

## Analysis on the Effect of Government Investment on Private Investment in Western China — Take Province A as an Example

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**Abstract** Since China began reforming and opening up its economy, and especially since the launch of development projects in western China, province A has attracted an increasing amount of investment, which is the main driving force for provincial economic growth. Hence, this study uses a state space model to examine how government investment has affected economic growth in province A in western China, and explains whether there is a crowding-in effect or a crowding-out effect of local government investment on private investment. The findings indicate that both government and private investments have a positive, stimulating influence on economic growth in province A, with the latter being more impactful than the former. Productive and non-productive investments have different effects on province A's economic growth. From the perspective of the trajectory of government investment elasticity, the elasticity of government and private investments in province A presents a very large spatio-temporal change. That is, from 1994 to 2009, government investment in province A had a crowding-in effect on private investment, but from 2010 to 2017, a crowding-out effect was observed.

**Keywords** province A in western China; government investment; private investment; state space model

## 1 Introduction

Government investment has always been a principal propeller of economic development in China. It plays an important role in improving social productivity, boosting economic activities and international competitiveness, and accelerating economic development. Particularly, since the Third Plenary Session of the 11th CPC Central Committee, China's economy has developed rapidly owing to the government's proactive fiscal policy. Government investment has always been an important driver of economic growth. For example, during the Asian financial crisis

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in 1998 and the global subprime mortgage crisis in 2008, China implemented a proactive fiscal policy and invested four trillion yuan into the economy, successfully offsetting the unfavorable impact of external economic forces on China's economic development. Due to this intervention, the Chinese economy was able to quickly recover and continue growing at a sustainable and steady rate despite the crisis. Since the reform and opening-up initiatives began, province A in western China (hereafter province A) has thoroughly implemented the state investment policy and achieved steady economic growth, with its real gross domestic product (GDP) rising from 27.4 billion yuan in 1990 to 1,598.365 billion yuan in 2021. However, the GDP growth has been volatile. In 2009, province A's economic growth rate of province A dipped to its lowest point in 30 years due to the international financial crisis and social factors. However, in 2010, owing to an improved international and domestic environment, the GDP growth rate improved significantly. Since then with the synchronous into the economic growth rate in schedule; throes of structural adjustment and preliminary stimulus digestion phase "three phase superposition" special stage; the obvious contradiction between excess capacity and demand structure upgrade; and the five priority tasks of reducing overcapacity, reducing excess inventory, deleveraging, lowering costs, and strengthening areas of weakness continuous progress, economic development has been relatively slow, until 2017, when the growth rate increased slightly. From the perspective of macroeconomic supply and demand, total social demand consists of investment, total retail sales of social consumer goods, and export; among these, investment is highly sensitive to policy and is the key to counter-cyclical adjustment, which is also the paramount factor. Generally speaking, province A's economic development has peculiar regional characteristics, and investment in the province is greatly affected by aid policies. Owing to the social development environment, transfer payments from the central government, and other factors<sup>[1-4]</sup>, especially aid policy since the implementation of western region development, China's investment into its western province increased significantly, effectively relieving the problem of a weak foundation<sup>[5-8]</sup>. Macroeconomic data analysis shows that, with the gradual deepening of national investment system reform, from 1995 to 2007 in province A, the investment scale fluctuated smoothly. In 2008, in response to the global financial crisis, to expand domestic demand, growth strategy and investment growth rate reached its peak, however, the rapid expansion of investment scale affected the economic growth, and consequently, investment and GDP growth rate plummeted in 2009. From the stage characteristics, during the 12th Five-Year Plan period, the change in the investment effect coefficient of the primary, secondary, and tertiary industries showed a downward trend year by year, while after the 13th Five-Year Plan period, it showed a slow upward trend. However, the highest investment rate is for the tertiary industry, followed by the primary industry and the secondary industry, in that order, mainly due to the large development potential of the tertiary industry and the rapid investment growth rate. The primary industry is related to the recent development strategy of poverty alleviation and rural revitalization in province A, which has helped increase the investment growth rate. In the secondary industry, due to overcapacity reduction, inventory reduction, and ecological constraints, investment is greatly affected, resulting in the slowest investment growth rate. In recent years, due to the international environment, the economic development of province A slowed down, and the investment increment decreased. By 2019, the investment began to rebound. Economic growth

in province A has shown an overall downward trend since 2016, especially after the COVID-19 outbreak in 2019, when the economic growth rate dropped to 3.4% in 2020. This shows the weakening of investment enthusiasm in recent years as well as the reduced driving effect of investment on economic growth. Under the new situation, province A is increasing its investment scale. How can the role of investment be optimized and maximized? This is a problem that both local governments and academic circles must focus on.

## 2 Literature Review

In neoclassical economics, the British economist Harrod<sup>[9]</sup> and the American economist Domar<sup>[10]</sup> studied the relationship between capital input and economic growth and established the famous Harrod-Domar model. Building on the model, Solow, et al.<sup>[11]</sup> further supplemented and improved exogenous conditions and established a new economic growth model, emphasizing the role of per capita capital input in the growth of per capita GDP. Later, many scholars empirically verified the role of input on economic growth<sup>[12–14]</sup>.

Government investment, as history has shown, is essential for national and regional economic development and a key strategy for maximizing the tertiary industrial structure<sup>[15]</sup>. This is especially true in the case of China, where government investment has greatly elevated economic development<sup>[16–18]</sup>. Although the Chinese government has maintained steady economic growth by investing 4 trillion yuan since the 2008 financial crisis, it is important to examine the related issues, such as the impact of government investment on private investment<sup>[19]</sup>. In the present economic stage of structural adjustment and stable development, re-examining the crowding-out or crowding-in impact between government and private investments is theoretical and practical. Especially for provinces with a weak economic development foundation in western China, the effect of government investment on private investment is worthy of being studied.

The crowding-out/crowding-in effect of government investment on private investment has been a highly debated issue in western academic circles since the 1970s; however, there is no consensus regarding the mechanism of the crowding-out or crowding-in effects. Friedman<sup>[20]</sup> believed that an increase in government spending (or deficit spending) leads to less investment in the private sector or an increase in interest rates. Fisher<sup>[21]</sup> adopted a cross-regional panel data regression analysis method and confirmed the existence of a link between changes in government spending and private investment. Increasing government expenditure would reduce fiscal budget surplus, that is, there would be a crowding-out effect on private investment. Bairam and Ward<sup>[5]</sup> conducted a comparative study on the investment data of 25 OECD countries and found that government expenditure crowded out private investment in 24 countries. Evans and Karras<sup>[22]</sup> analyzed the impact of government investment on the private sector based on the statistical data of 48 states in the United States from 1970 to 1980 and found that education investment had no obvious effect on other types of government investment, and even had a negative impact. Aschauer<sup>[23]</sup> believed that when public and private investments were complementary, the continuous increase in public input would promote the corresponding increase in marginal productivity of private capital, such that government investment promoted private investment. Sturm and Haan<sup>[24]</sup> used data from the United States and the Netherlands to conduct empirical analysis and found that public capital expenditure had a positive impact on

output. However, McMillin and Smyth<sup>[25]</sup> believed that the impact of public capital on private investment is not obvious.

In China, there is no consensus on whether government investment has a crowding-in or crowding-out effect on private investment. Four possibilities can be considered in this debate. First, government investment has a crowding-in effect on private investment. Guo and Jia<sup>[26]</sup> studied the dynamic influence of China's financial investment on the total output and private investment based on data from 1978 to 2004 and found that China's financial investment played a significant role in promoting economic growth and driving private investment. In particular, Lin, et al.<sup>[27]</sup> believed that under the economic boom cycle, enterprises are prone to a "tidal surge" in the investment process under the economic recovery environment due to information asymmetry. Similar to [27], Yu, et al.<sup>[28]</sup> also believed that "herd behavior" is prevalent in enterprises' investment decisions, and the fiscal expenditure level of local governments is significantly positively correlated with the investment of local enterprises. Second, government investment has a crowding-out effect on private investment. From the perspective of the theory of regional economic development, location choice, and focusing effect, Jin and Cai<sup>[29]</sup> conducted an econometric analysis of private investment in eastern, central, and western China from 1996 to 2002 by establishing a local adjustment model and concluded that private investment was negatively correlated with government investment scale. Third, in the short term, government investment has a crowding-in effect on private investment, and in the long term, there is a crowding-out effect. Hu and Kong<sup>[30]</sup> conducted a Keynesian-theory-based analysis of the quarterly data of China from 1998 to 2013 by establishing a spatial state model; the results showed that the governments large-scale and long-term expansionary fiscal policies and monetary policies had a short-term pulling effect and a long-term crowding-out effect on private investment. Zhou and Xu<sup>[31]</sup> analyzed the influences of government investment, GDP, tax revenue, and narrow-sense monetary supply on private investment by using China's data from 1990 to 2014 and found that large-scale and long-term expansionary fiscal policies had a short-term crowding-in effect and long-term crowding-out effect on private investment. Fourth, government and private investments are independent of each other and there is no significant internal relationship between them. Sun and Luo<sup>[32]</sup> studied the relationship between government and private investment from a purely theoretical perspective and found that there was no feedback effect between the two, and that government investment had a limited regulatory effect on private investment, without the crowding-in effect or crowding-out effect. Guo<sup>[33]</sup> stated that government investment had no significant or direct impact on private investment.

Comprehensive domestic and international research results show that findings vary based on the statistics, analysis methods, and index selection used. Most studies adopt the traditional Keynesian model and constant parameters of the linear regression method, ignoring the enterprise as the pursuit of utility maximization of micro individuals involved in macroeconomic policy, research methods and angles need to be improved. This study embarks from the economic theory and uses state space equations to analyze the influence of province A's local government investment on economic growth. Based on the analysis, this study examines the relationship between government and private investments so as to clarify whether government investment has a crowding-in or a crowding-out effect on private investment.

### 3 Theoretical and Methods

The state space model was first proposed by Kalman<sup>[34]</sup> based on his work on engineering control problems. The theory takes implied time as the independent variable and is a dynamic time-domain model; it is widely used to deal with economic problems, such as the estimation of economic trends and relevant cyclic components in the process of economic operation, and persistent income. It has the following two characteristics: 1) Unobservable variables (state variables) can be incorporated into the model, which is convenient for statistical testing of unobservable variables using known variable prediction. 2) Kalman filtering algorithm in the state space model can estimate the model unknown parameters and continuously modify the vector estimates. The fixed parameter model may ignore the corresponding changes generated over time when estimating variables. Hence, this study uses a model with time-varying parameters to explain how government and private investment affect economic growth in province A. According to Kalman and Liao<sup>[34, 35]</sup>, the basic model framework is as follows:

Measurement equation:

$$Y_t = H_t \times \beta_t + A_t \times z_t + e_t. \quad (1)$$

Transfer equation:

$$\beta_t = \bar{\mu} + F \times \beta_{t-1} + \nu_t. \quad (2)$$

In the above equations,  $e_t \sim \text{i.i.d } N(0, R)$ ,  $\nu_t \sim \text{i.i.d } N(0, Q)$ ,  $y_t$  is  $n \times 1$  dimensional vector composed of observed variables at time  $t$ ,  $\beta_t$  is a  $k \times 1$  dimensional unobservable vector,  $H_t$  is  $n \times k$  dimensional matrix, which describes the relationship between the observable vector  $y_t$  and unobservable vector  $\beta_t$ .  $z_t$  is an  $r \times 1$  dimensional vector composing exogenous or predetermined variables. The time-varying parameter model used in the empirical analysis in this study can be expressed as follows:

$$y_t = \beta_{1t} \times x_{1t} + \beta_{2t} \times x_{2t} + \cdots + \beta_{kt} \times x_{kt} + e_t, \quad e_t \sim \text{i.i.d } N(0, R), \quad (3)$$

$$\beta_{it} = \varphi_i \beta_{i \times t-1} + \nu_{it}, \quad \nu_{it} \sim \text{i.i.d. } N(0, \sigma^2), \quad i = 1, 2, \cdots, k. \quad (4)$$

Equations (3) and (4) can be converted into the following state-space model:

Measurement equation:

$$y_t = (x_{1t} + x_{2t} + \cdots + x_{kt}) \times \begin{bmatrix} \beta_{1t} \\ \beta_{2t} \\ \vdots \\ \beta_{kt} \end{bmatrix} + e_t. \quad (5)$$

Transfer equation:

$$\begin{bmatrix} \beta_{1t} \\ \beta_{2t} \\ \vdots \\ \beta_{kt} \end{bmatrix} = \begin{bmatrix} \varphi_1 & 0 & \cdots & 0 \\ 0 & \varphi_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \varphi_k \end{bmatrix} \begin{bmatrix} \beta_{1t} \\ \beta_{2t} \\ \vdots \\ \beta_{kt} \end{bmatrix} + \begin{bmatrix} \nu_{1t} \\ \nu_{2t} \\ \vdots \\ \nu_{kt} \end{bmatrix}, \quad (6)$$

where

$$\begin{bmatrix} v_{1t} \\ v_{2t} \\ \vdots \\ v_{kt} \end{bmatrix} \sim \text{i.i.d.N} \left[ \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{v1}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{v2}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{vk}^2 \end{bmatrix} \right].$$

Kalman filtering is an optimal estimation algorithm using the linear system state equation to estimate the observed variables in the system's input and output. Kalman filtering includes prediction, updating, and smoothing. Among them, prediction and smoothing belong to basic filtering. Prediction estimates parameter  $\beta_t$  by using relevant information obtained in period  $t$ . Smoothing includes estimating parameter  $\beta_t$  by using the relevant information obtained from the whole sample interval. For the model constituted by Equations (1) and (2), the basic formula of basic filtering and smoothing is:

Prediction:

$$\beta_{t|t-1} = \bar{\mu} + F \times \beta_{t-1|t-1}, \quad (7)$$

$$P_{t|t-1} = F \times P_{t-1|t-1} \times F' + Q, \quad (8)$$

$$\eta_{t|t-1} = y_t - y_{t-1} = y_t - H_t \times \beta_{t|t-1} - A \times Z_t, \quad (9)$$

$$f_{t|t-1} = H_t \times P_{t|t-1} \times H' + R. \quad (10)$$

Update:

$$\beta_t = \beta_{t|t-1} + K_t \times \eta_{t|t-1}, \quad (11)$$

$$P_t = P_{t|t-1} + K_t \times H_t \times P_{t|t-1}, \quad (12)$$

where  $K_t = P_{t|t-1} \cdot H_t' \cdot f_{t|t-1}^{-1}$  is the Kalman gain,  $t = T-1, T-2, \dots, 1$ ; then  $\beta_{T|T}$  and  $P_{T|T}$  can be obtained by smoothing iterations of basic filtering.

$$\beta_{t|T} = \beta_{t|t} + P_{t|t} \times F' \times P_{t+1|t}^{-1} \times (\beta_{t+1|T} - F \times \beta_{t|t} - \bar{\mu}), \quad (13)$$

$$P_{t|T} = P_{t|t} + P_{t|t} \times F' \times P_{t+1|t}^{-1} \times (P_{t+1|T} - P_{t+1|t}) \times P_{t+1|t}^{-1'} \times F \times P_{t|t}'. \quad (14)$$

In practice, the hyperparameters in the model are often unknown, so the hyperparameters and the state variable  $\beta_t$  can be obtained by Kalman filtering iteration and Maximum Likelihood Estimate. Assuming that the random disturbance term  $\bar{\mu}$  in the model is Gaussian distributed, the  $y_t$  conditional distribution of information  $\psi_{t-1}$  at time  $t-1$  is still Gaussian distributed.

$$y_t | \psi_{t-1} \sim N(y_{t|t-1}, f_{t|t-1}). \quad (15)$$

Then, the log-likelihood function of (15) is

$$\ln L = -\frac{1}{2} \times \sum_{t=1}^T \ln(2\pi f_{t|t-1}) - \frac{1}{2} \times \sum_{t=1}^T \eta_{t|t-1}' \times f_{t|t-1}^{-1} \times \eta_{t|t-1}. \quad (16)$$

$\eta_{t|t-1}$  and  $f_{t|t-1}$  in (15) and (16) can be calculated with Kalman filtering. Since the state variable  $\beta_t$  is not stationary and the initial estimate value may also lead to an inaccurate

likelihood value, the first  $\tau$  values can be discarded when calculating the likelihood function. According to (16), (17) can be used for maximum likelihood estimation.

$$\ln L = -\frac{1}{2} \times \sum_{t=\tau+1}^T \ln(2\pi f_{t|t-1}) - \frac{1}{2} \times \sum_{t=\tau+1}^T \eta'_{t|t-1} \times f_{t|t-1}^{-1} \times \eta_{t|t-1}. \quad (17)$$

In the process of using Kalman filtering and maximum likelihood estimation to obtain model hyperparameters and state variables iteratively, it is important to pay attention to the following aspects: 1) Assign reasonable initial values to hyperparameters; 2) Assuming a reasonable hyperparameter,  $\beta_{t|t}$  (state variable filter estimator) and  $\beta_{t|T}$  (smooth estimator) can be obtained by Kalman filtering iteration, while  $\eta_{t|t-1}$  (prediction error) and  $f_{t|t-1}$  (prediction covariance) are retained; 3) The estimated value of the hyperparameter can be obtained according to the maximized log-likelihood function of Model (3); Steps 2) and 3) are repeated, and the Kalman filtering and maximum likelihood function are used to estimate the hyperparameters and state variables until the estimated values show convergence state.

## 4 Empirical Analysis

### 4.1 Variable Description

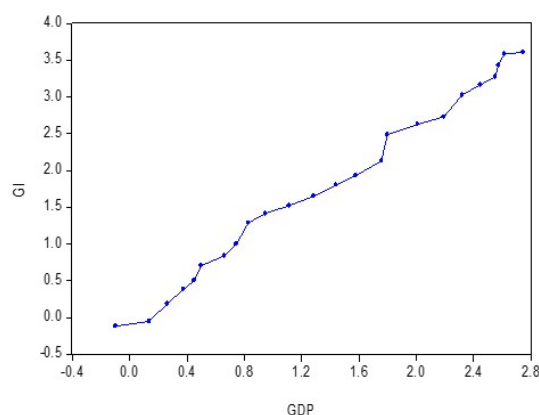
Government investment (GI) in province A measures government investment as the sum of government consumption and government budget investment. Private investment (NGI) is measured as the difference between total social capital formation and budget investment in fixed assets. Gross domestic product (GDP) is used to measure the overall economic development level; tax revenue (SS) represents the sum of taxes in all finance items; and the loan-to-deposit ratio (DI) represents the ratio of all deposits to all loans. Except for the loan-deposit ratio (DI), the above indicators in the statistical yearbook are nominal values. To investigate the real dynamic relationship between investment and the economy, the influence of price growth factors on each indicator should be excluded. Assuming 1994 as the base year, for example, real GDP is calculated using:

$$\text{GDP}_{i+1\text{real}} = \text{GDP}_{i\text{real}} \times (1 + (\text{GDP}_{i+1}\text{index} - 100)/100), \quad i = 0, 1, \dots, n.$$

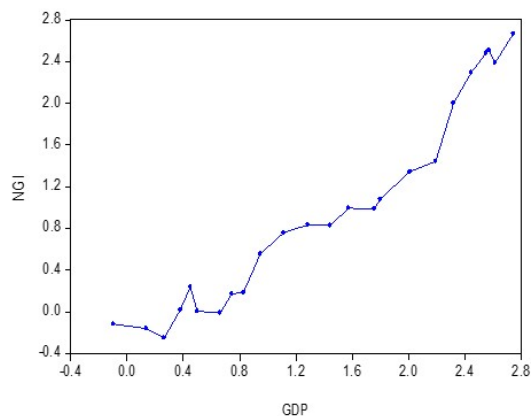
In the above formula,  $\text{GDP}_{i\text{real}}$  and  $\text{GDP}_{i+1}\text{index}$  represent nominal real GDP in year  $i$  and GDP index in year  $i + 1$ , respectively. To obtain an annual GDP deflator, the nominal GDP was divided by the calculated real GDP for each year. Except for the loan-to-deposit ratio (DI), the nominal index was divided by the corresponding annual contraction index to obtain the corresponding real value. To further reduce the impact of heteroscedasticity, we take logarithms of all variables, namely  $\ln \text{GDP}$ ,  $\ln \text{GI}$ ,  $\ln \text{NGI}$  and  $\ln \text{SS}$ . Because the loan-deposit ratio is a ratio, the logarithm is not taken, and only the stationarity test is performed. All data were obtained from the Statistical Yearbook of province A from 1994 to 2018.

### 4.2 Model Estimation and Result Analysis

As seen in Figures 1 and 2, there is a certain linear relationship between government investment and economic development, and both government and private investments play positive roles in promoting economic growth in province A, but both have obvious time-varying parameter characteristics.



**Figure 1** The relationship between government investment and economic growth



**Figure 2** The relationship between private investment and economic growth

The time-varying coefficient estimates of the effects of government and private investments on economic growth in province A are shown in Table 1. From 1994 to 1995, the effects of both government and private investments showed a significant downward trend. Government investment dropped from 1.2288 in 1994 to 0.7380 in 1995. The decline in private investment was more drastic from 5.2102 in 1994 to 3.3374 in 1995. After 1995, although the effects of both investments fluctuated slightly, overall they showed a stable trend. After the reform and opening up, both investments increased rapidly, but eventually, government investment rose higher than private investment. For example, in 1981, government and private investments were 1.815 billion RMB and 0.25 million RMB respectively, and government investment was 72.6 times higher than private investment. By 2013, private investment was 1.45 times higher than government investment. This clearly demonstrates the increasing proportion of private investment.

Furthermore, to understand the effect of fixed asset composition on economic growth in province A, this study analyzes the time-varying characteristics of productive and non-productive investments in fixed asset investment. Productive investment is the construction investment directly used in material production or in meeting the needs of material production. The current statistical scope includes construction investment in industry, construction, agriculture, forestry and water conservation, transportation, post and telecommunications, commerce and material supply, geological resources exploration, urban water and gas, and other public facilities. Non-productive investment refers to the part that is not profitable and cannot be recovered, and its reinvestment depends on social accumulation, such as investment in schools, national defense and security, social welfare facilities. There is also the investment that can be transformed into intangible goods, which can make profits recover investment, and even help realize value-added accumulation, such as investment in theaters, television stations, information centers, and consulting companies. Therefore, productive investment (PI) is described in terms of the sum of investments in agriculture, forestry, animal husbandry and fishery, mining, manufacturing, construction, transportation and storage, and postal services. Productive investment (NPI) is

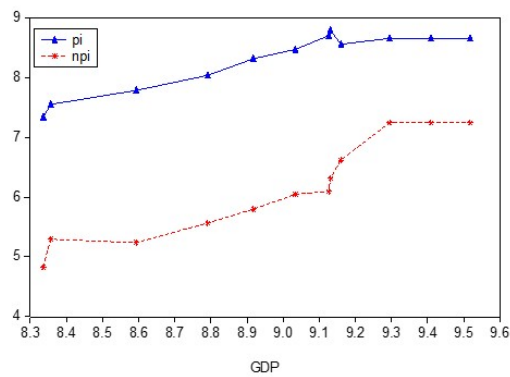


**Table 1** Estimation of time-varying coefficients of economic growth by government investment and private investment in province A in western China

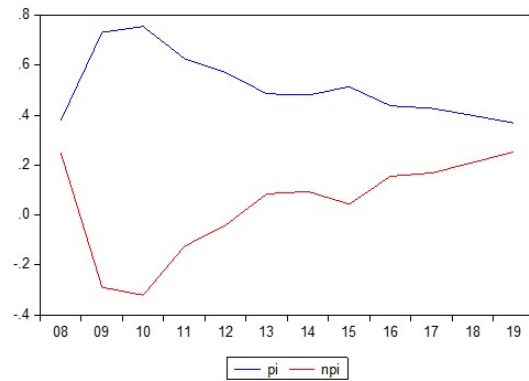
Year	Estimated value of government investment	Estimated value of private investment
1994	1.2288	5.2102
1995	0.7380	3.3374
1996	1.0244	1.8696
1997	0.8963	1.8385
1998	0.8455	1.0903
1999	0.7393	1.0896
2000	0.7365	1.0793
2001	0.7234	1.1239
2002	0.6790	1.2148
2003	0.6652	0.9699
2004	0.6749	0.8800
2005	0.6929	0.8996
2006	0.7111	0.9621
2007	0.7277	0.9939
2008	0.7426	1.0532
2009	0.7345	1.0824
2010	0.7369	1.0906
2011	0.7453	1.1072
2012	0.7463	1.0474
2013	0.7483	0.9905
2014	0.7507	0.9490
2015	0.7488	0.9238
2016	0.7445	0.9174
2017	0.7449	0.9045
$R^2 = 0.99$ , D.W.= 1.23		$R^2 = 1.94$ , D.W.= 0.54

described as the sum of culture, education, social welfare, administrative expenditure, national defense, and security. The data analysis method is consistent with the previous article. Figure 3 describes the relationship between productive investment, non-productive investment, and economic growth, and shows the linear relationship between them and economic growth. Figure 4 describes the dynamic effects of productive and non-productive investment on economic growth in province A. On the whole, from 2008 to 2010, the effect of productive investment on economic growth continued to rise, especially in 2011, the economic effect showed a gentle trend of decline. In contrast to productive investment, non-productive investment showed a sudden decline in economic effect from 2008 to 2009, and then increased, but remained negative until 2012, indicating that non-productive investment inhibited economic development. Since 2013, non-productive investment has been positive and gradually increasing. The effect

of productive investment on economic growth in province A has always been higher than that of non-productive investment.



**Figure 3** The relationship between productive and non-productive investment and economic growth in province A in western China



**Figure 4** Dynamic effects of productive and non-productive investment on economic growth in province A in western China

At present, China's economic development is accompanied by speedy high quality development. However, high-quality development requires coordination between economic, social, political, cultural and other comprehensive factors, so that government investment performs the dual functions of bringing "stable growth" and "improving quality and efficiency", along with the spillover effect of promoting high quality development<sup>[36]</sup>. Whether at the macro or micro level, as an important means to fulfill government functions, government investment has a significant impact on high-quality development<sup>[37]</sup>. However, the fact cannot be ignored that the rapid growth of private investment in recent years has promoted economic and social development through direct and indirect effects, and its influence is greater than that of government investment<sup>[38]</sup>. This study uses the state space model to further analyze the internal relationship between government and private investments in province A.

Since the government mainly uses fiscal and tax policies to regulate the economic market, the loan-to-deposit ratio (DI) and tax (SS) are introduced into the analysis model. To express unobservable factors between private investment and other variables and to avoid endogenous errors in the model, in combination with the Cass-Koopmans-Ramsey model, a spatial measurement model of variable parameters of private investment was established by referring to relevant research methods<sup>[31]</sup>:

Measurement equation:

$$\ln \text{NGI}_t = C_t + \beta_{1t} \times \ln \text{GI}_t + \beta_{2t} \times \ln \text{GDP}_t + \beta_{3t} \times \ln \text{SS}_t + \beta_{4t} \times \text{DI}_t + \mu_t. \quad (18)$$

Transfer equation:

$$\beta_{1t} = \tau_1 \beta_{1,t-1} + \varepsilon_{1,t}, \quad (19)$$

$$\beta_{2t} = \tau_2 \beta_{2,t-1} + \varepsilon_{2,t}, \quad (20)$$

$$\beta_{3t} = \tau_3 \beta_{3,t-1} + \varepsilon_{3,t}, \quad (21)$$

$$\beta_{4t} = \tau_4 \beta_{4,t-1} + \varepsilon_{4,t}. \quad (22)$$

Satisfies condition:

$$\begin{bmatrix} \mu_t \\ \varepsilon_t \end{bmatrix} \sim N \left[ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2 \\ 0 \end{bmatrix} \right], \quad t = 1, 2, \dots, T.$$

lnGI, lnGDP, lnSS, DI are observable variables that represent changes in government investment, economic development level, tax revenue, and market consumption, respectively.  $\beta_{1t}$ ,  $\beta_{2t}$ ,  $\beta_{3t}$ , and  $\beta_{4t}$  are random parameters estimated by observable variables and follow the AR (1) form.  $\mu_t$  is the disturbance term of the equation of state,  $\varepsilon_t$  is the perturbation term of the measurement equation, which is independent and follows normal distribution with mean of 0, variance of  $\sigma^2$  and covariance of  $Q$ .  $C_t$  is a constant, which represents the impact of other factors on private investment.

Augmented Dickey-Fuller Test Statistic (ADF) was used to conduct unit root test for each variable, and Table 2 showed that, except lnSS, when unit root test was conducted directly for time series data of each variable, the series data were not stable. When each variable was tested after the first-order difference, lnSS was stable at 10% confidence level, while other variables were stable at 5% confidence level. This indicates that the first-order difference sequence of lnGDP, lnGI, lnNGI, lnSS and DI is stationary.

**Table 2** Unit root (ADF) test for each variable. In the table ( $C$ ,  $T$ , and  $L$ ),  $C$  and  $T$  represent intercept items and trend items, respectively. If the value is 0, it indicates that the intercept items and trend items are not included.  $L$  represents the lag order of the difference term, and  $\Delta$  represents the first-order difference

Variable	ADF value	The critical value (5%)	( $C, T, L$ )	Prob	Conclusion
lnGDP	0.1104	-2.9981	( $C, T, 0$ )	0.9595	non-stabilized
lnGI	0.4717	-3.0299	( $C, T, 0$ )	0.9867	non-stabilized
lnNGI	0.4775	-2.9981	( $C, T, 0$ )	0.9819	non-stabilized
lnSS	-3.6908	-3.6998	( $C, T, 0$ )	0.0492	non-stabilized
DI	-1.6548	-3.0048	( $C, T, 0$ )	0.4391	non-stabilized
$\Delta$ lnGDP	-4.5669	-3.0049	( $C, T, 1$ )	0.0017**	stabilized
$\Delta$ lnGI	-3.1357	-3.0299	( $C, T, 1$ )	0.0408**	stabilized
$\Delta$ lnNGI	-3.9655	-1.9572	( $C, 0, 1$ )	0.004**	stabilized
$\Delta$ lnSS	-1.7263	-1.6081	( $C, 0, 1$ )	0.0797*	stabilized
$\Delta$ DI	-3.0487	-1.9572	( $C, 0, 1$ )	0.004**	stabilized

All the variables mentioned above are the same single time series, which indicates the possibility of co-integration in the time series. To test the co-integration relationship between the variables, the Engle-Granger (EG) two-step method is used to verify the conjecture. In the first step, the least square method is used to establish the regression equation between them, then the residual sequence is calculated and its stationarity is tested.

**Table 3** Unit root test for  $\mu$ 

Variable	ADF value	The critical value (5%)	( $C, T, L$ )	Conclusion
residual	-5.7945	-5.0236	(0, 0, 2)	stabilized

According to the co-integration test critical value table calculation, Table 3 shows that the residual ( $\mu$ ) sequence rejects the null hypothesis that there is a unit root at the 5% confidence level, indicating that the residual sequence is stable. Therefore, it can be seen that is  $I(0)$ : Namely stable. Therefore, the second step is to establish the long-term equilibrium equation and error correction model between  $\ln \text{NGI}_t$ ,  $\ln \text{GDP}_t$ ,  $\ln \text{GI}_t$ ,  $\ln \text{SS}_t$  and  $\text{DI}_t$  after accepting the assumption that they are co-integration relations:

Long-term equilibrium equation:

$$\ln \text{NGI}_t = 3.4155 \ln \text{GDP}_t - 0.3923 \ln \text{GI}_t - 0.927 \ln \text{SS}_t - 0.8566 \text{DI}_t - 10.6908 \quad (23)$$

and  $R^2 = 0.9537$ , D.W. = 1.2512.

Error correction model:

$$\begin{aligned} \Delta \ln \text{NGI}_t = & 0.8927 \Delta \ln \text{GDP}_{t-1} + 0.4788 \Delta \ln \text{GI}_{t-1} - 0.1174 \Delta \ln \text{SS}_{t-1} \\ & - 0.584 \Delta \text{DI}_{t-1} - 0.584 \Delta \text{ecm}_{t-1} - 0.031. \end{aligned} \quad (24)$$

First, a long-term equilibrium link between private investment and economic development level, government investment, tax revenue, and loan-saving ratio can be shown through the co-integration model and error correction model. Economic development level plays a positive role in promoting private investment, while government investment, tax revenue, and loan-saving ratio inhibit private investment. Second, the error correction coefficients of economic development level, government investment, tax revenue and loan-to-deposit ratio are 0.8927, 0.4788,  $-0.1174$  and  $-0.584$  respectively, indicating that in the short term, economic development level and government investment can positively promote private investment, but tax revenue and loan-to-deposit ratio still have a restraining effect.

Since there is a long-term co-integration relationship between private investment and various variables, the dynamic relationship between various variables and private investment is further discussed according to the state space model.

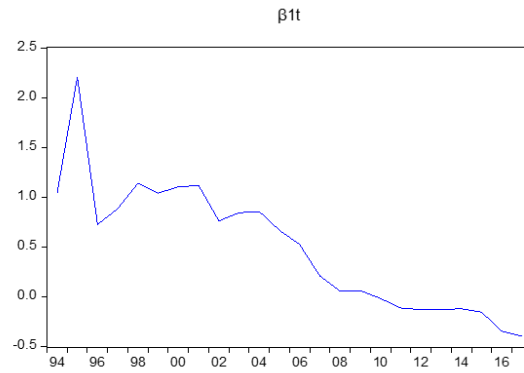
Table 4 shows the following results:  $\beta_{1t}$  passes the model test, but  $P(\text{Prob.})$  is at 10% confidence level, indicating that government investment has a significant impact on private investment. The Final State is negative, indicating that government investment has a significant crowding-out effect on private investment in the long term.  $\beta_{2t}$ ,  $\beta_{3t}$ , and  $\beta_{4t}$  have also passed the model test, and the 1% confidence level indicates that economic development level, tax revenue and loan-deposit ratio have extremely significant effects on private investment. But the final value (Final State) reflects positive as well as negative phenomena. The stable increasing level of economic development can attract more private investment into private enterprises in province A. Its flexible mechanisms, great potential, and high efficiency can help optimize the industrial structure adjustment of province A, promote the governmental function transformation, support basic market decision-making, and stimulate economic growth. Whereas, the total value of tax and loan-deposit ratio is negative. As the main source of government revenue, tax not only

ensures that the government remains financially stable, but also helps regulate social resources and wealth distribution. Some studies<sup>[39]</sup> have found that capital tax in province A generally promotes economic growth, but labor tax and consumption tax are not conducive to economic development, especially non-tax revenue is not conducive to economic growth in the long term. These factors have brought great challenges to private investment in province A. Therefore, the government of province A should adopt positive fiscal and tax policies to further attract private capital. As for the loan-deposit ratio, it reflects the matching degree of the total amount of deposits and loans, and its Final State is negative in the model result, indicating that the loan-deposit ratio has a restraining effect on private investment in province A. The government of province A should reduce the ratio of deposits and loans by vigorously developing the economy, vigorously promote the conversion of savings into investment, and provide convenient ways for economic subjects to optimize the inter-temporal and market transactions<sup>[40]</sup>.

Figure 5 shows the dynamic trajectory of government investment and private investment in province A obtained using Kalman filtering. On the whole, the elasticity of government investment's effect on private investment presents a very large spatio-temporal change.  $\beta_{1t}$  is consistently positive from 1994 to 2009, indicating that government investment has a crowding-in effect on private investment. From 2010 to 2017, it is consistently negative, indicating a crowding-out effect. The large spatio-temporal changes in  $\beta_{1t}$  are related to many factors such as policy changes, exogenous shocks and adjustment of economic layout, which affect private investment through different channels. In fact, due to the impact of the international financial crisis and the social development environment, the economic growth rate in 2009 was the lowest since the reform and development of province A. Since 2010, province A has entered a period marked by a change in the rate of economic growth, structural adjustment pains, and digestion of early stimulus policies. The implementation of the policy of "three go, one drop, one supplement" has raised the entry threshold of enterprises and affected the enthusiasm of private investment to a certain extent.

**Table 4** Estimation results of state space equation model

	Coefficient	Std. Error	z-Statistic	Prob.
$C(1)$	-10.69088	3.895944	-2.744104	0.0061
$C(2)$	-4.093644	0.47716	-8.579185	0.0000
	Final State	Root MSE	z-Statistic	Prob.
$\beta_{1t}$	-0.392385	0.22757	-1.724238	0.0847
$\beta_{2t}$	3.415557	0.084382	40.47736	0.0000
$\beta_{3t}$	-0.927006	0.190805	-4.858384	0.0000
$\beta_{4t}$	-0.856608	0.112513	-7.613418	0.0000
Log likelihood:	-22.65773		Akaike info criterion:	2.054811
Parameters:	2		Schwarz criterion:	2.152982
Diffuse priors:	4		Hannan-Quinn criter:	2.080855



**Figure 5** Government investment effect of private investment in a province in western China

## 5 Conclusions and Discussion

This study establishes the state space equation between economic growth and government investment's effect on private investment in province A based on data from the statistical year-books for the period 1994–2018. Our findings show that, in general, the relationship between government and private investments in province A has a positive driving effect on economic growth, and the positive impact of private investment on economic growth is stronger than that of government investment. Specifically, in 1994–1995, the effects of both government and private investments on economic growth showed a significant downward trend. As shown in Table 1, government investment decreased from 1.2288 in 1994 to 0.7380 in 1995, while private investment plummeted from 5.2102 in 1994 to 3.3374 in 1995. After 1995, saving for some fluctuations, the effects of both investments on economic growth remained stable. The co-integration test results show that government investment has a significant crowding-out effect on private investment in the long term. From 2008 to 2010, the effect of productive investment on economic growth in province A continued to rise, and especially in 2011, the economic effect showed a trend of gentle decline. In contrast to productive investment, non-productive investment's economic effect suddenly declined from 2008 to 2009, and then increased, but remained negative until 2012, indicating that non-productive investment inhibited economic development. Since 2013, non-productive investment has been positive, while exhibiting a gradual rise. The effect of productive investment in province A has always been higher than that of non-productive investment. However, the elasticity of government investment's effect on private investment presents a very large spatio-temporal change as both crowding-in and crowding-out effects are observed. Specifically, from 1994 to 2009, government investment in province A crowded in private investments, but from 2010 to 2017, a crowding-out effect was observed.

Our findings show that government and private investments play important roles in promoting the economic development of province A. However, they play different roles in the process of economic growth. Government investment is mainly directed towards major infrastructure projects and non-productive investment projects in public facilities to encourage private investment and ensure orderly economic and social development and growth. As the main body of market operation, private investment changes with time and external environment. It can not

only expand the aggregate demand, but also change the aggregate supply and expand the possibility boundary of production. In the current situation, the following problems are present in private investment and government investment in province A. First, there are financing difficulties in government investment. After a rapid increase in 2017, government investment in major infrastructure projects fell sharply in 2018, restricting the overall scale of investment. Moreover, some major infrastructure projects were suspended or postponed. Next, preventing and defusing the risks of local governments' hidden debts is another important task of government's "risk prevention" in province A. Due to the obvious increase in financing constraints of infrastructure investment projects, the traditional mode of relying on expansion of local governments' hidden debts to drive rapid growth of infrastructure investment is not sustainable. Insufficient investment in new and high technologies has resulted in a slow shift from old growth drivers to new ones. Furthermore, private investment in province A is restricted by institutional and policy obstacles. First, the allocation ratio of financial resources between "state" and "people", and "virtual" and "real" is not reasonable. There is a lack of targeted financing products and policy support for small and medium-sized enterprises besides an obvious tendency of "favoring the state and neglecting the private sector". Second, in some areas, new officials ignore the old debts, which dampens the government's credibility and the enthusiasm of private enterprises to invest. Third, due to the impact of private investment access restrictions or barriers, private investment in medical care, education, pension, and financial services is not sufficient. Fourth, the social capital of the vast majority of projects in province A comes mainly from state-owned enterprises and financial investment; participation from private enterprises is low due to constraints such as inadequacies in the government service level, absence of a government credit constraint system, and the development of a capital market.

Under the increasing downward pressure of the Chinese economy, the national fiscal policy has adopted an active fiscal direction as the main means of expansion. Policy efforts have been intensified, and the deficit-to-GDP ratio and debt-to-GDP ratio have continued to rise. Judging from the economic situation in China and abroad, the future economic trend will remain grim and complex, and the proactive fiscal policy will prevail. To achieve a win-win situation of controllable fiscal risks and economic growth recovery, the traditional routine of increasing government investment is not sustainable. Based on the above discussion, the following policy recommendations are proposed to province A: 1) Intensify social governance, crack down on illegal and criminal activities, and provide a favorable environment for private investment. Strengthen the capacity and quality of public services, formulate policies encouraging private investment, create a fair and competitive marketplace, and improve the attractiveness of areas to investors. 2) Continue to increase government investment, optimize and adjust the economic and production factor investment structure, and improve the efficiency of resource allocation to improve production efficiency and the resource utilization rate, and provide appropriate investment guidance for private enterprises. Province A must further increase non-productive expenditures, constantly improve infrastructure development and the urban environment, and provide strong material support for private investments. 3) Strengthen government investment in high and new technology and system innovation through vigorous demonstration area construction, system and mechanism innovation, optimization of science and technology innovation

service systems, innovative talent introduction, and transformation of scientific and technological achievements. Such efforts will give full play to the role of the government as an innovative economic incubator. Furthermore, the government must offer key support for project development in high and new technology enterprises, forge industry innovation capability plans and strategies, and actively guide private capital to enter the field of innovation in order to gather a driving force for high-quality development. 4) Promote the construction of the core area of the Silk Road (as it will boost economic growth), make effective use of both foreign and domestic markets, strive to build a core area connecting the mainland with central Asia and European markets, and actively create a service platform for enterprises to “walk in”. Through effective policy regulation and robust private investment, province A should ensure that consumption fuels economic growth. Province A must use private investment to improve the economic structure which would help protect its economy from adverse external shocks and curb economic cycle fluctuations. 5) Utilize superior resources, obtain policy support from aid policies, actively seek cooperation opportunities, introduce private investment projects combined with local resource endowment, and establish good strategic cooperative relations with more enterprises.

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