Aggregate Investment in People's Republic of China: Some Empirical Evidence

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Aggregate domestic investment in People's Republic of China is empirically modeled using quarterly data for the period 1994-2001. The total investment is disaggregated into two parts: business sector investment and government direct investment. The dynamic specification approach is adopted and the equilibrium-correction model form is used. Business sector investment is found to follow closely the standard capital input demand theory in the long run, but to respond positively to changes in government direct investment in the short run. It is found that government investment is driven, additionally to the revenue constraint, by the policy targets of maintaining steady economic growth and reducing unemployment. The resulting investment equations provide a sound model base for policy simulation and forecasting.

I. INTRODUCTION

Capital investment holds a key role in the economic growth and performance of the People's Republic of China (PRC). During the last two decades, fixed capital formation has taken up roughly one third of gross domestic product (GDP) and kept a double digit growth on average, albeit with remarkably volatile dynamics (5.5 percent growth in 1981, nearly 40 percent in 1985, −7 percent in 1989, over 60 percent in 1993, down to 5 percent in 1999, and well above 20 percent in 2003). Fixed capital investment was dominantly driven by government plans under the old centrally planned economic regime. What drives the fast-growing and volatile aggregate investment now that the PRC economy has become increasingly market-driven after over two decades of reforms? How much, in particular, is aggregate investment driven by market forces and how much is still affected by policy-led factors?

The present study attempts to answer these questions by econometric modeling. The data sample is quarterly for the period 1994Q1-2001Q4. According

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to the *Statistics Yearbooks of China* (SYC), the total investment is composed of two parts: domestic investment and foreign direct investment. The latter contributes to less than 10 percent of the total investment on average, despite its rapid increase since 1990.[1] Here, only the domestic investment part will be modeled.

As government policies still exert important impact on the dynamics of the aggregate investment (e.g., see Yu 2004), domestic investment is further disaggregated into two parts with respect to data availability: government direct investment and business sector investment. The latter covers state-owned enterprises (SOEs), collective-owned enterprises (COEs), and private enterprises (PEs). Around 90 percent of the total domestic investment has been made up of SOEs and COEs over the last two decades. Here, the SOEs are grouped together with COEs and PEs partly because of data constraints and partly because their business behavior has become largely market-oriented similar to other firms of different ownership since the early 1990s.

Investment behavior of SOEs has changed substantially over different stages of the economic reform. Briefly, when the PRC's economic reform started in 1978, SOEs were totally planned and controlled by the government in terms of their factor inputs and product outputs. The banking sector was directly accountable to government plans and had no autonomous dealings with SOEs' investment projects (see discussion in Shang 2000). Reforms of SOEs have been gradual and can roughly be divided into three phases (see Xiang 1999, Cong 2002). The first phase covers 1978-1986. Reforms during this period were carried out in several key aspects:

(i) delegating more decision-making power and economic responsibility to SOEs' managers;
(ii) allowing SOEs to retain part of their profits;
(iii) replacing the system of profit submission with that of tax payment; and
(iv) switching gradually from the system of government direct financing to that of bank lending.

The second phase covers the period 1987-1993, when SOEs' profits were in decline due to increasing competition from the rising non-SOE sectors. The key reform of this period was the implementation of the contract system, which was intended legally to clarify the separate rights and responsibilities between the state and the managers of state-owned enterprises. In practice, however, the contract system deferred SOE reforms, as many SOEs managed, in their contracts, to

[1]Foreign direct investment slightly exceeded 10 percent around the mid-1990s, as shown in *Statistics Yearbook of China.*

minimize the amount of profits to be submitted to the state and to maximize the part of their budget from the state plans.[2] The third phase is marked by a clear division between the ownership and the management of SOEs, initiated by enterprise tax reforms and by the founding of the China Development Bank in 1994. Since then, SOEs have been subject to a unified taxation system, which is applicable to all other types of domestic enterprises. State ownership has been explicitly embodied in the submission of a certain proportion of profits to the state. The SOEs have been allowed to lay off excess employees and their fixed investment has been completely severed from government fiscal financing.[3] To make bank lending activities more independent from state interventions, both the law of People's Bank of China (the central bank) and the law of commercial banks in the PRC were issued in 1995.[4] In light of the significant changes outlined above, it is reasonable to examine the investment behavior of various types of PRC enterprises in aggregate for the sample period.

Several empirical models of the PRC's aggregate investment can be found in the recent literature (e.g., see Sun 1998, Zhu and Liang 1999, Shen et al. 1999, Shen 2000, Song et al. 2001, Qin and Song 2003). Sun (1998) models the total fixed real investment by the state sector from the supply side perspective. He finds real investment forming a relatively constant, long-run cointegrated relation with per capita grain output and per capita energy consumption using annual data for 1953-1995. Zhu and Liang (1999) model domestic fixed capital investment as a function of the amount of total bank loans, government investment, enterprise profit, depreciation rate and real interest rate. Their approach was based on the argument that domestic investment mainly reflects government behavior because the investment of SOEs makes up of two thirds of the domestic investment. Zhu and Liang estimate a model using annual data of 1978-1997. Similarly, the models built by Shen et al. (1999) and Shen (2000) explain domestic fixed capital investment by government investment plans, total bank loans, and foreign direct investment and are estimated with annual data for 1979-1996. Conversely, Song et al. (2001) maintain that the PRC's investment system has changed fundamentally since the reforms, and model the total investment by the standard factor-input demand approach. Song et al. adopt equilibrium correction models (ECM) as their econometric model form and estimate the model with panel data of 28 provinces

[2]Government plans still dominated the allocation of commercial bank loans before 1995 (see, for example, Shang 2000, 120-4).

[3]Price reforms preceded enterprise reforms in the PRC. Shortly before the third stage, prices of the most commodities and services had been freed from state control (see Wang 2002, 94-8).

[4]The major source of external funding for SOEs is bank loans. Direct public borrowing via securities markets is still in its infant stage, as the two PRC stock markets (Shenzhen and Shanghai) only started to operate in 1992, and the number of firms listed has been very small.

for 1983-1995. They find the total investment cointegrating with GDP and the user cost of capital in the long run, but the equilibrium-correcting force is weak (i.e., the correcting coefficient is small). Qin and Song (2003) focus their attention on measuring investment efficiency using provincial panel data for 1989-2000. They also follow the factor-input demand approach and verify the existence of a long-run relation between investment and GDP. However, investment is found barely to respond to capital pricing signals in their model.

The present study aims at finding an empirical model of aggregate investment, which would be useful for policy simulation and forecasting.[5] Policy simulation and forecasting requires the model to be both structurally meaningful and time-invariant. The paper decomposes the changes of investment into dynamic responses to various shocks in the ECM form to ensure their meaningful interpretation. Recursive estimation checks for coefficient invariance. As mentioned earlier, behavioral equations are formulated separately for business sector investment and government direct investment. This not only facilitates further policy analysis but also enables examination of both demand side and supply side factors.

The rest of the paper is organized into three sections: Section II discusses the theoretical investment models to be used in econometric modeling; Section III reports and discusses the empirical results; and Section IV highlights the main conclusions.

II. THEORETICAL MODEL

Aggregate investment dynamics pose a key challenge for macro modelers (see Caballero 1999). There are two main approaches to this challenge. One is to elaborate, on the basis of a priori rational expectations and other microeconomic arguments, traditionally developed static investment models into dynamic and stochastic models by the Euler equation method. Unfortunately, empirical estimation results of such models have so far been unsatisfactory (see Oliner et al. 1995). The other approach is to regard traditionally developed static models as the essential, long-run equilibrating force embedded in dynamic models, which are identified via *a posteriori* econometric means; see Hendry (1995). The latter approach is adopted.

The task of this section is to postulate meaningful long-run equilibrium relations for the PRC's aggregate investment. As described in Section I, domestic investment, I, is disaggregated into government direct investment, I_G , and business sector investment, I_B :

[5] In fact, the model reported here forms part of a quarterly macro model of the PRC, which has been set up by the Institute of World Economics and Politics of the Chinese Academy of Social Sciences, jointly with Duo Qin for the Asian Development Bank.

$$I = I_G + I_B \tag{1}$$

Since the data set starts from 1994, when the market economy already prevailed in most business activities, it is appropriate to describe the business sector investment principally by the orthodox factor-input demand model, as Song et al. (2001) and Qin and Song (2003) have done.[6] As for government direct investment, its determinants are chosen from a mixture of essential policy targets and supply side constraints.

A. Business Sector Investment

Assume that the PRC business sector chooses its long-run desired capital, K_B^*, by optimizing its factor input subject to a constant returns to scale, Cobb-Douglas production technology.[7] The optimization problem leads to the following standard first-order condition:

$$K_B^* = \gamma \frac{Y}{c} \tag{2}$$

where γ is the elasticity of output, Y, with respect to capital, and c is the user cost of capital. For the latter variable, we follow the principle of Romer's definition (2001):

$$c = \frac{P_k}{P} \frac{(r + \delta - \pi)}{(1 - \tau)} \tag{3}$$

where P_k is the price of capital goods, P is output price, r is the nominal interest rate, δ is the rate of economic depreciation, π is the inflation rate defined by P_k, and τ is a composite tax rate (see the Appendix for a detailed definition of this variable).

Next, we follow the convention to define the desired investment, I_B^*, as keeping capital at its desired level over time:

$$I_{Bt}^* = (K_t^* - K_{t-1}^*) + \delta K_{t-1}^* \tag{4}$$

[6]Notice that Qin and Song (2003) have tried supply-side factors such as firms' debt and bank loans but find them insignificant.

[7]Note that output and factor prices are taken as given or unaffected by investment decisions in neoclassical theory (see Caballero 1999 and Romer 2001). As the present model of investment forms only part of a macro model, the issue of how investment interacts with output and prices is beyond the current discussion and should be tackled within the macro model.

Subtracting I^*_{Bt-1} from both sides of (4) and combining with (2), we get:

$$\Delta I^*_{Bt} = \gamma\Delta\left(\frac{Y}{c}\right)_t - \left[I^*_B - \gamma\delta\left(\frac{Y}{c}\right)\right]_{t-1} \tag{5}$$

As (5) resembles an ECM, we can regard the term in the squared brackets on the right hand as implying the long-run equilibrium relation: $I^*_B = \gamma\delta\frac{Y}{c}$. Considering the possibility that the PRC business sector investment may also be affected by the government investment policies, we extend that equilibrium relation by adding government direct investment as a new explanatory variable. Thus we have, in logarithm:

$$\ln I^*_B = \alpha_0 + \alpha_1 \ln Y + \alpha_2 \ln c + \alpha_3 \ln I^*_G \tag{6}$$

where $\alpha_0 = \ln\gamma\delta$. We expect that $\alpha_1 = 1$ and $\alpha_2 = -1$.[8]

B. Government Direct Investment

Unlike business investment, there are no well-established theoretical models for government direct investment. In view of the PRC's current situation, government investment can be seen to play mainly two roles (see, for example, Xiang 1999): first, the government is responsible for financing state-prioritized investment projects; second, government budgetary investment is still used as a major fiscal policy tool. Obviously, investment of the first type is planned within the state revenue, whereas investment of the second type is designed to serve key economic targets. Hence, it can be postulated that government direct investment is partly determined by government revenue and partly by two important economic targets: (i) stimulating economic development and stabilizing its growth rate, and (ii) reducing unemployment. Specifically, the following is the proposed long-run relation for the desired government direct investment I^*_G:

$$\ln I^*_G = \beta_0 + \beta_1 \ln G_R + \beta_2 \ln(Y/Y^T) + \beta_3 u \tag{7}$$

where $u = \frac{L_s - L}{L_s} \times 100\%$ denotes the unemployment rate, L_s is the economically active population or labour force and L employment, G_R is government revenue,

[8]Notice that this equation allows for a more general assumption than the constant return to scale assumption, i.e., $\alpha_1 > 0$. This also applied to the cost of capital elasticity, $\alpha_2 < 0$. In fact, the latter parameter is relaxed from unity in Caballero (1999).

and Y^T denotes the long-run production trend in Y. By economic reasoning, it can be expected that $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 > 0$.

As Y^T is unobservable, various methods have been proposed to measure it. Essentially, these methods differ in the smooth algorithm used to filter out the trend component from the actual output time series. The choice of algorithm is normally made either by economic criteria or time-series criteria. Here, we take both into consideration. In view of economics criteria, we propose to define Y^T by the symbolically market-driven Cobb-Douglas production function, with constant of returns to scale to reflect the long-run prospect:

$$\begin{aligned} Y^T &= AK^{\theta}L^{1-\theta} \\ \ln Y^T &= \ln A + \theta \ln K + (1-\theta)\ln L \end{aligned} \tag{8}$$

In view of time series criteria, the coefficients in (8) can be estimated by its long-run equilibrium solution (see the next section).

III. EMPIRICAL RESULTS

A. Econometric Issues

The study sample contains quarterly data of 1994Q1-2001Q4. Detailed definitions of variables and data sources are reported in the Appendix. Figure 1 plots the data series of main variables. It is obvious that some series contain strong seasonal patterns. This is mainly due to the current data collecting procedures of the National Bureau of Statistics (NBS).[9] Quarterly dummies filter out regular seasonal patterns. However, part of the seasonality in the investment series may have resulted from the convention of government investment plans. According to Shang (2000, 394), the People's Bank of China employed the strategy of "tightening in the first half of a year and expanding in the second half" in its relending operations during 1988-1991. It can be expected that significant effects from such strategies should be picked up by relevant short-run policy variables.

Equations (6) and (7) form the basis of the present study's econometric work. To enable estimation, we rewrite them as:

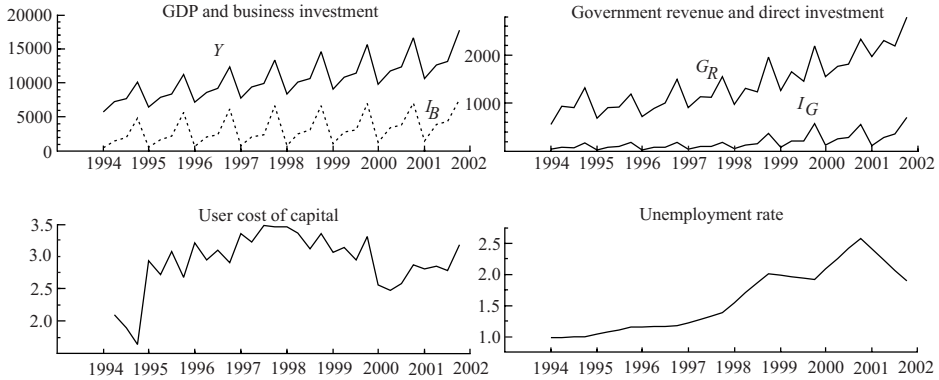
$$\ln I_{Bt} = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 \ln c_t + \alpha_3 \ln I_{Gt} + E_{Bt} \tag{6'}$$

$$\ln I_{Gt} = \beta_0 + \beta_1 \ln G_{Rt} + \beta_2 \ln(Y / Y^T)_t + \beta_3 u_t + E_{Gt} \tag{7'}$$

[9]The NBS began reporting quarterly national account statistics in 1992. However, calculation of the quarterly statistics is still relied heavily on the annual national account process. In fact, the quarterly statistics are only collected during the first three quarters, with the fourth quarter being left as the gap between the annual accounting results and the first three quarter results.

where E_{Bt} and E_{Gt} denote disequilibrium errors and are expected to be weakly stationary.

Figure 1. **Data Series of Main Variables**



Note: GDP, business investment, government revenue, and government direct investment are in 100 million *yuan*; user cost of capital and unemployment rate is in percentage points.

It is well known that direct regression of (6') and (7') may risk nonsense inference if some of the variables are nonstationary. From experience, variables such as investment, output, and income in (6') and (7') tend to exhibit nonstationary properties. A common solution under such circumstances is to employ cointegration analysis based on a general Vector AutoRegression (VAR) specification of (6') and (7'). However, two factors render this strategy unworkable here. The key factor is the limited sample size (32 observations). Another factor is that all the variables in a cointegration vector are required to be of the same degree of nonstationarity, whereas some of the variables in (7'), such as $\ln(Y/Y^T)$, are unlikely to be nonstationary. In fact, it is difficult to distinguish from the limited sample data whether the variables are nonstationary or trended stationary, as shown in Figure 1. To circumvent these problems, a single-equation, dynamic specification approach is adopted. Starting with an auto-regressive distributed-lag (ADL) model of (6') and (7') respectively, gradually reduce the model, and reparameterize it into a parsimonious, data-congruent, and economically interpretable ECM, which has the general form:[10]

[10]For the detailed econometric procedure see Hendry (1995). The software PcGive 10.0 is used in the model reduction and estimation (see Hendry and Doornik 2001).

$$\Delta \ln I_{Bt} = a_0 + \sum_{i=1}^{d} a_{0i} \Delta \ln I_{Bt-i} + \sum_{j=0}^{d} a_{1j} \Delta \ln Y_{t-j} + \sum_{j=0}^{d} a_{2j} \Delta \ln c_{t-j} + \sum_{j=0}^{d} a_{3j} \Delta \ln I_{Gt-j} + \lambda_B E_{Bt-1} + \varepsilon_{Bt} \quad (9)$$

$$\Delta \ln I_{Gt} = b_0 + \sum_{i=1}^{d} b_{0i} \Delta \ln I_{Gt-i} + \sum_{j=0}^{d} b_{1j} \Delta \ln G_{Rt-j} + \sum_{j=0}^{d} b_{2j} \Delta u_{t-j} + \sum_{j=0}^{d} b_{3j} \ln(Y / Y^T)_{t-j} + \lambda_G E_{Gt-1} + \varepsilon_{Gt} \quad (10)$$

where Δ denotes first difference, d is the minimum lag determined in such a way that the white-noise properties of residuals ε_{Bt} and ε_{Gt} are ensured. It is expected that $-1 \le \lambda_B < 0$ and $-1 \le \lambda_G < 0$ for the long-run equilibrium correction mechanism (6') and (7') to be at work. Notice that the long-run, equilibrium relation embedded in (10) differs from (7') in that the target variable, $\ln(Y / Y^T)$, is excluded. This is due to the expected stationarity of this variable and should not affect the economic meaning of (7).

One of the advantages of the ECM is its flexible capacity in dealing with nonstationarity. By taking differences, it generally removes any nonstationarity from its regressant and regressors. Moreover, it does not entail that all the variables within an equilibrium-correcting term should be nonstationary to the same degree. All it requires is stationarity of the equilibrium-correcting term, e.g., E_{Bt-1} in (9) or E_{Gt-1} in (10). This single-equation approach is susceptible to problems of simultaneity and related exogeneity. Two strategies are adopted to tackle these problems. One strategy, if simultaneity turns out to be present after reducing the models into parsimoniously ECMs by single-equation ordinary least square (OLS) methods, is to reestimate these ECMs by instrumental variable (IV) methods. The second strategy is to employ the recursive estimation method extensively as the means to check for exogeneity.[11]

B. The Business Sector Investment Model

Starting from a four-lag ADL form of (6'), together with constant and seasonal dummies, the following parsimonious ECM is obtained through model reduction:

[11] For the definition of various types of exogeneity, see Engle et al. (1983). For detailed discussion on handling exogeneity in single-equation empirical studies, see Qin (2003).

$$\Delta \ln \hat{I}_{Bt} = \underset{(0.0347)}{0.005433} - \underset{(0.0864)}{0.2788}\Delta_3 \ln c_t - \underset{(0.0174)}{0.922}\Delta_3 \ln I_{Bt-1} - \underset{(0.0848)}{0.3259}E_{Bt-1}$$
$$\underset{(0.0371)}{-0.00012} - \underset{(0.1252)}{0.3174} \qquad \underset{(0.0183)}{0.9197} \qquad \underset{(0.0958)}{0.3446}$$
$$+ \underset{(0.0515)}{0.1345}\Delta \ln I_{Gt-1} + \underset{(0.104)}{0.2272}\Delta \ln Y_{t-2} \qquad (9')$$
$$\underset{(0.0566)}{0.1443} \qquad \underset{(0.1102)}{0.2425}$$
$$E_{Bt} = \ln I_{Bt} - \ln Y_t + \ln c_t$$

where Δ_3 denotes difference of three period, e.g. $\Delta_3 \ln c_t = \ln c_t - \ln c_{t-3}$, and

$$c_t = \frac{P_{k,t}}{P_t} \frac{(r_t/4 - \frac{P_{k,t} - P_{k,t-1}}{P_{k,t-1}} * 100 + \delta_t/4)}{1 - \tau_t/100}$$

as defined in equation (3). Coefficients in the upper row are OLS estimates and those in the lower row are IV estimates to check for the possible simultaneous effect of $\Delta_3 \ln c_t$.[12] The two sets of estimates show little statistical difference, ruling out significant simultaneous-equations bias. Standard errors of the coefficient estimates are given in brackets below the estimates. Unit-root test results of all the variables are reported in Table 1. Actual and fitted values of $\Delta \ln I_{Bt}$ by the OLS, as well as the residuals are plotted in Figure 2. Diagnostic tests on model (9') are reported in Table 2. Figure 3 shows recursive OLS coefficient estimates of all the explanatory variables and various types of Chow tests based on the recursive estimation.

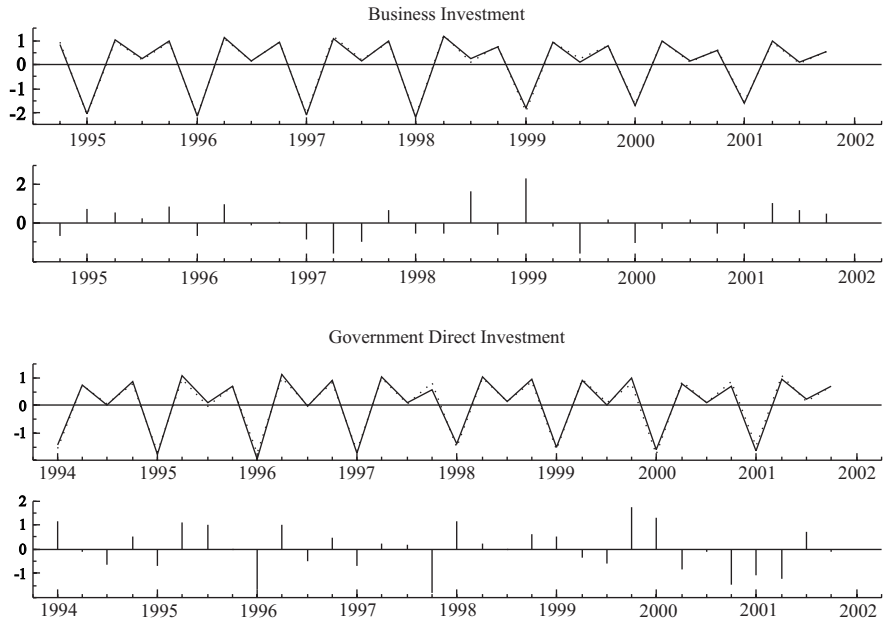
Table 1. **Augmented Dickey-Fuller (ADF) Unit-root Test (sample period 1994Q1-2001Q4)**

Variable	$\Delta \ln I_{Bt}$	$\Delta \ln Y_t$	$\Delta \ln I_{Gt}$	$\Delta_3 \ln I_{Bt}$	$\Delta_3 \ln c_t$	E_{Bt}	E_t^T	E_{Gt}
t-ADF	-4.906	-6.899	-4.312	-4.379	-3.751	-5.054	-4.928	-5.151
5% Critical Value	-2.96	-2.96	-2.96	-2.96	-2.97	-2.96	-2.96	-2.96

Notes: All used one lag except $\Delta_3 \ln c_t$ used no lag. Trend and seasonal dummies are used for $\Delta \ln I_t$, $\Delta \ln Y_t$, $\Delta \ln I_{Gt}$, and $\Delta_3 \ln I_t$.

[12] Its own lags are used as the instrument variables.

Figure 2. **Business Investment and Government Direct Investment in People's Republic of China**



Note: Actual values (solid line) and fitted values (dotted line) in the upper panels; residuals (scaled) in the lower panels.

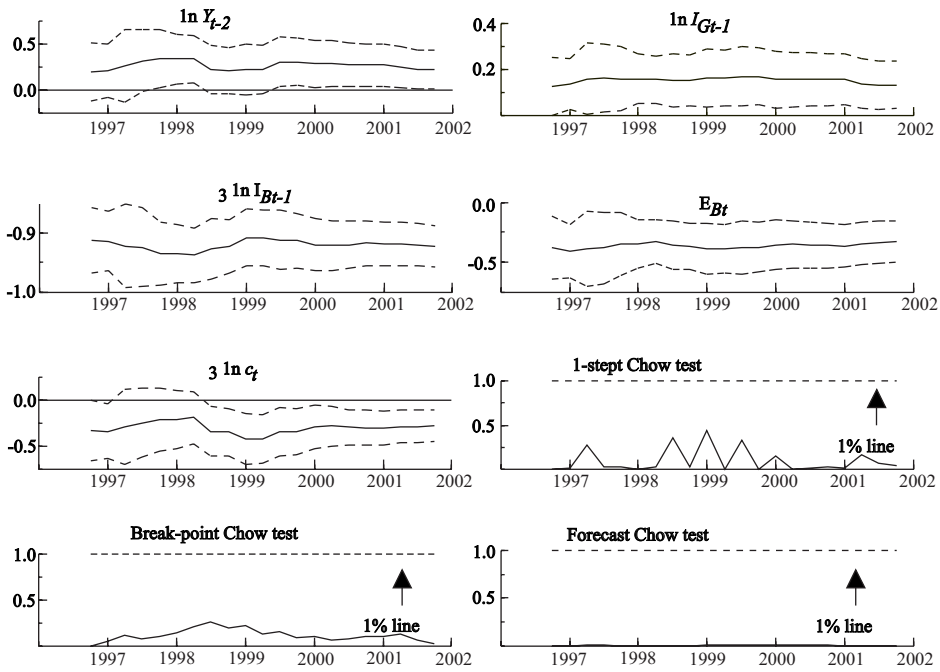
Table 2. **Diagnostic Test of Estimated Business Investment Equation (sample period 1994Q4 – 2001Q4)**

	OLS Estimate $\sigma_{\hat{u}}$ =0.0716866		**IV Estimate** $\sigma_{\hat{u}}$ =0.0719967	
Null Hypotheses (H0)	**Test Statistics**	**[p value]**	**Test Statistics**	**[p value]**
$\hat{u}$ No Autocorrelation	F(3,20) = 0.20735	[0.8901]	F(3,20) =0.18584	[0.9048]
$\hat{u}$ Normality	$\chi^2(2)$ = 1.3371	[0.5125]	$\chi^2(2)$=0.75317	[0.6862]
$\hat{u}$ Homoscedasticity	F(10,12) = 0.82227	[0.6164]	F(10,12) =0.82033	[0.6179]
RESET	F(1,22) = 0.11970	[0.7326]	$\chi^2(1)$ =1.0594	[0.3034]

The long-run coefficients $\alpha_1 = 1$ and $\alpha_2 = -1$ in E_B are imposed after observing that these values are within the 95 percent confidence intervals of the long-run estimates of α_1 and α_2 during model reduction. The resulting long-run equilibrium equation confirms the a priori supposition of a constant return to

scale, Cobb-Douglas technology in (2) of Section IIA,[13] suggesting strongly that aggregate business investment demand is now largely market-driven in the PRC. However, the recursive graph (Figure 3) of the short-run effect of the user cost of capital reveals that this variable becomes significant and relatively constant only after 1998, indicating that dominance of the market pricing signals is a fairly recent phenomenon. This may explain why the cost variable is found insignificant in Qin and Song (2003), as their model is focused on long-run factors and estimated using the annual data of 1989-2000.

Figure 3. **Recursive Estimation Results of Business Investment**



Note: Actual values (solid line) and fitted values (dotted line) in the upper panels; residuals (scaled) in the lower panels.

The presence of $\ln c$ in (9') carries interesting policy implications, as it includes two important policy instruments, namely interest rate and tax rate (see equation [3]). Equation (9') shows that reduction of interest rate and/or tax rate would stimulate business sector investment by reducing the user cost of capital. This equation also shows that it takes around three quarters of a year for the

[13]The result of $\alpha_1 = 1$ is also confirmed by Song et al. (2001) and Qin and Song (2003).

business sector investment to adjust and absorb such policy shocks through the long-run equilibrium error variable (i.e., the feedback coefficient being –0.3259). Investment models built on annual data could therefore be ineffective for such policy analyses. Obviously, more precise policy analysis about the magnitude and dynamics of the impact of various interest rate and tax rate shocks entails simulation of a whole macro model. Nevertheless, the result is encouraging for further quantitative policy studies. Such studies are badly needed in view of the recent debates among the PRC's economists concerning the feasibility of monetary policy versus fiscal policy in combating deflationary pressure and bad bank loan problems (e.g., see Yu 1999).

Noticeably from (9'), government direct investment is absent from the long-run solution but exerts a positive short-run impact with a three-month lag. This can be regarded as a distinct feature of a transitional economy, as it shows that active fiscal policy via direct investments feeds its effect through business investment within one year, and that the effect is "crowd in" by nature, instead of the conventionally expected crowding-out effect (see Dornbusch 2001). This result is fairly consistent with the recent empirical findings by Atukeren (2004) on the interactions between public and private investment from a number of developing economies. In particular, this result helps to explain why the PRC's aggregate investment dynamics is so volatile: any changes in the government investment get propagated quickly in the business investment.

C. Government Direct Investment Model

Before estimating (10), (8) must be estimated in order to measure the unobservable long-run production trend, Y^T. Equation (8) is rewritten in terms of the actual output:

$$\begin{aligned} \ln Y_t &= \ln A + \theta \ln K_t + (1-\theta)\ln L_t + E_t^T \\ \ln\left(\frac{Y}{L}\right)_t &= \ln A + \theta \ln\left(\frac{K}{L}\right)_t + E_t^T \end{aligned} \qquad (8')$$

where $E_t^T = \ln(Y/Y^T)_t$ and is expected to be weakly stationary. Estimation of θ and A takes two steps. First, obtain the long-run solution from the OLS estimation of a 4-lag ADL of the lower equation of (8'):

$$\ln\left(\frac{\hat{Y}}{L}\right)_t = -\underset{(2.692)}{2.3056} + \underset{(0.24)}{0.9516}\ln\left(\frac{K}{L}\right)_t \qquad (8'')$$

The unit-root test on E_t^T rejects nonstationarity, as shown in Table 1. Next, use E_{t-1}^T as the equilibrium-correcting variable in a 4-lag ECM of the upper equation of (8') to make sure that E_t^T indeed exerts negatively feedback on the output growth. Notice that $\hat{\theta}$ in (8'') is very large with a relatively wide 95 percent confidence interval (0.46, 1.20). This parameter is normally found to be well below 0.5 in most market economies. Such a large capital elasticity reflects the persistent problem of overemployment in the PRC, which makes capital the dominant input constraint on the whole. However, the problem should alleviate as a market economy becomes established. In view of model forecasting, we experiment with downward adjustment of θ within its confidence interval during the second step of ECM modeling. The adjustment aims at finding the minimum acceptable value of the elasticity to sustain a parsimonious and meaningful ECM. The resulting estimate settles at $\hat{\theta} = 0.85$.

The search for a parsimonious and economically meaningful (10) follows exactly the same procedure as used in obtaining (9') and yields the following:

$$\Delta \hat{\ln} I_{Gt} = \underset{(0.109)}{1.096} - \underset{(0.177)}{0.3759} E_{t-1}^T - \underset{(0.143)}{0.4838} E_{Gt-1} - \underset{(0.111)}{2.07} S_1 - \underset{(0.144)}{0.3103} S_2 - \underset{(0.0626)}{0.7429} S_3 \qquad (10')$$

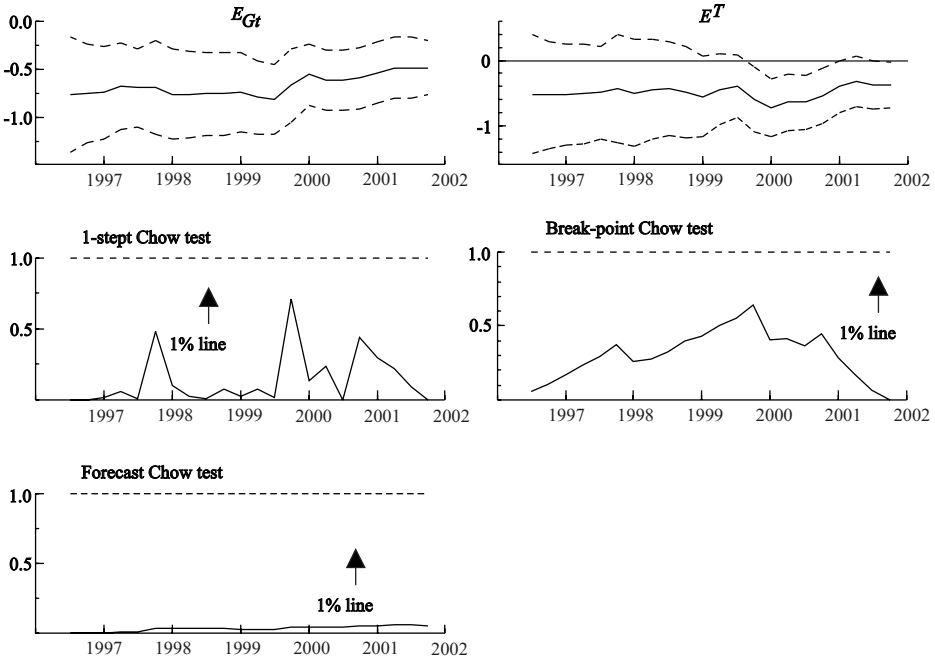
$$E_{Gt} = \ln I_{Gt} - 0.5 \ln G_{Rt} - 0.7 u_t$$

where S_1, S_2 and S_3 are seasonal dummies of the three quarters, respectively. Diagnostic tests of (10') are reported in Table 3. The actual and fitted values, together with the residuals are plotted in Figure 2. Recursive estimation results are given in Figure 4.

Table 3. **Diagnostic Test of Estimated Government Direct Investment Equation (sample period 1994Q1 – 2001Q4)**

	$\sigma_{\hat{u}}$ = **0.123718**	
Null Hypotheses (H_0)	**Test Statistics**	**[p value]**
$\hat{u}$ No Autocorrelation	F(3,23) = 0.28111	[0.8385]
$\hat{u}$ Normality	$\chi^2(2)$ = 0.30267	[0.8596]
$\hat{u}$ Homoscedasticity	F(7,18) =0.65625	[0.7052]
RESET	F(1,25) =0.39184	[0.5370]

Figure 4. **Recursive Estimation Results of Government Direct Investment**



Notes: For a description of the various plots, see the notes in Figure 3.

It is confirmed in (10') that government investment is constrained by budgetary revenue in the long run, but the elasticity is quite small, $\hat{\beta}_1 = 0.5$. This reflects the gradual withdrawal of the state from ordinary investment projects during the reforms. Unemployment is found to exert a long-run effect with a semi-elasticity of $\hat{\beta}_3 = 0.7$. This fairly large semi-elasticity suggests that persistent employment pressure remains a top concern in government investment planning. The relatively large disequilibrium-correcting coefficient of –0.4838 reflects a very speedy investment plan adjustment process by the state, well within a one-year period. As E_t^T (i.e., the GDP gap) is stationary, its impact on the government investment is short-run and found with a one-quarter lag. The negative response of $\hat{\beta}_2 = -0.3759$ shows that stabilizing and maintaining economic growth also plays an important role in government investment planning. These results show again that models built on annual data would not be of much use for policy analysis. Finally, the strong seasonal effects confirm the earlier description of the uneven seasonal distribution of investment in government budgetary plans.

IV. CONCLUSION

Disaggregation of business sector investment and government direct investment enables economically meaningful structural equations for these two parts of the PRC's aggregate domestic investment. A number of interesting observations can be drawn from the econometric results.

First, business sector investment is largely determined by market forces. Remarkably, the long-run equilibrium relation for investment demand is found to follow the standard theory of a constant return to scale, Cobb-Douglas production function. However, signs of the PRC economy in transition are discernible from the significant, short-run stimulus of the government direct investment growth rate, as well as from the growing significance of the user cost of capital variable over time. These mixed-economy features carry interesting policy implications. The short-run "crowding-in" effect of government investment helps to explain why aggregate investment in the PRC has been more volatile than what is expected normally of the investment series from a market economy. The significance of the cost variable in both the long run and the short run provides a potential to simulate policy impact on aggregate investment via two instruments: interest rate and tax rate.

Second, government direct investment is found to bear strong planned features. While bounded by government revenue in the long run, government direct investment is very responsive to unemployment. It is also significantly responsive to the GDP gap. The significance and the coefficient signs of these two policy targets confirm that the PRC government still resorts heavily to planned fixed investment as a major countercyclical measure to smooth economic growth. The finding that changes in government investment transmit positively and swiftly into the domestic business sector investment justifies the government's reliance on such a fiscal policy instrument. The very active use of the instrument also distinguishes the role of the PRC's fiscal policy from the normal roles of fiscal policies currently used by many other market economies.

Third, the empirical equations are obtained not only on the basis of their economically interpretable specification but also on the basis of their relatively constant coefficient estimates and good Chow forecasting test results, in addition to satisfactory diagnostic test results. Coefficient invariance boosts confidence in using the equations for short-term forecasting. More importantly, it provides empirical validation to use the equations for policy simulation, since the invariance is a vital condition for super exogeneity of the exogenous variables, i.e., to assure that the equations are unlikely to suffer from the Lucas critique when used in policy simulation (see Engle et al. 1983).

Finally, adjustment of both types of investment to short-run dynamic shocks is found to be quite speedy, mostly within one year. This suggests that

macroeconometric models built on annual data would not be very useful for policy simulation and forecasting analysis.

APPENDIX: VARIABLE DEFINITION AND SOURCE

Variable Name	Definition	Source
I_B	Real business fixed investment defined as fixed capital investment, excluding government investment and foreign direct investment and divided by the fixed investment price index. Measured in 100 million *yuan*.	CMEI
Y	Real GDP defined as nominal GDP divided by GDP deflator.	CMEI
I_G	Real government investment defined as government investment divided by fixed investment price index.	CMEI
G_R	Real government revenue defined as nominal government revenue divided by GDP deflator. Measured in 100 million *yuan*.	CMEI
P	GDP deflator.	CMEI
P_k	Fixed investment price index.	SYC and CMEI
δ	Depreciation rate of fixed assets.	Estimated
r	Annual nominal interest rate of lending adjusted on daily average within the corresponding quarter. Measured in percentage point.	QB
u	Rate of unemployment. Measured in percentage point.	Calculated
τ	The sum of value-added taxes, consumption taxes, business taxes, and enterprise income taxes divided by GDP. Measured in percentage point.	CMEI
L	Employment. Measured in 10 thousands.	SYC
L_s	Economically active population. Measured in 10 thousands.	SYC
K	Fixed capital stock. Measured in 100 million *yuan*.	YFIC

Notes: (1) P_k is only given in half year and annual; it is assumed that the price changes gradually within a half-year period.
(2) The amount of capital formation at the end of 1991, given in YFIC, is used to calculate K in the following period by using $K_t = K_{t-1} * (1-\delta) + I_t$.
(3) L and L_s are only given in annual data; it is assumed that they change gradually within a year.
(4) δ is taken as a constant of 5 percent.

Sources: National Bureau of Statistics: *Statistics Yearbook of China* (SYC), *China Monthly Economic Indicators* (CMEI), *Yearbook of Fixed Investment of China 1950-1995* (YFIC); People's Bank of China: *Quarterly Banking* (QB).

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