Research Article

CRITIC-Based Vertical Collusion Control Quality Prediction Based on the Coupling and Coordination Degrees of Socioenvironmental and Public-Investment Bidding Systems in China

Chongsen Ma*, Yun Chen*, Liang Ou*, and Kangyang Jiang*

College of Transportation Engineering, Changsha University of Science and Technology, Changsha 410000, Hunan, China

Correspondence should be addressed to Chongsen Ma; machongsen@stu.csust.edu.cn

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Currently, in China, the bidding processes for government socioenvironmental projects face threats of collusion between officials and vendors. This study introduces a coupling and coordination degree-measurement model to study the relationship between the quality of vertical collusion controls and the socioenvironmental system of China based on bidding data taken from 2006 to 2020. The coupling degree describes the socioeconomic influence felt between systems, and the coordination degree refers to their sustainable focused cooperation and mutual influence. The criteria importance through intercriteria correlation method was used to quantify these degrees. To smooth out periods of missing data, the autoregressive integrated moving average model was employed, and the first-order, one-variable, time-series forecasting method was then used to project the trend to 2025. The results revealed that the quality of vertical collusion controls based on the degrees of coupling and coordination between external socioenvironmental and public investment systems ranged from 0.151 to 0.700. Dissonance was detected from 2006 to 2015, but the overall coupling degree has been on an upward trend, peaking in 2020. Currently, the quality of vertical collusion controls is in its primary coordination stage, although it is improving rapidly. From the projected years, both coupling and coordination degrees will enter an intermediate coordination stage by 2022, when the growth rate of the coupling degree is overtaken by that of the coordination degree, as long as active strategies are applied to harmonize the systems in terms of anticollusion measures.

1. Introduction

Since the passage of the Law of the People’s Republic of China on Bidding and Tendering in 1999, China’s bidding and tendering market has developed rapidly. Most government-invested public construction projects use bidding processes to determine construction and operational vendors and resources. However, with the very rapid growth of the Chinese construction market, problems of collusion between government officials and vendors are inevitable. Bidding (vertical) collusion, although often justified by the notion of benefiting local labor markets, has the potential to hamper project completion, overrun budgets, and counteract the intended social benefits. Furthermore, it breeds corruption. Thus, the relationship between socioenvironmental and public infrastructure funding systems is certainly affected by the quality of the anticollusion measures applied. Therefore, a good balance of coupling and coordination is critical to positive social and environmental developments and improvements.

In recent years, sustainable development and synergy theories have been applied to sociological research. Notably, the coupling degree between systems describes the socioeconomic influence felt between them, and the coordination degree refers to their sustainable focused cooperation and mutual influence. Of the many studies published regarding such relationships, the quality of vertical collusion controls applied to socioenvironmental public infrastructure bidding processes has not been well examined. Notably, social policy formulation is supposed to enforce the altruistic intentions of
public infrastructure. Hence, the role of vertical collusion control is of utmost importance in China, the largest developing country and the second largest economy in the world. Therefore, a thorough assessment of the degrees of coupling and coordination between the socioenvironmental and public infrastructure systems in China using vertical collusion controls as the exogenous variable will be useful for adjusting public policy as necessary in support of the country’s national objectives with utmost reduction in corruption.

To assess the situation, this study leverages government investment bidding data from 2006 to 2020 to examine the quality of collusion control measures from the perspective of system coupling and coordination. The criteria importance through intercriteria correlation (CRITIC) method is used to determine the index weights, and the evaluation index system is scientifically clarified. It is more scientific, objective, and reasonable than existing questionnaire-based collusion research results, and it extends existing bidding collusion research. To smooth out periods of missing data, the autoregressive integrated moving average (ARIMA) model is applied, and the first-order, one-variable, grey model (GM(1, 1)) time-series forecasting method is then used to project the trend to 2025. On this basis, targeted measures are proposed to provide a scientific reference for achieving sustainable development and optimal regulation.

The global implications of this article include the direct correlation found between the quality of vertical collusion controls with the degrees of coupling and cooperation between the external socioenvironmental system and the government-run public investment system. Furthermore, new data are provided to further support normative development policies for the Chinese market and to provide generalizable measures for other countries in similar circumstances.

The contributions of this article are as follows:

(i) An evaluation index of the degrees of coupling and coordination between socioenvironmental and public infrastructure funding systems based on the quality of vertical collusion control measures

(ii) The first coupling and coordination relationship model focusing on vertical collusion that integrates the perspectives of both public agencies or governments and external socioenvironmental participants

(iii) Collusion countermeasures that promote the coupling and coordination of socioenvironmental and public infrastructure funding systems

The remainder of this article is structured as follows. The literature review is presented next, followed by the research methodology and evaluation indices used for this research. Results and analyses are presented next, including anticipated future coupling and coordination degrees. The final section presents conclusions and recommendations.

2. Literature Review

Aligning policymaking with the needs of the social environment is the cornerstone of quality social development, and vertical collusion puts such goals at risk [1–3]. Most extant research on collusive bidding has focused on corruption networks, behavioral detection, and gaming theory aspects [4–8]. Some studies have even examined how external systems affect enterprise decision making, including that of governments [9, 10].

2.1. Impact of Vertical Collusion on the Social Environment.

The social environment comprises many aspects, including psychological, organizational, economic, political, and cultural aspects. Using provincial panel data from Chinese provinces collected from 2002 to 2016, Guangming constructed a new typology of government-enterprise relations while applying dimensions of corruptibility and market-ability, finding that vertical collusion has a significant positive effect on the size of informal employment and self-employment related to public works [11]. Nie and Li argued that collusion between local governments and vendors led to the combination of high growth and accident rates in the Chinese economy [12]. Apriliyanti and Kristiansen performed a case study in Indonesia, finding that vertical collusion and corruption hinder governance reforms in state-owned enterprises. These findings imply that the external social environment may facilitate collusion control [13].

2.2. Coupling and Coordination of Socioenvironmental and Public Funding Systems in Light of Vertical Collusion Control Quality.

Campante et al. found a U-shaped relationship between the stability of government officials and collusion [14], and Yu et al. found one between cadre tenure and environmental pollution [15]. Kai and Ds used these relationships to construct a counterfactual framework to analyze the negative effects of government-vendor collusion [16]. Notably, it was shown that if mayors are citizens from their own district, they are more likely to collude with hometown vendors to promote local economic development. On the basis of the principal-agent theory, Chen Yongtai established an anticollusion contract for firms and local governments, taking the central government’s social welfare maximization priority as the starting point [17]. He argued that punishment mechanisms would promote healthy and sustainable economic development, proposing that the central government should incentivize and restrain behavioral decisions by adjusting the weight of economic construction and environmental protection.

In summary, although many researchers have examined the effects of government collusion with vendors on the social environment, scant effort has been afforded to public works bidding processes from a systems coupling and coordination aspect [18–21]. Therefore, this study aims to fill the gap by measuring their degrees longitudinally while providing improvement recommendations.

3. Method

3.1. ARIMA Model. The data used in the model were retrieved from publicly available databases, some of which were missing year-2020 data. Hence, the ARIMA model, a common time-series forecasting capability [22] that derives
future conditions from historical data, was applied for supplementation. In the function ARIMA\( (p, d, q) \), \( p \) is the number of autoregressive terms, \( d \) is the number of non-seasonal differences needed for stationarity, and \( q \) is the number of lagged forecast errors in the prediction equation. This study uses the Akaike information criterion value minimization approach to determine the best ARIMA model.

3.1.1. Autoregression (AR) Model. To describe the direct relationship between predicted and historical data at the current moment, the \( p \)-order AR model with random perturbation terms is expressed as

\[
X_t = \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \cdots + \alpha_p x_{t-p} + u_t = \sum_{i=1}^{p} \alpha_i x_{t-i} + u_t, \tag{1}
\]

where \( X_t \) is the predicted data at time \( t \), \( p \) denotes the number of predicted moments, \( u_t \) denotes the random perturbation term, and \( \alpha_i \) is the model parameter.

3.1.2. Moving Average (MA) Model. To account for the variation of series data for smoothness, the random disturbance term in the AR model is considered an MA term of order \( q \). Therefore, the calculation is as follows:

\[
u_t = \varepsilon_t + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + \cdots + \beta_q \varepsilon_{t-q} = \varepsilon_t + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j}, \tag{2}
\]

where \( \varepsilon_t \) is the white-noise sequence, \( q \) denotes the number of moments affected by the white-noise sequence, and \( \beta_j \) is the model parameter.

3.1.3. ARIMA Model. To predict the number of differences, \( d \), in the time-series data, unsteady data must be first obtained:

\[
X_t = \varepsilon_t + \sum_{i=1}^{p} \alpha_i x_{t-i} + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j}, \tag{3}
\]

3.2. CRITIC Weighting. The objective CRITIC weighting method assigns weights to indicators by contrast intensity and conflict index. Contrast intensity is calculated using standard deviation, and the higher the data volatility is, the higher is the weighting. The conflict index measure is expressed using the correlation coefficient, and the greater the correlation between indicators is, the smaller is the conflict and the smaller is the weighting of indicators. Indicator weights are obtained by multiplying and normalizing the contrast intensities and conflict index measures [23].

The CRITIC method is a highly practical and improved entropy weighting method, and its calculation steps are described as follows:

1. The initial indices are unified in terms of magnitude using positive or negative indexing, and the Z-score normalization method is used to understand how far the data point is from the mean and to unify the metrics. The treatment formula is

\[
x'_i = \frac{x_i - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}}, \tag{4}
\]

where \( x'_i \) is the normalized index value.

2. The CRITIC method reflects the variability and conflict among the indicators using standard deviation and the correlation coefficient, which is calculated by

\[
\xi_j = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (S'_{ij} - \bar{S}_j)^2}, \quad j = 1, 2, \ldots, n, \tag{5}
\]

\[
r_{ij} = \frac{\text{cov}(S'_i, S'_j)}{\xi_i \xi_j}, \quad i, j = 1, 2, \ldots, n,
\]

where \( \xi_j \) is the standard deviation of the \( j \)th indicator, \( r_{ij} \) is the correlation coefficient between the \( i \)th and \( j \)th indicators, and \( S'_i \) and \( S'_j \) are the \( i \)th and \( j \)th columns of the normalization matrix.

3. To calculate the objective weights, the formula used to determine the amount of information contained in the \( j \)th indicator is

\[
E_j = \xi_j \frac{1}{\sum_{i=1}^{n} (1 - r_{ij})}. \tag{6}
\]

The magnitude of \( E_j \) reflects the amount of information contained in the indicator; hence, the weight is sized correspondingly. The proportion of information in the \( j \)th indicator to the total information is taken as the objective weight, \( \sigma_j \):

\[
\sigma_j = \frac{E_j}{\sum_{j=1}^{n} E_j}. \tag{7}
\]

3.3. Coupling and Coordination Evaluation Methods. The degree of coupling, a context borrowed from physics, describes the degree of socioeconomic influence felt between systems (human organizations). The degree of coordination refers to the sustainable focused cooperation and mutual influence between systems [24]. Controlling the vertical political interfaces in government investment projects is particularly complex and is influenced by many factors, such as the external economic environment, corporate collusion intentions, and the strength of social controls. The efficacy and quality of vertical collusion controls rely on the support of the external environment. The bidding process for public works is especially vulnerable to collusion. By construing an evaluation index system, the degrees of coupling and coordination can be determined.

Given a coupled system, the quality of the vertical collusion controls is given in equation (8), and the degree of system coupling is given in equation (9):
The value of $C$ ranges from 0 to 1. When $C=0$, the coupling degree between the two systems is at its lowest, reflecting little-to-no correlation. When $C=1$, the coupling degree is at its maximum and the system is moving in the direction of order. Notably, the coupling degree only provides half of the story. A coordination degree model is also needed to understand how strongly the coupling is being controlled. In our case, we want to understand the level of control because it pertains specifically to anticollision measures. Hence, we have equations (10) and (11):

$$D = \sqrt{C \cdot T},$$
$$T = \alpha u_1 + \beta u_2,$$

where $D$ denotes the degree of coupling coordination, $C$ is the coupling degree, and $T$ is the coordination degree. Variables $\alpha$ and $\beta$ denote the weights of the vertical collision control quality subsystem and the external socio-environmental system, respectively. In other studies, a value of 0.5 is usually assigned to $\alpha$ and $\beta$. However, this study uses the CRITIC method to assign the weights, which aims to provide more realistic results.

In this article, coupling and coordination degrees are divided into four classes based on the guidance of other scholars. Table 1 provides this division.

3.4. GM$(I, 1)$. The influence of the socioenvironmental system on collision control quality has highly nonlinear uncertainty. Hence, the GM$(I, 1)$ prediction model leverages differential equations to make accurate predictions for forecasting monotonous processes. The method requires little information, has high computational accuracy, and is easy to test. Additionally, there is no need to consider the distribution pattern and change trend. However, this model is only suitable for short- and medium-term forecasting. As China is developing at a fast pace and long-term forecasting may be unreliable, GM$(I, 1)$ is suitable for our purposes. GM$(I, 1)$ is specifically used to forecast the coupled coordination model for the future dates of 2021–2025. The calculation steps are as follows:

Relevant data are collected and organized, arranged in chronological order, and labeled. The original series values of the data are

$$X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \ldots, X^{(0)}(N)\}.$$  \hspace{1cm} (12)

The cumulative serial values of the data are

$$X^{(1)} = \{X^{(1)}(1), X^{(1)}(2), \ldots, X^{(1)}(N)\},$$

$$X^{(1)}(N) = \begin{cases} X^{(0)}(1), & N = 1, \\ X^{(1)}(N - 1) + X^{(0)}(N), & N = 2, 3, \ldots \end{cases}.$$  \hspace{1cm} (13)

The cumulative predictive value equation established is

$$X^{(1)}(t) = X^{(0)}(1) - \frac{u}{a} e^{-\alpha(t-1)} + \frac{u}{a}.$$  \hspace{1cm} (14)

In (14), $a$ and $u$ are matrix parameters from (15):

$$\tilde{a} = \left[ \begin{array}{c} a \\ u \end{array} \right]$$

$$= (B^T B)^{-1} B^T Y_n.$$  \hspace{1cm} (15)

In equation (15), the sliding average matrix $(B)$ and the data vector $(Y_n)$ are calculated as

$$B = \left[ \begin{array}{c} \frac{1}{2} (X^{(1)}(1) + X^{(1)}(2)), \\ \frac{1}{2} (X^{(1)}(2) + X^{(1)}(3)), \\ \ldots \\ \frac{1}{2} (X^{(1)}(N - 1) + X^{(1)}(N)), 1 \end{array} \right],$$

$$Y_n = \begin{bmatrix} X^{(0)}(2), \\ X^{(0)}(3), \\ \vdots \\ X^{(0)}(N) \end{bmatrix}.$$  \hspace{1cm} (16)

The final prediction equation is

$$\hat{X}^{(0)}(t) = \left\{ \begin{array}{ll} \tilde{X}^{(1)}(t), & t = 1, \\ \tilde{X}^{(1)}(t) - \tilde{X}^{(1)}(t-1), & t \geq 2. \end{array} \right.$$  \hspace{1cm} (17)

To test the reliability of the model, the residuals are tested first. The relative error formula is

$$\Delta(x) = \frac{|X^{(0)}(t) - \hat{X}^{(0)}(t)|}{X^{(0)}(t)}.$$  \hspace{1cm} (18)
The model passes the residual test when the mean error is less than 0.2. The model is also subjected to a posteriori difference testing:

\[ S_1 = \sqrt{\frac{\sum_{i=1}^{n} (X^{(0)}(t) - \bar{X}^{(0)}(t))^2}{n-1}} \]

\[ S_2 = \sqrt{\frac{\sum_{i=1}^{n} (\Delta(x) - \bar{\Delta}(x))^2}{n-1}} \]

\[ (19) \]

The a posteriori test difference ratio is \( C = S_2/S_1 \). The model grade classification is shown in Table 2.

### 4. Results and Discussion

#### 4.1. Evaluation Index Construction

There is indeed a coupling relationship between socioenvironmental and public infrastructure funding systems in China. As such, the degree of coordination was found to affect the quality of vertical collusion controls. Moreover, there are obvious mutual influence, constraint, and promotion. Therefore, appropriate indicators from the results can be used to extrapolate the efficacy of the socioenvironmental system on improving the quality of collusion controls. However, there is no current standard of indicators to use for social development status, external influences, and governance quality. Furthermore, vertical collusion has a wide range of influencing factors, which currently cannot be singled out. Therefore, we refer to the research results of Chen and Ding, and many others [25–33] who developed and refined a process of constructing an evaluation index system using the same data types collected in this study. In this research, we hypothesised that there is a link between the quality of collusive bidding governance and the external social environment. Data variation is balanced between years of data.

The process is as follows:

1. Initial data collection mainly takes the form of questionnaires. Hence, web-based questionnaires were distributed to 10 experts and relevant researchers, and relevant data were analyzed.
2. For statistical screening, the collected data were analyzed using SPSS AU software, and the indicators were screened. A total of 11 evaluation indicators were finally determined.
3. The weights of the indicators were then clarified using the CRITIC method.
4. We then divided the indicators into two major systems (i.e., vertical collusion control quality and socioenvironment indicators). The latter was divided into three subsystems (i.e., social justice climate, construction market development status, and government investment efforts). To prevent subjective factors from influencing the results, we adopted the CRITIC method to assign weights to the indicators. The weighting results are shown in Table 3.

#### 4.2. Data Sources

The study data were retrieved from the Chinese National Statistical Yearbook [34], which is highly credible and publicly available. The number of cases received per 10,000 people, closure rates, number of corruption cases, and total construction enterprise liabilities were missing in 2020. The ARIMA method was therefore used to forecast the relevant missing data.

#### 4.3. Coupling and Coordination Degree Analysis

On the basis of the adopted indexing system, the quality of vertical collusion controls and their relationship to socioenvironmental and public investment systems were calculated and analyzed, as shown in Table 4. The coordination degree between the quality of vertical collusion controls and the socioenvironmental system in China ranged from 0.176 to 0.766, which indicates an improvement from little-to-no to moderate coordination in a developing trend. 2006 and 2007 reflected low but quickly increasing coordination degrees. It reached its highest point of 0.819 in 2017. Afterward, coordination moderated, perhaps because, after the 18th National Congress, the government began cracking down on corrupt social bidding practices. The coupling degree in 2020 was 0.625, which is 3.55 times that of 2006.

The coupling degree between the quality of vertical collusion control and the socioenvironmental system in China was poor in 2006–2015, and the vertical collusion control subsystem did not fully adapt to the needs of the socioenvironmental system. The two were in a state of mutual competition for a long time as China’s bidding market slowly became standardized. Hence, relevant laws and regulations were lacking. In any case, China’s construction industry enjoyed a boom, which indirectly led to additional difficulties controlling collusion. The coupling degree has significantly increased since the 18th National Congress, and it reached its highest value in 2017, followed

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Table 1: Criteria for classification of coupling coordination levels.

| Coordination degree (D) value interval | Coordination level | Coordination degree description |
|--------------------------------------|-------------------|-------------------------------|
| (0.0–0.4) | 1 | Little-to-no coordination |
| [0.4–0.6) | 2 | Some coordination |
| [0.6–0.8) | 3 | Moderate coordination |
| [0.8–1.0) | 4 | Highly coordinated |

Table 2: Model grade classification table.

| Level      | C  |
|------------|----|
| Excellent  | ≤0.35 |
| Qualified  | 0.36–0.50 |
| Barely pass| 0.51–0.65 |
| Fail       | >0.65 |

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by a slight decline, but with gradual stabilization and moderation.

From the line graph in Figure 1, the coupling degree has risen since 2006, with a few unstable fluctuations (including its fastest growth) in 2006-2008, which certainly corresponds to the reality of the gradual formalization of government bidding projects in China. External policy changes also contributed to the rapid improvements to coupling. Between 2009 and 2015, a relatively stable growth rate was maintained, although it was not high. On the other hand, there was a decline in 2015, when China notably amended the bidding and tendering law, and the Ministry of Transport and other agencies introduced corresponding regulations to bidding and tendering processes. After 2015, the coupling degree showed rapid growth, stabilizing at moderate coordinated development.

4.4. Analysis of Coordination Degree Results. The coupling degree concordance between the quality of vertical collusion controls and the socioenvironmental system in China have risen considerably, but the overall degree of coordination is lower than that of system coupling. Coupling rose quickly from 2006 to 2015 and dropped in 2016 for reasons already discussed, reflecting a general public works bidding process with disorderly collusion controls. With the continuous attention being paid to the socioenvironmental system and the increase in reforms and anticorruption policies affecting the public works collusion control subsystem, the coupling and coordination degrees have drawn a picture of struggling and competing forces, as illustrated in Figure 1, from 2015 to 2020. The future state of the degree of coordination seems hopeful but uncertain. This is where the GM(1, 1) prediction model comes into play.

| Year | C   | T   | D   | Coupling level | Coordination level | Coordination degree     |
|------|-----|-----|-----|----------------|--------------------|-------------------------|
| 2006 | 0.176 | 0.130 | 0.151 | 1              | 1                  | Little-to-no coordination |
| 2007 | 0.366 | 0.161 | 0.243 | 1              | 1                  | Little-to-no coordination |
| 2008 | 0.505 | 0.172 | 0.295 | 2              | 1                  | Little-to-no coordination |
| 2009 | 0.506 | 0.228 | 0.340 | 2              | 1                  | Little-to-no coordination |
| 2010 | 0.553 | 0.245 | 0.368 | 2              | 1                  | Little-to-no coordination |
| 2011 | 0.565 | 0.256 | 0.380 | 2              | 1                  | Little-to-no coordination |
| 2012 | 0.584 | 0.286 | 0.409 | 2              | 2                  | Some coordination        |
| 2013 | 0.654 | 0.305 | 0.447 | 3              | 2                  | Some coordination        |
| 2014 | 0.714 | 0.365 | 0.510 | 3              | 2                  | Some coordination        |
| 2015 | 0.553 | 0.395 | 0.468 | 2              | 2                  | Some coordination        |
| 2016 | 0.732 | 0.446 | 0.571 | 3              | 2                  | Some coordination        |
| 2017 | 0.819 | 0.525 | 0.656 | 4              | 3                  | Moderate coordination    |
| 2018 | 0.766 | 0.517 | 0.629 | 3              | 3                  | Moderate coordination    |
| 2019 | 0.687 | 0.662 | 0.674 | 3              | 3                  | Moderate coordination    |
| 2020 | 0.625 | 0.783 | 0.700 | 3              | 3                  | Moderate coordination    |

Table 3: CRITIC method weighting results.

| Systems                                  | Subsystems                              | CRITIC weighting calculation results |
|------------------------------------------|-----------------------------------------|--------------------------------------|
| Quality of vertical collusion governance | Quality of governance                   | Indicator variability                |
|                                          |                                         | Indicator conflict                   |
|                                          |                                         | Amount of information                |
|                                          |                                         | Weight (%)                           |
| Social justice atmosphere                |                                        |                                      |
|                                          |                                        |                                      |
| External environment indicators          | Construction market development status  |                                      |
|                                          |                                        |                                      |
| Government investment efforts            |                                        |                                      |

Table 4: Calculation results of coupling coordination.

6 Discrete Dynamics in Nature and Society
The long-term vision and associated cultivation of China’s economy correspond to a rapidly changing social ethos toward higher controls and compliance in business. Predicting the behavior of this coupled coordination over the next five years would provide great assistance to policy formulation. Hence, the GM(1, 1) model error test and prediction data are shown in Table 5, and the trends of the predicted indicators are shown in Figure 2.

4.5. Forecasted Degrees of Coupling and Coordination As It Pertains to the Quality of Public Works Collusion Controls and the Socioenvironmental System in China. According to the analysis, the GM(1, 1) model predicted a coupling degree of 0.2015 and a coordination degree of 0.022, both less than 0.35. Hence, model accuracy is high enough to predict the future degrees of 2021-2025. The results are shown in Table 5, showing a gradual increase with improving coordination by 2022. The synergistic effect will hence significantly increase. However, the rising trend of coupling will be significantly weaker than that of system coordination. Thus, it will be necessary to moderate and tune external pressures to promote improved coupling over the long term. For this reason, we provide conclusions and recommendations next.
5. Conclusions and Recommendations

5.1. Conclusion. Over the past 20 years, China’s bidding market has developed rapidly. The emergence of government investment projects has been tailored to promote societal advancements. However, with fantastic opportunity comes risks of corruption. This article introduced a coupling and coordination degree-measurement model to study the relationship between the quality of vertical collusion controls and the socioenvironmental system of China based on bidding data taken from 2006 to 2020. A summary of the main findings is as follows:

1. The coupling degree between the quality of vertical collusion controls and the socioenvironmental system ranged from 0.176 to 0.819, changing from a declining little-to-no coordination relationship to a developing moderate coordination relationship. 2006 and 2007 reflected little-to-no coordination, but it improved quickly afterward, reaching its highest point of 0.819 in 2017. Afterward, the relationship remained moderate.

2. The coordination degree between the two systems grew fast. The average level of the sample period was 0.456, which reflects some coordination. The decreasing and increasing coordination degrees reflect the strong coupling between the two systems, implying that as the level interaction increases, the benefits gradually improve.

3. Both coupling and coordination degrees are expected to steadily increase from 2021 to 2025, with few changes in the growth rate. However, with the coupling degree measure falling short of the coordination degree measure in 2020, continued development will be slower than the examined period of the past.

5.2. Recommendations. As the coupling between the quality of the public works collusion control subsystem and the socioenvironmental system in China continues to grow and mature, more active statutory and regulatory measures will be needed to maintain coordinated development. The following are key recommendations taken from our examination of the projection data:

1. Anticorruption campaigns should be strengthened, and a normalized method of monitoring violations should be established. Using relevant data, the coupling and coordination degrees should be continually monitored to verify their expected growth. Noting that the current anticorruption efforts seem to have worked, localities should establish normalized supervision pathways to promote continued progress.

2. The socioenvironmental system in China should be continually improved and empowered so that homogeneous anticollusion measures can be applied nationally to ensure homogeneous results. Efforts should be made to create a social atmosphere that is reluctant to collude and to reward compliance and the lawful behavior of agencies and vendors.

3. Federated controls should be afforded to achieve the coordinated development of quality vertical collusion governance and a provincially run socioenvironmental system that enforces policies.

5.3. Study Limitations. Although this study reached some valuable conclusions, a few shortcomings remain:

1. The relationship between vertical collusion governance and the social environment is extremely complex with many influencing factors, both internally and externally. This study was unprecedented, and indicator determination was freshly conducted. Thus, incomplete or inappropriate indicators may have led to biased conclusions.

2. Although a homogeneous application of anticorruption measures was presumed, development efforts vary greatly among Chinese provinces, and the degree of coupling between systems may differ.
accordingly and into the future. Thus, the lack of region-specific analysis may be a shortcoming. Further research should be conducted to address the key differences among regions, provinces, and cities on this topic.

(3) The article used standard time-series models. The dynamics of the application of the coupling model was immature, and more examinations and experienced tailoring are needed to produce more reliable results. Furthermore, our use of lagged variables only shows effects, lacking causal analysis.

(4) This article combined Chinese and international study results to derive our study approach. Additional methods will be needed to better triangulate the results.

Data Availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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