high quality, optimal structure, and high efficiency).

Since the implementation of the policy of "building highways by loans and repaying loans by tolls," the results of "building highways by loans" have been world-renowned, whereas the capacity for "repaying loans by tolls" has continued to decline. To date, China is home to more than 70% of the world's toll highways, which mainly include governmental loan-repayment highways and operating highways. By the end of 2018, China's toll highways extended for a cumulative distance of 168,100 km, including 93,300 km of governmental loan-repayment highways, accounting for 55.5% of all toll highways in the country. The governmental loan-repayment highways were monopolized by solely state-owned highway corporations (or highway authorities) at different levels (e.g., provincial level, city level, and district level). Existing studies and evidence show that the economic performance of governmental loan-repayment highway enterprises is the worst in the toll highway sector (in 2018, governmental loan-repayment highways alone incurred an income deficit of 201.85 billion yuan), and such enterprises are universally insufficiently-motivated to reduce costs and improve efficiency. The virtual inflation of operating costs has become a bottleneck to the improvement of economic performance in the sector. Notwithstanding a slightly better economic performance, operating highways are also faced with an income deficit of about 200 billion yuan; in other words, their operating performance is not favorable. This study investigates this genuine problem and attempts to find a solution to it.

In the demand of reducing fiscal expenditure and improving the efficiency of public service supply, the application of the user-pays in highways is becoming a reform attempt in many developing and developed countries [1]. In China, 95.45% of highways are built on a user-paid basis. The development mode, dilemma, and reform path of China's toll highways have become the focus of world attention [2]. Wei et al. [3] stated that the operational efficiency of toll highways is the key to reducing operating costs and achieving sustainable infrastructure. Xu et al. [4] thought that the poor operational efficiency is the main problem of the supply side of toll highway industry, and the development of toll highways should be transformed from scale expansion to quality and efficiency improvement.

Improving the supply quality and efficiency of public service has always been the core pursuit of government managers and scholars. Many researchers analyzed the loss mechanism of the operational efficiency of toll highway enterprises from different perspectives, such as property rights structure [5], market structure [6], and administrative monopoly [4]. In recent years, the public–private partnership (PPP) mode has been favored by industry managers because PPP can not only introduce private capital but also pay attention to the competitive advantages so as to achieve efficiency improvement theoretically [7], However, PPP had not been supported by empirical evidence in practice, and concession did not significantly improve operational efficiency in toll highways [8]. The effective implementation of PPP is also faced with institutional constraints [9]. More and more scholars realize that the root of improving the operational efficiency of infrastructure lies with the institution [10]. As a typical institutional feature of China, administrative monopoly plays a decisive role in the operation of toll highways [11].

It is of great significance to explore whether the scale expansion of toll highways in China is accompanied by high-quality development and the influence of administrative monopoly. Hence, this study examines the relationship between economic performance, administrative monopoly, and scale efficiency with respect to toll highways, and explores how the administrative monopoly with Chinese characteristics affects the transformation of toll highways from scale to efficiency.

2. Literature Review

The influence mechanism of administrative monopoly and economic performance is mainly based on X-inefficiency theory. Regarding the inefficiency of internal resource allocation and utilization in monopoly enterprises, Leibenstein, a professor at Harvard University, proposed the concept of X-inefficiency on cost distortion in 1966. Subsequent theoretical studies can be summarized according to two aspects: (1) different understanding and interpretations of the status and causes of X-inefficiency, Naughton and Frantz [12], Bi et al. [13]; (2) investigation of economic efficiency based on the basic principle of "no waste of resources" by integrating X-inefficiency with technology efficiency, allocation efficiency, and scale efficiency, Pu et al. [14], Yang et al. [15], Zhang et al. [16], Li et al. [17], You et al. [18]; (3)The mainstream studies concentrated on the theoretical exploration and empirical measurement of the mechanism of X-inefficiency and degree of efficiency loss.

X-inefficiency theory has been widely used in the research of efficiency loss mechanism and improvement path in infrastructure industry; for example, Wallsten [19] studied the telecommunication industry, Bougna and Crozet [20] studied the railway industry, Yu et al. [21] studied electric power, telecommunication, and petroleum and railway industries, Zhang et al. [22] studied port enterprises, Jia [23] studied listed airport companies. In addition, X-inefficiency is also applied to the tobacco industry [24], Internet industry [25], family firms [26], National Defense Science and technology industry [27], insurance industry [28], forestry [29], etc. The numerous studies reach a consensus that a monopoly leads to significant X-inefficiency at different levels.

The research on administrative monopoly and economic performance has gradually expanded from qualitative analysis to quantitative analysis to empirical testing of specific impact mechanisms. Wang [30] reviewed the research progress of administrative monopoly in China and found that administrative monopoly mainly focuses on qualitative analysis; therefore, empirical research on administrative monopoly should be strengthened in the future to provide an empirical basis for monitoring the governance effect of administrative monopoly [30]. Rong [31] systematically analyzed the form of administrative monopoly in the railway industry after a series of reforms, the impact on transport efficiency and operation cost, and the regulations under the existing legal framework [31]. Dai et al. [32] used absolute market concentration and relative market concentration to represent the administrative monopoly degree of civil aviation transportation industry, and empirically tested the relationship between administrative monopoly and production efficiency. Yu et al. [33] conducted an empirical study and found that the impact of private hospital entry on the efficiency of the medical industry is not significant. They stressed that it is necessary to further break administrative monopoly so as to foster a competitive market environment. Velinov et al. [34] examined the effect of the administrative monopoly tariffs on the regional energy efficiency and proved that administrative barriers not only affect the efficiency and competitiveness of enterprises but also affect the final price of goods and services of final consumers. Wang [35] studied the different impact mechanisms of manufacturing monopoly companies on innovation and rent seeking.

In the field of toll highways, a wide range of studies on administrative monopoly and economic performance mainly focuses on the form of administrative monopoly in the toll highway industry and the influence mechanism of administrative monopoly on performance. The forms of administrative monopoly in the toll highway industry mainly include the unity of government and enterprise, and the failure of regulation caused by it [4]; the government uses administrative power to exclude market competition in the concession stage [8]; and the hierarchical management system of toll highways. Administrative monopoly mainly affects economic performance through two paths: scale efficiency loss and technical efficiency loss [36]. Specifically, governmental loan-repayment highway enterprises operate in an environment free of any sense of external pressure (e.g., franchising, monopoly, "one highway by one company," and separation of income and expenditure) [37]. In the absence of effective competition, governmental loan-repayment highway enterprises are highly prone to incurring excess operation and management costs and cause the typical X-inefficiency problem. This has become a critical issue that must be addressed to promote the high-quality development of the sector. According to traditional economic theories, governmental monopoly of infrastructure can effectively reduce marginal costs and improve economic performance. This conclusion has been widely questioned in the practice of China's toll highway sector. In China, the rapid development of toll highways is powerfully impelled by the administrative forces of governments. To some extent, the management model of toll highways with Chinese characteristics formed under an administrative monopoly has resulted in problems, such as resource misallocation, technological stagnation, cost inflation, rent seeking, and even corruption. Moreover, the operation mode of "one highway by one company" has caused huge losses from scale efficiency and directly suppressed any improvement to the economic performance of the toll highway sector.

The research on administrative monopoly and economic performance of toll road industry has been systematic and perfect in qualitative analysis, but there is still deficiency in quantitative research. Xu et al. [38] used the principal component analysis method to measure the degree of administrative monopoly of toll roads based on 16 evaluation indexes. Chang [39] conducted a correlation analysis on the degree of administrative monopoly and economic performance of toll roads, and concluded that there is a negative relationship between them, which preliminarily verified the conclusion that administrative monopoly would cause performance loss. Wang et al. [11] and Wei et al. [27], respectively, evaluated the maintenance performance and operational efficiency of toll roads, and the empirical test showed that administrative monopoly is an important factor influencing infrastructure operational and maintenance performance. In addition, Zhou [40] said that toll road debt is still an unavoidable problem. Mao et al. [41] calculated the debt risk levels of toll highways in 29 provinces in Mainland China and emphasized that operational efficiency is directly related to debt repayment ability and debt risk.

To sum up, the existing research does not systematically and empirically analyze the relationship among administrative monopoly, scale, economic performance, and debt of toll road industry. To fill this gap, this study examines the relationship between the administrative monopoly, operation scale, and economic performance, and analyzes the root causes of the operational inefficiency of the toll highway sector, as well as the associated transmission mechanism. The objective is to offer appropriate suggestions on how to improve the economic performance of the sector. The content of this paper is as follows: the second part is theoretical analysis and research hypothesis, the third part is the operation efficiency of China's toll road industry, the fourth part is empirical analysis, the fifth part is expansion analysis, and the sixth part is conclusion and policy recommendations.

3. Theoretical Analysis and Hypothesis Presentation

3.1. Administrative Monopoly and Economic Performance of the Toll Road Industry. The academic literature widely accepts that highway infrastructure can promote regional economic development. Following the track of Adam Smith, researchers continue to deepen and verify the understanding of how transportation infrastructure provides an effective support for economic development. In particular, with the extension of neoclassical growth theory, infrastructure analysis has entered the stage of normative analysis, and the studies of acting paths continue to be optimized [42–45].

Toll highways emerged in China in the late 1980s. At the initial stage of reform and opening-up, China's economic development first encountered a severe shortage of infrastructure. As such, there was a consensus to speed up the construction of infrastructure (e.g., highways). Subsequently, China underwent miraculous economic growth, during which the rapid development of highway infrastructure played a pioneering role. Over a short period of 20 years, the scale of China's toll highways expanded to rank first globally. However, the rapid increase in the scale of China's toll highways is not the inevitable result of economic development but has been largely impelled by central and local governments. Evidently, scale growth and the monopolization of China's toll highway sector are backed by nonmarket forces. Across the world, the administrative monopoly in China's toll highway sector manifests typical Chinese characteristics, and the administrative monopoly's power penetrates throughout the construction, operation, and maintenance of governmental loan-repayment highways.

The administrative monopoly is a scarce institutional resource. The use of an administrative monopoly not only incurs transaction costs but also reaps corresponding revenue. As the effect of the administrative monopoly on toll highways continues to increase, the marginal revenue (MR) of the administrative monopoly increases, whereas the marginal cost (MC) of the administrative monopoly decreases with the improvement of scale efficiency. When the administrative monopoly reaches a degree where the MR is equal to the MC, the effect of the administrative monopoly on the toll highway sector is optimal or rather appropriate. Before the administrative monopoly reaches the point of balance, its MR is greater than its MC. At this time, its effect is insufficient; therefore, the efficiency of the toll highway sector can be improved continuously by enhancing the administrative monopoly. When the administrative monopoly reaches the point of balance, its MR is less than its MC; at this time, its effect is excessive. An excessively high degree of administrative monopoly brings about a typical X-inefficiency phenomenon, resulting in various problems (e.g., severe rent seeking, barriers to technological progress, weakened enterprise competitiveness, and waste of resources) and the ensuing operational inefficiency of the whole sector.

Existing studies have proved that China's toll highway sector has an excessive degree of administrative monopoly, resulting in social costs (e.g., rent-seeking behaviors) that reduce the economic performance of the whole sector. In other words, an excessive administrative monopoly is the primary cause of the poor economic performance of the whole sector. Social costs incurred by the administrative monopoly include external efficiency loss (Harberger Triangle), internal efficiency loss (Leibenstein Quadrilateral), and rent dissipation (Tullock Rectangle) [46]. In recent studies, the estimated administrative monopoly degree of toll road industry is about 88.64% [47] or 81.8% [37], and the rent dissipation degree of government loan-repayment highways caused by administrative monopoly is about 63.5% [48]. Considering the possible impact of administrative monopoly, we propose the following hypothesis:

Hypothesis 1. There exists scale efficiency loss in China's toll road industry.

3.2. Management System and Operation Performance of the Toll Highway Sector. The operation management system of toll highways refers to the organizational form and the acting mechanism that are intended to ensure the normal operation of toll highways. Since the advent of toll highways in China, the central government has implemented the management system known as unified leadership and hierarchical management. This management system has stimulated the enthusiasm of governments at all levels for the construction of toll highways, but it has various defects. Over the years, nonprofit highway authorities have been restructured as enterprise groups, and regional transportation authorities have roughly developed two operation management systems for provincial governmental loan-repayment highways. Some governmental loan-repayment highways are directly managed by nonprofit highway authorities under the provincial Department of Transportation; most governmental loan-repayment highways are centrally managed by operating highway group companies under the provincial Department of Transportation or State Asset Regulatory Commission. Highway group companies or highway authorities set up branch offices or management offices, which are responsible for the operation management of specific highway sections. Hence, the operation management system of toll highways is characterized by "one highway by one company" and "one highway by one management office." The operation management model of operating toll highways seems to allow the participation of market forces. Under the constraint of the overall environment of the toll highway sector, operating toll highways actually present an operation management model similar to that of governmental loan-repayment highways.

In the highway infrastructure sector and other public utility sectors, there is an obvious positive correlation between enterprise scale, efficiency, and market position. The current operation management system of China's toll highways is characterized by "one highway by one company" and "one highway by one management office." Specifically, for each newly built toll highway, an extra branch office or management office is set up under a group company or highway authority; then, toll management stations are set up under the management office, and toll stations are set up under the management stations. Hence, the finalized multilevel operation management system comprises the group company or highway authority, branch office or management office, toll management stations, and toll stations or overload control stations. As a result, the length of highway sections varies significantly, and the highway section operated by a small-scale branch office can be as short as a few dozen kilometers; hence, it is very difficult to allow full play to scale efficiency.

In China, there is a special economic relationship between the central government and the local governments. This special nature is manifested in the bureaucratic organizational system with the integration of political centralization and financial decentralization [49], which can be referred to as an "authoritarian system with regional decentralization" [50, 51]. High centralization of political power and personnel management power is closely combined with the high decentralization of administrative power and economic power. Hence, local governments are not only passive executors of central policies but also selective executors and sometimes even make local policy innovations [49]. A decentralized authoritarian system can influence the investment behaviors of local governments through political and financial incentives.

The administrative monopoly in the toll highway sector, which manifests itself through "one authority for one province" or "one group company in one province," has caused various problems. Many researchers contend that the management system of the infrastructure sector should be reformed by taking the paths of competitive intervention, privatization of public sectors, and diversification of public investors [52–54]. Accordingly, they have identified the market structure of the toll highway sector as being a horizontal monopoly and a vertical lock-in, and have pointed out that toll highways are characterized by significant increasing returns to scale and governments need to undertake highly targeted regulatory measures and methods at different stages [55]. Li et al. [56] contend that toll highways should be operated as enterprises through a shareholding reform to prevent various problems (e.g., ambiguity of power and responsibility, confusion about the functions of governments and enterprises, policy conflict between different departments, and inefficiency); Liu et al.

[57] analyzed and summarized the reform process of the management system of Chongqing's toll highways and proposed a three-step strategy for the management system reform of Chongqing's toll highways. Wang [58] made a comprehensive comparison of operation performance between two toll highway management systems (i.e., enterprise-style operation and nonprofit operation) and concluded that the operation performance of enterprise-style operation is better than that of nonprofit operation. Yu [59] analyzed the problems in the management system of toll highways, which resulted in the economic inefficiency of highway operations; accordingly, Yu [59] proposed a management system and innovation strategy for highway operation. In the context of worldwide governmental system reform, Dan [60] discussed the reform model for Shaanxi's comprehensive transportation management system. Li [61] investigated the existing highway management system of Jilin Province and offered specific optimization suggestions.

Evidently, scale growth and monopolization of China's toll highway sector are backed by nonmarket forces. Therefore, the transformation from scale and monopoly into operational efficiency may encounter obstacles, resulting in the operational inefficiency of the whole sector. Therefore we propose:

Hypothesis 2. Excessive administrative monopoly is the reason that the increase of scale cannot improve the efficiency of the toll road industry.

4. Measurement of the Operating Efficiency of the Toll Road Industry

4.1. Measurement Method. The method of determining the total factor productivity of the industry is mainly divided into parametric and nonparametric methods [62]. The nonparametric method is represented by data envelopment analysis (DEA). The DEA model from the perspective of the "black box" ignores the internal structure and production process of the decision-making unit (DMU), so the network DEA emerges as required over time. The network DEA model is deep inside the decision-making unit in evaluating the subsystem, and the difficulty is to give weight to the initial investment [63]. However, whether it is the network DEA model or the traditional DEA model, they can only process cross-sectional data. Therefore, to dynamically compare DMUs, the Malmquist index has been widely used in the measurement of total factor productivity in various industries [64–67]. The operational efficiency of the toll road industry is the relative relationship between the input and output of toll roads in business activities. Most of the existing results are concentrated on the qualitative aspect but lack qualitative measures, that is, by comparing the economic benefits before and after institutional changes (policy adjustments) and using industrial organization theory to explain the institutional level. Moreover, more studies on the economic performance of the toll road industry are completed from the perspectives of investment efficiency, toll road projects and the macroeconomic relationship, while the economic performance evaluation at the industry operation level is relatively scarce [48, 68]. In addition, it is rare to find papers that analyze the inefficient operation of the toll road industry from the perspective of economies of scale.

For the measurement of toll road operating efficiency, the more mature DEA series algorithm is proposed to consider the technological advancement or degradation leading to movement of the production frontier. This algorithm, in turn, causes the decision units of different periods to lack the benchmark for vertical comparison. The classic DEA model cannot process cross-sectional data. For the panel data selected in this paper, the global reference DEA-Malmquist index is used to measure the operational efficiency of China's toll roads from 2010 to 2017.

The Malmquist model of the global reference proposed by Pastor and Lovell [69] is a Malmquist index calculation method. The reference set is the sum of all periods sets; i.e., the common reference set for each period is

$$\begin{aligned} S^g &= S^1 \cup S^2 \cup \cdots \cup S^p \\ &= \left\{\left(x^1, y^1\right)\right\} \cup \left\{\left(x^2, y^2\right)\right\} \cup \cdots \cup \left\{\left(x^p, y^p\right)\right\}. \end{aligned} \tag{1}$$

As the reference of each period is the same frontier, the calculation obtained is a single Malmquist index:

$$M_g\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \frac{E^g\left(x^{t+1}, y^{t+1}\right)}{E^g\left(x^t, y^t\right)}. \tag{2}$$

Among these, (x^t, y^t)represents the input for period t, and the output vector E^g indicates the DEA efficiency value with the global leading edge as the reference plane. The Malmquist index can be further broken down into Pure Technical Efficiency Changes (PTEC), Scale Efficiency Changes (SEC), and Technological Progress Changes (TC):

$$\begin{aligned} &M_g\left(x^{t+1}, y^{t+1}, x^t, y^t\right) \\ &= \left(\frac{E_C^{t+1}\left(x^{t+1}, y^{t+1}\right)}{E_C^t\left(x^t, y^t\right)}\right)\left(\frac{E_C^{t+1}\left(x^{t+1}, y^{t+1}\right)/E_V^{t+1}\left(x^{t+1}, y^{t+1}\right)}{E_C^t\left(x^t, y^t\right)/E_V^t\left(x^t, y^t\right)}\right) \\ &\cdot \left(\frac{E^g\left(x^{t+1}, y^{t+1}\right), E_C^t\left(x^t, y^t\right)}{E_C^{t+1}\left(x^{t+1}, y^{t+1}\right), E^g\left(x^t, y^t\right)}\right) \\ &= \text{PTEC} \times \text{SEC} \times \text{TC}. \end{aligned} \tag{3}$$

Among these, E_C^t and E_V^t show the DEA efficiency values under the assumptions of constant return to scale and variable return to scale, respectively. Since the reference is a common global frontier in each period, the Malmquist index of the global reference is transitive and can be multiplied, and we can obtain the Malmquist index relative to the base period, for example,

$$M_g(3, 1) = M_g(2, 1) \times M_g(3, 2). \tag{4}$$

4.2. Data Processing and Result Analysis. Pertaining to data selection, in view of the special nature of the toll road industry's operations and management, the provincial panel data are used for empirical analysis. Since there are no toll roads in general in Hainan and Tibet, after removing the Hainan, Tibet, Hong Kong, Macao, and Taiwan regions, this paper selects the remaining 29 provinces as research samples. Public data that can be used to measure the operational performance of the toll roads include the 2010 provincial toll road operation data carried out by the Ministry of Transport and five other ministries and commissions in 2011 during the national toll road special clean-up work, as well as the provincial and municipal toll road statistics bulletins from 2013 to 2017.

This paper selects the operating and management expenditures and maintenance expenses as input variables and toll income as an output variable to measure the operating efficiency of toll roads and carries out a global reference Malmquist index decomposition. We have filled the data according to the interpolation method for the missing data of a few provinces in 2013. The results of these calculations are shown in Tables 1 and 2 .

Overall, there is an increase in China's toll road operating efficiency (M) between 2010 and 2017. In 2017, the national toll road operating efficiency averaged 1.1125, an increase of 11.25% compared to 2010. Technological Progress Change Index (TC) is 0.9829 while the Efficiency Change Index (EC) is 1.1545. The latter contributes more to promoting the national toll road operational efficiency. With further decomposition of EC, the Scale Efficiency Change Index (SEC) is 1.0460 while the Pure Technical Efficiency Change Index (PTEC) is only 1.1638. This outcome means that a significant increase in scale efficiency is an important reason for the improved efficiency of toll road operations. However, during 2010–2017, the compound annual growth rate of toll road mileage is 1.03%, while the annual compound growth rate of the SEC is only 0.56%, which is much smaller than the former. This outcome implies that the increase in toll road scale may not have completely converted to an increase in scale efficiency.

Regionally, the average operating efficiency of central provinces from 2013 to 2017 is 1.0524, which is higher than that of the rest of the country. As in Figure 1, the average operating efficiency of western provinces and northeastern provinces is smaller than 1, which means there is a decline compared to those in 2010. The annual compound growth rates of toll roads in the western and northeastern provinces are 0.24% and 7.34%, respectively (the corresponding mileage indices are 1.0024 and 1.0734, respectively), while the annual compound growth rates of the scale efficiency index are −0.99% and −1.62% (corresponding to the SEC index of 0.9901 and 0.9838, respectively). This outcome means that the increase in toll road mileage in the western and northeastern provinces has not improved scale efficiency.

5. Empirical Analysis

5.1. Models, Variables, and Data. To test Hypothesis 1, we use the panel data of China's 29 provinces from 2013 to 2017 to construct the following measurement model:

$$\text{eff}_{it} = \beta_0 + \beta_1 \,\text{Toll}_{it} + B_1 X_{it}^1 + B_1 X_{it}^2 + \mu_i + \varepsilon_{it}, \quad (5)$$

where eff_{it} is the operating efficiency of province i at period t. Toll_{it} is the scale of regional toll roads, calculated in terms of the density of the toll road (kilometers of toll road per square kilometer of land). X_{it}^1 and X_{it}^2 represent two sets of control variables, among which X_{it}^1 includes some provincial-level control variables: regional urbanization rate Urban, i.e., urban population/total regional population, regional unemployment rate, Unemploy, proportion of employed persons in the regional road transport industry Eply_{it} , i.e., the employment of the regional road transport industry/the total urban employment population; X_{it}^2 includes some industrial-level control variables, such as the number of toll gates on toll roads, recorded as Toll_Station_{it}, road carrying capacity Ltc_{it}, i.e., natural logarithm of highway freight turnover, labor value level of highway industry, recorded as Ave_Salary_{it} , i.e., average wages of transportation, storage, and post/average wages of regional cities and towns. The variables μ_i and ε_{it} are individual effects and random error terms.

To test Hypothesis 2, the influence of administrative monopoly on toll road operating efficiency, we introduce an intersection term (Toll_int_{it}) of administrative monopoly (int_{it}) and toll road scale (Toll_{it}) into equation (5), obtaining the following model:

$$\text{eff}_{it} = \beta_0 + \beta_1 \,\text{Toll}_{it} + \beta_2 \,\text{Toll\_Int}_{it} + B_1 X_{it}^1 + B_1 X_{it}^2 + \mu_i + \varepsilon_{it}. \quad (6)$$

The strength of administrative monopoly is defined at both provincial and sector levels. At the provincial level, the ratio of general budget expenditure in local public finance to regional gross domestic product is used as the proxy variable of administrative monopoly [21, 47, 70]. At the sector level, two proxy variables are used. The first is the ratio of the scale of governmental loan-repayment toll highways to the total scale of toll highways, since governmental loan-repayment toll highways are affected by administrative monopoly more significantly in terms of fund source, debt structure, and operation, compared with operating toll highways. The second is the ratio of cumulative capital funds for the construction of governmental loan-payment toll highways to the total investment of the toll highway sector, since cumulative capital funds are completely sourced from local governments and are highly representative of administrative monopoly.

The above data are mainly from the public database of China's National Bureau of Statistics, the Wind database, and provincial statistical yearbooks under the China Economic and Social Development Statistics Database. Descriptive statistics of the main variables are shown in Table 3.

5.2. Analysis of Empirical Results

5.2.1. Empirical Results of Hypothesis 1. Table 4 shows the parameter estimation results from formula (5), where (I), (II), and (III) are robust least squares estimation of heteroscedasticity using mixed cross-sectional data; (IV), (V), and

Table 1: Average operating efficiency and index decomposition of toll roads in 29 provinces (with 2010 as the base period).

	M	TC	EC	PTEC	SEC	Mileage
2013	1.071306	1.094891	0.992049	1.015689	0.983596	1.010025
2014	1.010079	0.915136	1.125439	1.151682	0.993856	1.049554
2015	1.056895	0.945972	1.134623	1.105395	1.050528	1.061550
2016	1.10107	1.016904	1.097999	1.10819	1.020136	1.104533
2017	1.146968	1.061034	1.096073	1.078796	1.062107	1.057047
2018	1.112477	0.982934	1.154477	1.163751	1.046036	1.085031
Annual compound increase	1.34%	−0.21%	1.81%	1.91%	0.56%	1.03%

Note. M is the Malmquist index; TC is the index for technological progress change; EC is the index for efficiency changes and can be broken down into PTEC (Pure Technical Efficiency Change Index) and SEC (Scale Efficiency Change Index). The above average is the arithmetic mean of the efficiency indicators of 29 provinces per year. Mileage is the toll road mileage index (the annual toll road mileage/2010 toll road mileage). The compound annual growth rate represents the annual compound growth rate of each index in 2010.

Table 2: Annual average operating efficiency and index breakdown by province between 2013 and 2017 (with 2010 as the base period).

Eastern provinces	M	TC	EC	PTEC	SEC	Mileage
Average	**1.0086**	**0.9855**	**1.0236**	**1.0032**	**1.0218**	**1.0131**
Beijing	0.9596	1.0111	0.9490	0.9493	0.9997	1.0201
Tianjin	0.9810	0.9713	1.0099	1.0400	0.9711	1.0302
Hebei	0.9754	0.9721	1.0034	0.9349	1.0733	1.0316
Shanghai	1.0527	0.9888	1.0646	1.1095	0.9595	1.0037
Jiangsu	1.0055	0.9885	1.0173	0.9788	1.0393	1.0046
Zhejiang	1.0240	0.9947	1.0295	1.0000	1.0295	0.9965
Shandong	1.0242	0.9713	1.0545	0.9778	1.0784	0.9792
Fujian	1.0083	0.9714	1.0380	1.0387	0.9993	1.1011
Guangdong	1.0463	1.0005	1.0458	1.0000	1.0458	0.9512
Central provinces	M	TC	EC	PTEC	SEC	Mileage
Average	**1.0524**	**1.0086**	**1.0431**	**1.0332**	**1.0098**	**1.0614**
Shanxi	1.0197	0.9742	1.0466	1.0297	1.0164	1.0577
Anhui	0.9974	0.9974	1.0000	1.0000	1.0000	1.0594
Jiangxi	1.0004	0.9845	1.0161	1.0144	1.0017	1.0373
Henan	1.1146	1.0638	1.0478	1.0077	1.0398	1.0253
Hubei	1.1158	1.0325	1.0807	1.0798	1.0008	1.0675
Hunan	1.0667	0.9994	1.0674	1.0674	1.0000	1.1214
Western provinces	M	TC	EC	PTEC	SEC	Mileage
Average	**0.9781**	**0.9862**	**0.9913**	**1.0015**	**0.9901**	**1.0024**
Inner Mongolia	0.9502	0.9712	0.9784	0.9477	1.0323	1.0005
Guangxi	1.1761	1.0203	1.1526	1.1558	0.9973	0.9352
Chongqing	1.0100	1.0256	0.9848	0.9929	0.9919	1.0633
Sichuan	1.0245	0.9713	1.0548	1.0371	1.0170	0.9182
Guizhou	0.9998	0.9826	1.0175	1.0000	1.0175	1.1701
Yunnan	0.9506	0.9667	0.9833	0.9847	0.9986	0.9621
Shaanxi	0.9824	0.9816	1.0009	0.9696	1.0322	0.9767
Gansu	0.8467	0.9830	0.8613	0.8635	0.9975	0.9595
Qinghai	0.9329	1.0034	0.9297	0.9730	0.9556	1.0180
Ningxia	0.8394	0.9713	0.8642	1.0000	0.8642	0.9540
Xinjiang	1.0464	0.9714	1.0772	1.0919	0.9865	1.0684
Northeastern provinces	M	TC	EC	PTEC	SEC	Mileage
Average	**0.9448**	**1.0006**	**0.9474**	**0.9646**	**0.9838**	**1.0734**
Liaoning	0.9141	0.9715	0.9409	0.9461	0.9945	1.0451
Jilin	1.0310	0.9712	1.0615	1.1040	0.9616	1.0596
Heilongjiang	0.8894	1.0590	0.8398	0.8438	0.9953	1.1157

Note. The average operational efficiency in each province for the period 2013–2017 is the geometric mean of the efficiency values for each year. The reason for choosing the geometric mean is to avoid the effects of extreme values for a certain year; at the same time, the geometric mean reflects the annual compound change in efficiency.

(VI) are generalized method of moments (GMM) estimates of panel data.

In column (I), the explained variable is the total factor productivity of toll road industry (TFP). The estimated coefficient of toll road density is 6.678, which is statistically significant at 1% level. Column (II) reports the impact of toll road density on scale efficiency of toll road industry (SEC). The estimated coefficient is positive but not statistically

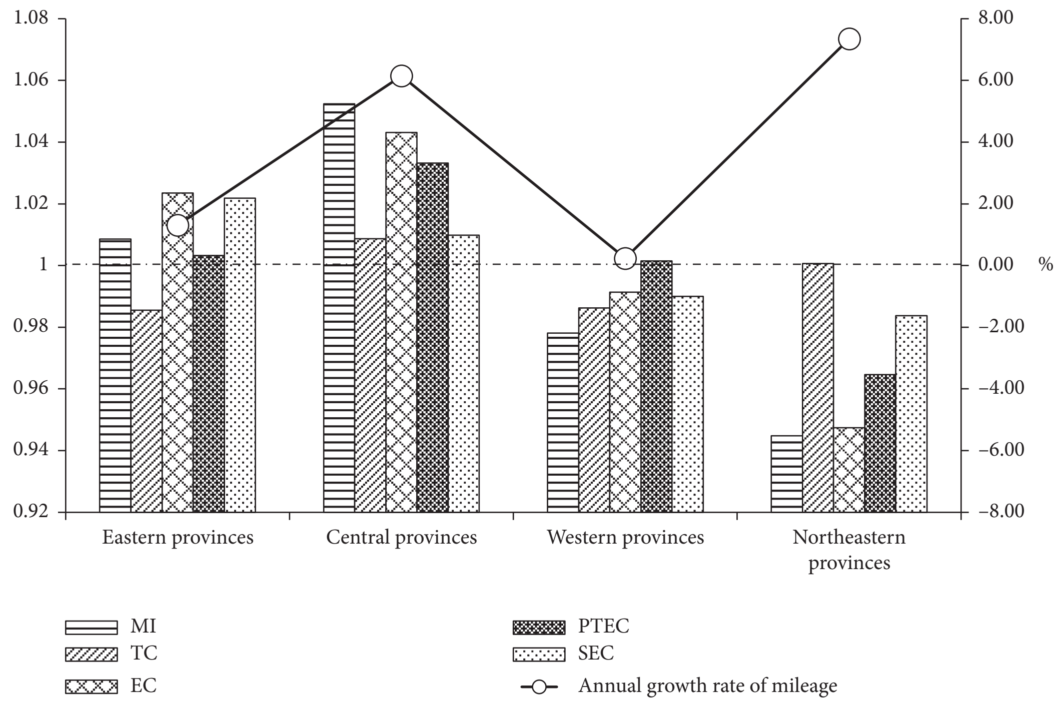

Figure 1: Average operating efficiency in China.

Table 3: Descriptive statistics of the main variables.

	Num.	Mean	Std. dev.	Min	Max
TFP	174	1.069116	0.457933	0.349773	3.284483
SEC	174	1.025559	0.185348	0.416441	1.592271
Toll	203	0.035724	0.024199	0.003651	0.107734
Urban	203	57.38752	12.46630	33.80282	89.60663
Unemploy	203	3.336453	0.633825	1.200000	4.500000
Eply	203	2.057652	0.644237	0.628608	4.390450
Toll_Sation	203	57.34975	58.48951	12.00000	334.0000
Ltc	203	7.219520	0.970183	4.620945	9.053704
Ave_Salary	203	1.114986	0.117489	0.733414	1.423991

Table 4: Parameter estimation results.

	(I) TFP	(II) SEC Pooled OLS	(III) PTEC	(IV) TFP	(V) SEC Panel GMM	(VI) PTEC
Toll	6.678***	0.888	6.851***	5.725***	1.858*	6.591***
	(3.92)	(1.28)	(3.04)	(2.79)	(1.95)	(3.78)
Urban	−0.0138***	−0.000636	−0.00912**	−0.00724*	−0.00414***	−0.0118**
	(−3.01)	(−0.42)	(−2.13)	(−1.91)	(−2.83)	(−2.38)
Unemploy	−0.144**	−0.0368**	−0.00992	−0.239***	−0.0483***	−0.0401
	(−2.39)	(−2.15)	(−0.17)	(−3.77)	(−4.19)	(−0.61)
Eply	0.192***	0.0378*	0.144**	0.151***	0.0308*	0.159***
	(3.77)	(1.76)	(2.37)	(3.47)	(1.66)	(4.09)
Toll_Station	−1.642***	0.618***	−1.407***	−2.887***	0.442	−2.009**
	(−4.02)	(4.76)	(−4.08)	(−2.68)	(0.68)	(−2.05)
Ltc	0.161***	0.117***	−0.00765	0.207***	0.116***	−0.00746
	(4.76)	(6.71)	(−0.27)	(6.03)	(8.68)	(−0.34)
Ave_Salary	0.203	−0.0534	0.668**	0.518	−0.214**	0.940**
	(0.77)	(−0.34)	(2.22)	(1.32)	(−2.41)	(2.18)
_cons	0.372	0.245	0.459	−0.177	0.660***	0.376
	(0.56)	(0.89)	(0.78)	(−0.21)	(3.75)	(0.55)
Hansen	—	—	—	1	1	1
AR	—	—	—	0.126	0.131	0.797
N	174	174	174	145	145	145

Note. *Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level. The *t*-statistics calculated with the standard error of heteroscedasticity are reported in brackets.

significant. Column (III) examines the impact of toll road density on pure technological progress efficiency of toll road industry (PTEC). The estimated coefficient of toll road density is 6.851 and statistically significant, which is close to the estimate in column (I). These results imply that the total factor productivity of toll road industry will increase significantly with the increase of toll road scale, but this is mainly due to the improvement of pure technical progress efficiency, rather than the improvement of scale efficiency. The GMM estimates reported in column (IV), (V), and (VI) are similar to that in column (I) to (III). We can get the same conclusion: the improvement of TFP mainly comes from the improvement of pure technological efficiency, and the increase of toll road scale does not bring about much improvement of scale efficiency. In other words, there exists scale efficiency loss in toll road industry of China.

In the above benchmark regression, toll highway density ($Toll_{it}$) is selected as the proxy variable of toll road scale. Among the toll highways, expressways are characterized by the highest technical standard, the highest construction cost, and the highest operation efficiency, and they account for at least 80% of toll highways. Using expressway density as a proxy variable (Exp_per_land), the conclusions based on the above reference model are subjected to a robustness test. Table 5 lists the parameter estimation results of equation (5) after toll highway density is replaced, where (I) and (II) are robust least squares estimation of heteroscedasticity using mixed cross-sectional data, (III) and (IV) are generalized method of moments (GMM) estimates of panel data.

High expressway density can improve the TFP of the toll highway sector more significantly than scale efficiency. Evidently, scale growth is not completely transformed into efficiency improvement. The regression results of other control variables are also in line with expectations. The results of the robustness test show that we can still obtain parameter estimation results that are highly consistent with those based on the reference after toll highway density (a proxy variable) is replaced. Therefore, we believe Hypothesis 1 is verified and robust.

Table 5: Robustness test results.

	(I) TFP	(II) SEC	(III) TFP	(IV) SEC
	Pooled OLS		Panel GMM	
Exp_per_land	7.526***	1.360**	7.287***	3.135***
	(4.43)	(2.00)	(3.07)	(2.67)
Urban	−0.0156***	−0.00147	−0.00972**	−0.00257
	(−3.10)	(−0.98)	(−2.12)	(−1.22)
Unemploy	−0.164***	−0.0411**	−0.152***	−0.0926***
	(−2.64)	(−2.34)	(−3.20)	(−12.52)
Eply	0.152***	0.0334*	0.122***	0.0519**
	(3.00)	(1.67)	(2.85)	(2.53)
Toll_Station	−1.095**	0.734***	−1.525**	1.121***
	(−2.60)	(5.03)	(−2.46)	(7.51)
Ltc	0.166***	0.116***	0.179***	0.122***
	(5.12)	(6.78)	(4.36)	(15.09)
Ave_Salary	0.197	−0.0385	0.582*	0.317***
	(0.77)	(−0.25)	(1.81)	(2.71)
_cons	0.573	0.286	−0.242	−0.0358
	(0.82)	(1.10)	(−0.30)	(−0.19)
Hansen	—	—	1	1
AR	—	—	0.107	0.101
N	174	174	145	145

Note. *Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level. The *t*-statistics calculated with the standard error of heteroscedasticity are reported in brackets.

5.2.2. Empirical Results of Hypothesis 2. Table 6 lists the parameter estimation results of equation (6) when the ratio of general budget expenditure in local public finance to regional gross domestic product is used as the proxy variable of administrative monopoly. Columns (I) and (II) of Table 6 list the least squares estimation results of heteroscedasticity robustness, and columns (III) and (IV) list the results of the panel generalized method of moments (GMM) estimation. Across different parameter estimation and statistical inference methods, the estimated values and significance levels of the main parameters are approximated to each other. The regression results in columns (I) and (III) show that, after an interaction term is introduced, toll highway density has a positive effect on the TFP of the toll highway sector. However, the positive effect is weakened by fiscal decentralization. Compared with the results of columns (II) and (IV) of Table 4, the results of Equations (II) and (IV) in Table 6 show that high toll highway density has a positive effect, instead of a nonsignificant effect, on the scale efficiency of the toll highway sector. However, the positive effect is weakened by significant fiscal decentralization. Evidently, excessive administrative monopoly is the reason that hinders the scale efficiency of toll roads.

Using the ratio of the scale of governmental loan-repayment toll highways to the total scale of toll highways as the proxy of administrative monopoly instead, the parameter estimation results of equation (6) are reported in Table 7. Columns (I) and (II) list the least squares estimation results of heteroscedasticity robustness, and columns (III) and (IV) list the results of panel GMM estimation. Across different parameter estimation and statistical inference methods, the estimated values and significance levels of the main parameters are approximated to each other. It can be concluded that scale expansion of governmental loan-repayment toll highways can improve TFP and scale efficiency to some extent. However, its role in transforming sector scale into TFP and scale efficiency is significantly weakened by the interaction between administrative monopoly in the sector and toll highway density. Hypothesis 2 is corroborated from the perspective of the sector structure.

In order to verify the robustness of the above results, expressway densityExp_per_land is used to replace toll road density, and (V) and (VI) in Table 7 reports the estimated results. The sign and significance level of the core explanatory variables and the main control variables have not changed significantly, which means that the conclusion is stable and credible from the perspective of industry structure.

In addition, in terms of the source of construction funds (particularly capital funds), governmental loan-repayment highways are obviously different from operating highways.

Table 6: Parameter estimation results.

	(I) TFP	(II) SEC	(III) TFP	(IV) SEC
	Pooled OLS		Panel GMM	
Toll	14.65***	5.858***	10.42***	5.858***
	(4.72)	(5.24)	(5.81)	(5.24)
Toll_int	−39.54***	−24.34***	−26.51**	−24.34***
	(−2.94)	(−4.31)	(−2.33)	(−4.31)
Urban	−0.0188***	−0.00409**	−0.00882**	−0.00409**
	(−4.26)	(−2.57)	(−2.29)	(−2.57)
Unemploy	−0.123*	−0.0432***	−0.178***	−0.0432***
	(−1.93)	(−3.80)	(−3.08)	(−3.80)
Eply	0.220***	0.0276	0.210***	0.0276
	(4.39)	(1.51)	(5.61)	(1.51)
Toll_Station	−1.623***	0.771***	−1.640**	0.771***
	(−3.96)	(7.42)	(−2.33)	(7.42)
Ltc	0.102***	0.0837***	0.129***	0.0837***
	(2.71)	(4.90)	(2.82)	(4.90)
Ave_Salary	0.0117	−0.198	0.647***	−0.198
	(0.05)	(−1.54)	(3.39)	(−1.54)
_cons	1.192*	0.895***	−0.0533	0.895***
	(1.93)	(4.20)	(−0.08)	(4.20)
Hansen	—	—	1	1
AR	—	—	0.146	0.137
N	174	145	145	145

Note. *Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level. The *t*-statistics calculated with the standard error of heteroscedasticity are reported in brackets.

Table 7: Parameter estimation results.

	(I) TFP	(II) SEC	(III) TFP	(IV) SEC	(V) TFP	(VI) SEC
	Pooled OLS		Panel GMM		Panel GMM	
Toll	8.300***	3.105***	9.038**	6.965***	—	—
	(3.60)	(3.17)	(2.50)	(3.27)		
Exp_per_land	—	—	—	—	2.674*	11.86***
					(1.82)	(3.14)
Toll_int	−7.471*	−2.806*	−8.325**	−8.847*	−5.895*	−9.682**
	(−1.97)	(−1.65)	(−2.07)	(−1.87)	(−1.77)	(−2.44)
Urban	−0.0124**	−0.00278*	−0.0276*	−0.00469***	0.00141	−0.0467***
	(−2.58)	(−1.91)	(−1.91)	(−2.95)	(0.63)	(−2.94)
Eply	0.255***	0.0536***	0.242***	0.0621**	0.0487***	0.157***
	(5.62)	(2.69)	(3.93)	(2.52)	(2.71)	(3.05)
Toll_Station	−1.583***	0.659***	−2.067***	0.784***	0.000752***	−0.000854
	(−3.53)	(4.14)	(−3.20)	(4.59)	(3.57)	(−1.27)
Ltc	0.108**	0.0168	0.0482	−0.0134	0.0602***	−0.0450
	(2.35)	(1.00)	(0.44)	(−0.82)	(3.29)	(−0.48)
Ave_Salary	−0.112	−0.230**	−0.761	−0.230	−0.165	−1.425*
	(−0.31)	(−2.04)	(−1.16)	(−1.32)	(−1.04)	(−1.80)
Hansen	—	—	1	1	0.999	1
AR	—	—	0.113	0.405	0.205	0.274
N	174	174	145	145	145	145

Note. *Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level. The *t*-statistics calculated with the standard error of heteroscedasticity are reported in brackets.

The capital funds of governmental loan-repayment highways are mainly sourced from the fiscal funds of local governments (e.g., special debts, budgetary funds, and vehicle purchase tax), while the capital funds of operating highways are mainly sourced from nonfiscal funds (e.g., social capital and enterprises' self-raised funds). Thus, we can use the ratio of cumulative capital funds for the construction of governmental loan-payment toll highways to the total investment of the toll highway sector as the proxy of administrative monopoly, to test Hypothesis 2. The estimation results are reported in Table 8, where columns (I) and (II) list the least squares estimation results of

Table 8: Parameter estimation results.

	(I) TFP	(II) SEC	(III) TFP	(IV) SEC
	Pooled OLS		Panel GMM	
Toll	7.213***	1.845**	13.32***	3.041***
	(3.74)	(2.29)	(4.15)	(2.63)
Toll_int	−20.69**	−7.119*	−61.30**	−12.81**
	(−2.41)	(−1.83)	(−2.55)	(−1.97)
Eply	0.257***	0.0591***	0.334***	0.0643***
	(6.97)	(2.95)	(5.60)	(4.21)
	0.0167***	−0.00238	0.00779	0.00290*
Urban	(−3.50)	(−1.30)	(−0.91)	(−1.91)
	(2.82)	(2.28)	(5.27)	(2.48)
Toll_Station	−1.506***	0.603***	1.881***	0.845***
	(−3.71)	(3.70)	(−4.29)	(8.36)
Ltc	0.110**	0.0362*	0.0216	0.00475
	(2.39)	(1.81)	(0.34)	(0.27)
_cons	0.195	0.209	−1.777	0.0840
	(0.37)	(1.00)	(−1.47)	(0.44)
Hansen test	—	—	1	1
AR test	—	—	0.136	0.136
N	174	174	145	145

Note. *Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level. The *t*-statistics calculated with the standard error of heteroscedasticity are reported in brackets.

heteroscedasticity robustness, and columns (III) and (IV) list the results of panel GMM estimation.

Across different parameter estimation and statistical inference methods, the estimated values and significance levels of the main parameters are approximated to each other. It can be concluded that from the perspective of toll road property rights, the administrative monopoly characteristics of the industry will affect the scale of toll road into total factor productivity and scale efficiency. Hypothesis 2 is further verified from the perspective of industrial property structure.

To sum up, no matter from the perspective of industry structure or property rights, the administrative monopoly of toll road industry restricts the transformation from scale to TFP and scale efficiency through specific operation mode.

6. Extended Discussion: Administrative Monopoly and Debt in the Governmental Loan-Repayment Highway Sector

The unique management system of toll highways produces the market structure and property rights structure with Chinese characteristics. The institutionalized administrative monopoly is not only the critical factor in the institutional environment of the toll highway sector but also primarily accounts for the economic performance, enterprise behaviors, market structure, and property structure of the toll highway sector. The multilevel analysis and empirical test above show that these factors affect the transformation from sector scale to TFP or scale efficiency. Therefore, no significant scale effect has emerged in the toll highway sector over a long period. Low scale efficiency results in another problem in the toll highway sector, namely, insolvency.

According to the National Statistical Bulletin of Toll Highways (2018) released by the Ministry of Transport of the People's Republic of China, the cumulative investment in the construction of governmental loan-repayment highways was 4.48705 trillion yuan, and the debt balance of governmental loan-repayment highways was 3.05361 trillion yuan by the end of 2018. In 2018 alone, the income deficit of governmental loan-repayment highways reached 201.85 billion yuan. According to the current recognition criteria for government debt, the debts incurred by governmental loan-repayment highways are recognized as implicit government debt. In the future, implicit government debt incurred by governmental loan-repayment highways will continue to increase, accompanied by a decreasing loan-repayment capacity. Hence, the debt risk is emerging. Specifically, huge fund investment is required throughout the construction, operation, and maintenance of toll highways, and toll income alone cannot cover the huge debt burden. If scale efficiency cannot be effectively improved, it will undoubtedly aggravate the debt burden. Today, local government debt incurred from the investment in infrastructure (e.g., toll highways) has received increasing attention, as it will bring about hidden trouble for local governments. To resolve the problem, the first step is to ascertain the cause of debt accumulation in the sector.

In order to test the impact of administrative intervention on industry debt, the following measurement model is constructed:

$$\text{Debt}_{it} = \beta_0 + \beta_1 \text{Toll}_{it} + \beta_2 \text{Toll\_Int}_{it} + B_1 X_{it}^1 + B_1 X_{it}^2 + \mu_i + \varepsilon_{it}. \quad (7)$$

Among these, Debt_{it} represents the cumulative total debt of the toll road industry, and tollis the density of regional toll road. The regional-level control variable, Ratio_GDP, refers to the level of regional economic development, measured by the proportion of regional GDP to national GDP. Industry-level control variables: toll road management expense Cost_manage, toll road maintenance expense Cost_main, and toll road toll station number Toll_Station_{it}.The proxy variable for administrative monopoly is the ratio of the scale of governmental loan-repayment toll highways to the total scale of toll highways, and the ratio of cumulative capital funds for the construction of governmental loan-payment toll highways to the total investment of the toll highway sector; thus, the intersection terms are recorded as Toll_Int1 andToll_Int2, respectively, in Table 9.

Table 9 lists the GMM estimates using panel data. The empirical test results show that the administrative monopoly at the industry level will increase the debt burden of the toll road industry, whether from the perspective of industry structure or property rights.

Evidently, the "inherent" administrative monopoly in the toll highway sector, if controlled to an appropriate extent, can promote the development of the sector. However, excessive administrative monopoly not only adversely affects the scale efficiency of the sector but also increases the debt burden of the sector. In the long run, excessive

Table 9: Parameter estimation results.

	(I) l_Debt	(II) l_Debt
Tollway_Mile_	−7.009*** (−3.53)	−9.008*** (−5.81)
Toll_int1	6.259** (1.97)	—
Toll_int2	—	14.00*** (3.40)
Ratio_GDP	−0.165*** (−6.27)	−0.111*** (−3.51)
l_cost_manage	1.473*** (13.41)	1.278*** (7.79)
l_cost_maintain	0.115* (1.89)	0.0855 (1.07)
Toll_Station_1	−8.027*** (−3.72)	−5.748*** (−6.48)
_cons	3.870*** (25.66)	4.305*** (15.34)
AR test	0.302	0.365
Hansen test	0.984	1
N	145	145

Note. *Statistical significance at the 10% level; **statistical significance at the 5% level; ***statistical significance at the 1% level. The *t*-statistics calculated with the standard error of heteroscedasticity are reported in brackets.

administrative monopoly is not beneficial to the sustainability of the governmental loan-repayment highway sector.

7. Conclusions and Policy Recommendations

This paper analyzes the current situation and influence factors of the inefficient toll road operations in China and discovers that an excessive administrative monopoly weakens the economies of scale effect. That is, the increasing road scale has an effect on the promotion of total factor productivity in the industry, but excessive administrative intervention greatly reduces the economies of scale. Therefore, to continue improving the economic performance of the toll road industry, it is necessary to govern an excessive administrative monopoly by bringing out the effect of the economies of scale and overall improve the toll road industry's economic performance. Specifically, the following few aspects could be started:

First, it is necessary to redefine the efficiency boundary between the government and the market. For the construction of toll roads, charge management, maintenance, service area operations, etc., the market mechanisms can play a role, and the effective allocation of economic resources should be returned to the market to ensure the priority role of the market mechanisms in resource allocation. The government should take the initiative to withdraw from specific business areas, weaken the degree and scope of the administrative monopoly, and focus on industry regulation.

The government should also restructure the functions and roles of government departments in the toll road industry. In practice, the excessive administrative monopoly of the toll road industry leads to the coexistence of the "offside" and the "absence" of the functions of the government industry authorities. On the one hand, the government has interfered too much with the market players, constraining the vitality and space of social capital and creating power rent-seeking and corruption. On the other hand, the government is unable to function effectively in areas that require government regulations such as environmental protection and franchise regulations. Therefore, the premise of the role of the market mechanism is for the government to restructure its functions and role in the toll road industry.

Second, it is necessary to realign the toll operations and management model. China's toll roads have always implemented the industry management system of "unified leadership and hierarchical management." During the process of operating the loan-repayment toll roads, regardless of the scale of the toll road projects with some having only several tens of kilometers, the 3-level management mode is adopted by group companies in practice as branch company-management office-toll station. A number of levels and institutions have been set up, and the increase in economies of scale is first shackled by the operating system. Therefore, the suggestion is to actively pilot a 2-level operating and management mode of "branch office-toll station" and explore the management mode of "large administrative regional branch company-management office-toll station." Adopting the operational model innovation by lowering the cost and increasing efficiency will lead to operational management intensification and help in achieving the goal of realizing industry operational efficiency with economies of scale.

Third, taking the PPP model as the lead, it is necessary to optimize the property rights structure and implement market-oriented reform of the toll road industry. Implementing the optimization of the property rights structure is an important way to break the administrative monopoly of the industry. The single property right structure under the control of the "state-owned" government repayment roads severely constrains the resource allocation role of the market mechanism and provides objective conditions for the formation of an excessive administrative monopoly. Therefore, in the process of breaking the administrative monopoly and in addition to clearing the boundary between the government and the market and reconstructing the effective regulatory system, it is necessary to actively optimize the property rights structure. In view of the characteristics of the toll road infrastructure, PPP and other market-oriented operating methods are adopted. Social capital is financed, constructed, and operated under the government's franchise system, breaking administrative monopoly in the form of public–private cooperation. Market-oriented reform is the path to improve industry economic performance.

In summary, low operating efficiency of the toll road industry has become an important problem that urgently needs a solution in the industry. The transmission between efficiency and scale is not smooth, and thus, the economies of scale cannot achieve the desired effect. Moreover, the unique operational organization of the toll road industry with a strong administrative monopoly power is the key to the above problems. Therefore, rationally defining the government's functions in the industry and formulating a scientific reform path is the focus of this research.

Data Availability

Data are available upon request to the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

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