# Multiple Intervention Effects and ARIMAX Forecasting: An Application of a World Bank Project in China

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## Abstract

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## Full Text

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**Key Words:** World Bank; Foreign loan assistance projects; Green finance; ARIMAX intervention model; Qiandao Lake
**Classification:** F831.2, F284, X52, F812.7

## 1. Introduction

### 1.1 Project Background

Zhejiang Province's "mother river," the Qiantang River, relies on its upstream reservoir—Qiandao Lake (the Xin'an River Reservoir)—as a crucial component of provincial water environment management strategy. The Xin'an River originates in Anhui Province and flows into Qiandao Lake in Chun'an County, Zhejiang. The lake receives inflow at Jiekou (upper left point in Figure 1 [FIGURE:1]) and discharges at Baqian (bottom right point in Figure 1).

From a national perspective, Qiandao Lake is China's largest freshwater artificial lake, serving as an essential strategic water source and ecological barrier in the Yangtze River Delta region. From a provincial perspective, it is the direct drinking water source for Hangzhou, Zhejiang's capital. To protect these high-quality water resources, Zhejiang Province and the World Bank signed an agreement in July 2018 to implement the "World Bank-financed Zhejiang Qiandao Lake and Xin'an River Basin Water Resources and Ecological Environmental Protection Project" (hereafter "Qiandao Lake Project" or QLP). Spanning from 2018 to 2024, the QLP's construction efforts in Chun'an County include upgrading water conservancy facilities, controlling agricultural non-point source pollution, and restoring forest ecosystems. Upon completion, the nitrogen load is expected to decrease by 25%, phosphorus load by 30%, and soil loss by 20%.

The QLP aims to strengthen comprehensive pollution management in the river basin, with lessons that can extend to broader ecological protection and environmental management within China and other countries facing similar challenges. To analyze the QLP's implementation outcomes and create a best-practice benchmark, we adopt a quantitative perspective to evaluate the role of green finance within the project. Previous literature, such as Lu and He (2014) [1], focused on chemical oxygen demand (COD) to assess whether Payment for Ecosystem Services (PES) programs significantly improved water quality, employing an ARIMA model with a single intervention without additional control variables. In contrast, this paper contributes by applying an ARIMAX multiple interventions model at the intersection of green finance and water conservation. To our knowledge, this is the first empirical application of such a model in this context, providing robust evidence for evaluating World Bank-financed projects and a methodological example for assessing similar projects elsewhere.

### 1.2 Literature Review

Few domestic studies have examined the impact of World Bank loans on water source protection in Zhejiang, leaving a significant gap in the literature. This study addresses that gap by evaluating the effect of green sovereign credit funds (the World Bank-financed QLP) on Qiandao Lake's water quality. Specifically, we assess whether the World Bank loan has significantly and positively influenced the lake's water quality and, if so, provide empirical evidence to support applying World Bank funding in Zhejiang.

Regarding the role of green finance in ecological protection and high-quality development [2], Chen Xutong (2019) [3] used provincial panel data to examine the effects of green investment on industrial wastewater discharge and treatment. Wang Xuxia (2021) [4] constructed a comprehensive index system to analyze the relationship between green finance and environmental governance, using panel data from 31 Chinese provinces (2004–2018). These studies generally adopt a macro perspective (e.g., national scale or Yellow River Basin [5]). In contrast, our study focuses on a specific and important water source in Zhejiang Province, highlighting a clear methodological and contextual difference.

Regarding forms of green finance supporting ecological protection, Xu Shilong, Yang Xia, et al. (2022) [6] constructed a water resource balance sheet for Gansu Province. By measuring ecological value, they proposed enhancing green finance support to realize the value of ecological products, recommending the leveraging of policy-based finance and thematic bonds for ecological protection to raise low-cost funds for major water resource protection projects. Zhejiang's introduction of sovereign external debt aligns with these recommendations. However, unlike previous research, this paper provides an empirical assessment, testing the effectiveness of World Bank-financed projects using quantitative models.

## 2. Research Methods

### 2.1 Research Methods

When studying whether Qiandao Lake's water quality is positively affected by green finance from the Zhejiang Provincial World Bank-financed project, the most direct evidence would be a positive trend in water quality that meets or exceeds the standards stipulated by national regulations. Therefore, according to the "Environmental Quality Standards for Surface Water" (GB 3838-2002) currently implemented by the State Environmental Protection Administration, we selected publicly available data indicators from the 24 basic items at the

Qiandao Lake water quality monitoring station. The most representative permanganate index (CODMN), ammonia nitrogen (TAN), total phosphorus (TP), and total nitrogen (TN) were chosen as explanatory variables.

Figure 2 [FIGURE:2] shows the permanganate index (abbreviated as codmn) in Qiandao Lake (2015.1–2024.6). Note that a lower codmn value indicates better water quality. codmn_{in} indicates the quality of incoming water, codmn_{out} indicates the quality of outbound water, and codmn_{net} = codmn_{out} - codmn_{in}. If outbound water quality is measured unilaterally, the direct cause of deteriorating outbound water quality might simply be deterioration of inbound water quality, which would obscure the project's governance effect. In other words, using inbound water as a control group to observe changes in outbound water quality better reflects project governance effectiveness.

In studying time series data on water quality, we observed nonlinear fluctuations, prompting our use of the Autoregressive Integrated Moving Average (ARIMA) model with a superimposed intervention model. Considering that virtually all governance of Qiandao Lake involves multiple interventions, we employ an intervention model to evaluate the effectiveness of the World Bank's loan for the Qiandao Lake Project.

### 2.2.1 ARIMA Model

The ARIMA model is well-suited for modeling fluctuating time series, as nonstationary sequences can generally be converted into stationary time series through multiple differencing. ARIMA models typically contain AR terms and MA terms, so we first define the AR term of order p and the MA term of order q.

The autoregressive term AR(p) expressed as a lagging operator L, where B = 1 - L, is shown in Equation (1):

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$$

The moving average term MA(q) expressed as a lagging operator is shown in Equation (2):

$$\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \cdots + \theta_q B^q$$

Combining equations (1) and (2) forms an ARIMA model, as shown in equation (3):

$$\phi(B)(1 - B)^d y_t = \theta(B)\epsilon_t$$

where d indicates that after d-degree differencing, a stationary sequence is obtained.

### 2.2.2 Intervention Model

Time series are often disturbed by external interventions during development. The World Bank's Qiandao Lake project should have a certain treatment effect or intervention effect on water quality. Box and Tiao [7] (1975) and Box and Jenkins [8] (1976) proposed the concept of the ARIMA intervention model, which can be formally expressed as shown in Equation (4):

$$y_t = \mu + \frac{\omega(B)}{\delta(B)} I_t + N_t$$

where $\mu$ is the constant term, $N_t$ is the ARIMA model introduced earlier, $b$ indicates lagged b period, and if b = 0, then $I_t = S_t^T$, meaning the intervention effect is considered effective immediately. We omitted the term if we assumed the intervention term takes effect at once, making $I_t$ the only intervention term. $I_t$ represents the form of the intervention, with coefficient $\omega(B)$ also called the Transfer function, which can be written in the form of Equation (5):

$$\omega(B) = \omega_0 + \omega_1 B + \omega_2 B^2 + \cdots + \omega_r B^r$$

Classified according to form and effect, there are generally two types of interventions, as shown in formulas (6) and (7):

$$Ladder\ intervention : I_t = S_t^T = \begin{cases} 0, & t < T \\ 1, & t \geq T \end{cases}$$

$$Pulse\ intervention : I_t = P_t^T = \begin{cases} 0, & t \neq T \\ 1, & t = T \end{cases}$$

If there are multiple intervention events, say k, then Equation (4) could be rewritten as shown in formula (8):

$$y_t = \mu + \sum_{i=1}^{k} \frac{\omega_i(B)}{\delta_i(B)} I_{it} + N_t$$

where $I_{it}$ is the intervention function, which depends on the real situation.

## 3. Model Specification

### 3.1 Explained Variable

First, we subtract the CODMN index value of inbound water from the CODMN index value of outbound water to obtain the full-time series of the codmn_{net} sample, as shown in Figure 3 [FIGURE:3]. In Figure 3, it can be seen that the indicator has maintained a negative value throughout the sample period (2015.1–2024.6), meaning outbound water quality is better than inbound water quality, reflecting that Qiandao Lake's water quality has been under treatment effect. Since nearly 70% (actually 68%) of Qiandao Lake's water source comes from the Xin'an River, the water quality of the entry point greatly determines the quality of Qiandao Lake. If there were no water environment treatment projects, in a tourist resort area like Qiandao Lake, where water flows through Chun'an County with a population of more than 300,000 registered residents (with even more fluid population), downstream water quality would generally not be better than upstream water quality. Even considering the dilution and purification effect of local water sources, only 30% of local streams (such as Wuqiang Stream, the second largest water source of Qiandao Lake) cannot fundamentally impact water quality self-purification.

### 3.2 Choice of Intervention Timing

Negotiations for the World Bank-financed Qiandao Lake Project were completed at the end of March 2018, with the Loan Agreement and Project Agreement signed on July 31, 2018. On November 26, 2018, the head of the relevant World Bank department sent a letter to Zhejiang officially confirming completion of all legal procedures, marking the beginning of the Qiandao Lake project's full-scale construction and implementation. Therefore, November 2018 represents the official launch of the Qiandao Lake project.

Additionally, we note that the QLP is not the only project significantly improving water quality indicators. Since 2014, several projects have been carried out in the Qiandao Lake reservoir area, with the most representative and influential being the implementation of the "five-water co-governance river chief system" and the operation of the "Qiandao Lake Water Fund."

**3.2.1 Five Water Co-governance River Chief System** 2014 marked the first year of "five-water co-governance" in Zhejiang Province and Chun'an County. Since our research data begins in 2015, the five-water co-governance project runs throughout the Bank's project period. In August 2021, Chun'an County was included in the Zhejiang Provincial Water Resources Department's Water Resources Intensive and Safe Utilization Comprehensive Experimental Zone, and the Qiandao Lake Water Supply Project was awarded the first batch of Zhejiang Province's "Five Water Co-governance" practice windows. Considering that the five-water co-governance and river chief system has been implemented, it is reasonable to assume that its effects may continue throughout the sample period.

**3.2.2 Qiandao Lake Water Fund** The World Bank-financed project has been accompanied by several other influential green projects implemented in parallel. For example, the "Qiandao Lake Water Fund" project was also carried out in the Qiandao Lake basin to explore and promote agricultural non-point source pollution control. The project vision is to explore a sustainable model of ecological governance to protect long-term water security in the Qiandao Lake basin. According to "Nature-Based Solutions: China's Practice in Dealing with Water Resources Crisis: A Case for Water Source Conservation in Qiandao Lake in Zhejiang" published by Jin Tong, Mu Quan, Wang Longzhu, Guo Feifei et al. (2021) [9], it is clearly stated that "since 2016, The Nature Conservancy

(TNC) has established the 'Qiandao Lake Water Fund' with several partners to explore NbS (Nature-based Solution) application in water source protection." The launch of the Qiandao Lake Water Fund project in Hangzhou on February 6, 2018, can be understood as the formal establishment at the mechanism level. Therefore, we can infer that water quality before November 2018 was also under the governance and impact of other projects. Note that we do not mention the impact of the "Xin'an River Qiandao Lake Basin Ecological Compensation" project between Anhui and Zhejiang provinces because we use a differential method for generating codmn_{net} indicators, so changes in incoming water from Anhui have already been taken into account.

### 3.3 Stationarity and Bounded Cointegration Tests

Since the project start time was set in November 2018, to model pre-intervention time series, the period from 2015.1–2018.10 was tested for stationarity and white noise. The results are shown in Table 1 .

**Table 1 Stationary Tests for codmn_{net} variable**

| Inspection model | Hysteresis order | Level+Trend | codmn_{net} |
|---|---|---|---|
| Level+Trend<br>Note: Level = constant term, Trend = Trend term | PPERRON | Level+Trend | |

p-value outcome: stationary conclusion: stationary

With all three test methods, we can determine that the codmn_{net} time series is stationary, and subsequent white noise tests also confirm it is non-white noise, so modeling can continue.

In addition, since Qiandao Lake's water quality is affected by complex factors such as the surrounding natural environment, production, and living conditions, the control variables considered in this study mainly include temperature and precipitation in the natural environment (Figure 4 [FIGURE:4], Figure 5 [FIGURE:5]).

We also performed stationarity tests for these control variables, with results shown in Table 2 .

**Table 2 Stationary tests for control variables**

| variable | Inspection model | lntemp | Level+Trend |
|---|---|---|---|
| (The logarithm of temperature)<br><br>Level+Trend | diff(lnrain) | (Precipitation logarithm, first-order difference) | PPERRON |

Note: Level = constant term, Trend = Trend term, Hysteresis order p-value outcome: stationary conclusion: stationary

Due to the introduction of first-order integrated variable diff(lnrain), we also conducted a bounded cointegration test [10]. The F-statistic = 4.61, greater than the 5% bound upper limit of 4.203, therefore we determine that a cointegration relationship exists and regression can proceed. The stability graph is shown in Figure 6 [FIGURE:6].

## 4. Empirical Results

### 4.1 ARIMA Model Before QLP Intervention

Since the data satisfies stationarity and non-white noise conditions, we established a pre-intervention model based on the QLP intervention time point of November 2018. The model aims to predict a counterfactual situation after the intervention: how water quality would have evolved assuming the QLP was not implemented. Additionally, considering that before QLP implementation, several water quality treatment-related projects were carried out (such as the 2014 "Five Water Co-governance" three-year investment plan in Chun'an County, the 2015 river and lake chief system first implemented in Chun'an Qiandao Lake, and the 2016 Water Fund Project kickoff), these also brought lagging treatment effects on water quality. To exclude these interventions from the governance effect and isolate the QLP's impact, we must consider these earlier intervention effects—in other words, these factors need to be controlled in an ARIMAX model.

Based on analysis of time series mutation values, we obtained Table 3 , which shows all mutation time points (rows 1 to 2) before November 2018 as intervention effects from a series of water quality control policies such as the five-water co-governance, river and lake chief system, and water fund.

**Table 3 Automated analysis results on detected intervention types and time points**

| Outliers: index | 2015m3 | 2016m10 | 2023m5 |
|---|---|---|---|
| coef | hat | tstat | |

Note: As defined in R package tsoutliers in function tso: Outliers have innovational outliers ("IO"), additive outliers ("AO"), level shifts ("LS"), temporary changes ("TC") and seasonal level shifts ("SLS"). Generally "AO","LS" are with "S" transfer function and "TC" with "P".

Since all interventions have been automatically detected, the SARIMAX intervention model could be implemented as equation (9) by filling equation (8) with the Table 3 information:

$$codmn\_nett = \mu + \phi_1 codmn\_net_{t-1} + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \beta_1 temp_t + \beta_2 rain_t + \omega_1 I_{2015m03,t} + \omega_2 I_{2016m10,t} + \epsilon_t$$

At the same time, the auto.arima function judges the proper SARIMAX model in the form of “SARIMA(p=1,d=0,q=2, P=1,D=0,Q=1) with non-zero mean and with seasonal lag pattern PDQ.” Parameter estimates using maximum likelihood estimation are shown in Table 4 .

**Table 4 Parameter Estimates**

| Parameter | Estimate | Std.Error | z value | Pr(> | z | ) |
|---|---|---|---|---|---|---|
| | 141.5063 | <2.20E-16 | 0.00E+00 | 8.97E-01 | <2.20E-16 | 2.00E-15 |
| | 112.9529 | <2.20E-16 | 0.00E+00 | 2.41E-10 | 1.99E-07 | |
| ts.lntemp | 2.34E-03 | | | | | |
| ts.lnrain | | | | | | |
| X2015m03-MA0 | 8.72E-02 | 1.52E-02 | | | | |
| X2016m10-MA0 | <2.20E-16 | 4.53E-11 | | | | |

Note: 1. signif. codes: 0 ‘***’ 0.001*** ’’ *0.01* ” 0.05 ‘.’ 0.1 ’ ’ 1; log-likelihood = -4.94, sigma^2 estimated as 0.05633: AIC = 21.88

The plot of the model (equation 9) with estimated parameters is shown in Figure 7 [FIGURE:7]. From Figure 7, we can intuitively see that the model simulates actual values very well. The model was then tested for normality using Shapiro-Wilk (p-value = 0.7092), confirming residuals conform to normal distribution. The Box-Ljung white noise test yielded p-value = 0.5713, showing white noise. ACF and PACF plots of the residuals show no hysteresis order exceeding the confidence interval, also indicating good model fit.

Using this model, we can plot the impact of other water quality protection-related events before QLP implementation, as in Figure 8 [FIGURE:8]. It can be observed that a series of previous water environment treatment projects produced certain treatment effects on Qiandao Lake’s water quality indicators, with effects showing continuity and gradual attenuation.

### 4.2 Counterfactual Predictions of Pre-intervention Models

Using actual temperature and precipitation data from November 2018 to June 2024 while controlling for other projects’ effects, we used the previously developed model to predict the water quality control index codmn_{net} after November 2018. The predicted values are shown by the solid line in Figure 9 [FIGURE:9].

The graph is divided into left and right parts by the timeline of November 2018 (when the Qiandao Lake project started). The left side shows actual values, reflecting water quality status before project implementation. We can see that pollution indicators of lake outflow minus inflow yield a negative difference, indicating downstream water quality improved compared to upstream, attributable to treatment projects like five-water co-governance, river and lake chief system, and World Bank’s previous water fund projects.

On the right side, assuming no Qiandao Lake project, the predicted value regresses toward 0, meaning downstream water quality approaches upstream water quality. Note that effects of various previous water quality treatment projects have been accounted for. When the indicator curve reaches the X-axis (equals 0), upstream and downstream water quality are identical; when it crosses into positive territory, downstream water quality becomes worse than upstream (as shown in Figure 10 [FIGURE:10]).

However, observed water quality (displayed by dotted lines) remains below the counterfactual curve, indicating that treatment after November 2018 achieved the effect of making downstream water quality better than upstream. The largest water environmental impact project in the Qiandao Lake reservoir area after November 2018 is the World Bank-financed Qiandao Lake Project, making it reasonable to attribute the constant effect of downstream water quality improvement over upstream to the QLP. We net actual against predicted values (i.e., actual – forecast) to obtain the quantitative intervention effect of the QLP (as shown in Figure 11 [FIGURE:11]).

As can be seen from the figure, the Qiandao Lake project launched in November 2018 did not immediately show water quality improvement effects (codmn_{net} above zero means no effects). Over time, initial effects began appearing around April-May 2019 (codmn_{net} gradually fluctuating below and above the zero axis). Since the second half of 2021, the QLP has steadily exerted significant effects (codmn_{net} stably below the zero axis), meaning downstream outbound water quality (flowing out from the Baqian section of the Qiandao Lake Dam in Zhejiang) is stably better than inbound water quality (from Anhui Province flowing in from the Jiekou entrance section).

## 5. Discussion

### 5.1 Remarkable Environmental Governance Results

Through water quality analysis using the ARIMA intervention model for the Baqian and Jiekou sections, the permanganate index (codmn_{net}) shows a significant downward trend 2–3 years after project start, with codmn_{net} remaining negative. This indicates that treatment group data not only showed significant concentration decreases compared to the control group but also continued to demonstrate treatment effects. After controlling for natural factors (such as self-purification in the lake area and impacts of temperature and precipitation) and accounting for government actions and other projects (such as five-water co-governance, river and lake chief system, and water fund project implementation), we still obtain stable results supporting the judgment that the World Bank-financed Qiandao Lake project has significant positive effects on the lake reservoir's water quality.

### 5.2 Synergy Between Qiandao Lake Project and Water Fund

Due to the early start of the Qiandao Lake Water Fund in basin governance, with scientific and effective treatment methods, it has undoubtedly had very positive impacts on Qiandao Lake's water quality. Before QLP implementation, when we added the impact of the ARIMA intervention model to the Qiandao Lake Water Fund, we observed significant impacts on the permanganate index (codmn_{net}), proving that the Water Fund plays a significant role in purifying Qiandao Lake's water environment. From a synergy perspective, the Water Fund project itself is a pioneering attempt within the World Bank-financed "Qiandao Lake and Xin'an River Basin Water Resources and Eco-environmental Protection Project," exploring long-term sustainable mechanisms after various environmental protection projects conclude.

### 5.3 Long-term Mechanisms Require Attention

During QLP implementation, although the codmn_{net} indicator performs well, this index is only a relative value. Much more attention should be paid to controlling absolute water quality index values in the reservoir area. If we only maintain healthy relative indicators while ignoring declines in absolute pollutant numbers, we still cannot achieve water quality improvement. Due to current technology levels and treatment intensity, pollutants have been entrenched around fixed low values for a long time, making it difficult to achieve further significant improvement. An important implication is that ecological compensation actions between Zhejiang and Anhui provinces need continuous promotion. In fact, upstream water plays a baseline role in Qiandao Lake area water quality—downstream can only be governed on this basis—so special attention should be paid to dynamic maintenance, exploration, and development of mutually beneficial and win-win mechanisms with upstream regions.

### 5.4 Bottleneck Period for Some Water Quality Indicators

If we observe total phosphorus (TP), total nitrogen (TN), and total ammonia nitrogen (TAN), we find these indicators have extremely small amplitudes and remain almost constant (as seen in Figures 12 [FIGURE:12], 13 [FIGURE:13], and 14

, which show these indicators have been stable and slightly fluctuating around excellent values in the downstream section).

Through observation, we can see that Qiandao Lake's water quality has maintained a constant trend for many years from the perspective of TP, TN, and TAN, without significant decreases due to project implementation. In other words, the Qiandao Lake project has not shown obvious treatment effects on these TP, TN, and TAN index values, suggesting we have reached ability limitations under current treatment technology and processes. The low levels of TP, TN, and TAN indexes have been maintained at relatively high-quality levels mainly through previous five-water co-treatment and multiple rounds of river

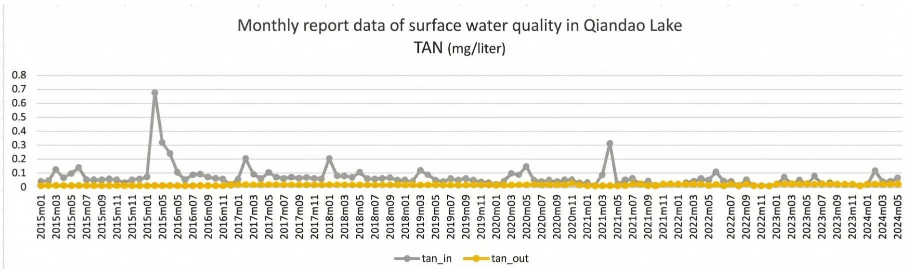


Figure 1: Figure 14

basin ecological compensation. If we want to further improve water quality, in addition to greatly improving upstream water quality in the Qiandao Lake reservoir area, we will likely need to improve the scientific and technological level of water environment governance as well as strengthen the breadth and depth of governance.

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