

Does public investment determine private investment?  
Non linear cointegration approach: Case of Saudi Arabia

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**Abstract**

This paper investigates the long-run equilibrium relationship between real private investment and public investment in Saudi Arabia by threshold cointegration test. The results show the stability of the private investment efforts both above and mainly below the threshold. This finding indicates the strength of the Saudi economy against the shocks and mostly negative shocks.

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## **1 Introduction**

This article analyses the impact of public investment on private investment. The idea is to consider the long run relationship between the public investment (Budget infrastructure investment, Budget productive investment and public investment enterprises) and the private investment and to determine the complementary or the substitution effects of public investment on private investment.

The methodology used considers demand approach which consists to estimate an investment function. This approach permits to evaluate the effect of demand expectations and compare the theory of irreversible investment in uncertainty conditions (Jorgenson model). If the assumption of asymmetrical adjustment costs would appear to be most appropriate for modeling private investment (Dixit & Pindyck 1994), it is reasonable to postulate an asymmetrical adjustment of the equilibrium relationship between the public investment and private investment. In the private sector the investment decision depends upon favorable economic condition, hence the variation in policy of public investment stimulates or discourages the private investment in different proportions. The hypothesis considered is that the effects of increase and decrease in public investment are not symmetric. Therefore, the appropriate methodology consists to use non linear cointegration in the investigation of long run relationship.

This article is organized as follows the first section concerns the introduction, the theoretical bases are described in second section. The empirical results are presented in third section and the fourth section exhibits the conclusions.

## 2 The investment equation and threshold cointegration test

### 2.1 The model of investment

The contribution of this paper is to test the asymmetries effects of public investment on private investment by using the nonlinear cointegration. There are few empirical studies which seek to identify a relation between irreversible investment with uncertainty and the impact of public investment on private investment. The private investment is considered a dependent variable whose behavior is explained implicitly as following:

$$IPR_t = IPR(IPR_{t-1}, IPU_t, IBG_t, Y_t^*, CRE_t, ucc_t) \quad (1)$$

where the variables IP,  $Y^*$ , IG, CRE and ucc design respectively the private investment, expected demand, public investment, credit to private sector and user cost of capital (i.e. real short-term interest rate). The positive coefficient of lagged private reflects the irreversibility of investment. The public investment can have either a negative or a positive effect, if the coefficient is negative it shows substitution effect, whereas if the coefficient is positive it indicates complementarity's effect (Oliveira & Teixeira, 1999 ; Khan & Kumar, 1997). In the latter case, the public investment notably in infrastructure can reduce uncertainty by reducing costs and raising productivity in the private sector by increasing private returns.

Public sector investment has also been suggested to affect private investment, although its effect remains ambiguous. In contrast, public investment may crowd out private investment if the additional public investment is financed by a deficit, which leads to an increase in the interest rate, credit rationing, and a tax burden (Rossiter, 2002).

The flexible accelerator model suggests that the private investment is affected positively by expected demand. It has also been hypothesized that the private investment is positively related to the growth of real GDP.

If the user cost of capital has a negative effect, this endows with the theory of Jorgenson (1967). In revenge, a very small value of coefficient would endow with the theory of irreversible investment in conditions of uncertainty. The user cost of capital can be approximated by the real interest rate which is calculated using the following formula:  $ucc_t = \text{Ln}(1 + r_t)/(1 + \pi_t)$  where  $r_t$  and  $\pi_t$  denote respectively nominal interest rate and inflation rate.

The effect of credit on private investment is expected to be positive. With financial markets being generally reticent, credit policies generally affect private sector investment via the stock of credit available to firms that have access to preferential interest rates.

Bearing the above arguments in mind, the long run equation of the private investment, in logarithm form, is assumed to be given by:

$$\text{LnIPR}_t = \beta_0 + \beta_2 \text{LnIPU}_t + \beta_3 \text{LnIBG}_t + \beta_4 \text{LnGDP}_t + \beta_5 \text{LnCRE}_t + \beta_6 ucc_t + \varepsilon_t \quad (2a)$$

$$\text{LnIPR}_t = \beta_0 + \beta_2 \text{LnIPU}_t + \beta_3 \text{LnIBG}_t + \beta_4 \text{LnGDP}_t + \beta_5 ucc_t + \varepsilon_t, \quad \varepsilon_t \sim iid(0, \sigma_\varepsilon^2) \quad (2b)$$

where  $\varepsilon_t$  represent the error term, which is an indicator for macroeconomic instability. It is assumed that the expected demand is the sum of the GDP and a fraction of the error term  $\varepsilon_t$ . All parameters exhibit elasticities which can provide more reliable results. If the relationship in (2a) or (2b) is stable, that is, cointegrated with symmetric or asymmetric adjustment, the crowding-out or crowding-in effect are checked (Shafik 1992, Ramirez 2000, Ahmed & Miller 2000, Naqvi 2002). Then, we test for cointegration with unspecified

vector. We assume that the adjustment will be asymmetric e.g. either because the public investment could be rigid downwards but not upwards or because the central bank has different preferences regarding deviations from the long run equilibrium.

## 2.2 Threshold cointegration

We employ the threshold cointegration approach (Balke & Fomby 1997, Enders & Siklos 2001) to test for a cointegration relationship with asymmetric adjustment. As the assumption of tests for threshold cointegration, let  $\{x_{it}\}_1^T$  denote observable random variables I(1). The long run equilibrium relationship is given by:

$$x_{1t} = \hat{\beta}_0 + \hat{\beta}_2 x_{2t} + \dots + \hat{\beta}_n x_{nt} + e_t \quad (3)$$

where  $\hat{\beta}_i$  are estimated parameters (elasticity), and  $e_t$  is the disturbance term i.e. residue. The existence of the long-run equilibrium relationship involves stationary  $e_t$ . To accept stationarity of  $e_t$ , we have to obtain  $-2 < \rho < 0$  in the second step procedure given by:

$$\Delta e_t = \rho e_{t-1} + u_t \quad (4a)$$

where  $u_t$  is the white-noise disturbance. If  $-2 < \rho < 0$  then the long-run equilibrium relationship (3) with symmetric adjustment (4a) is accepted. However, the standard cointegration framework in (4a) is misspecified if the adjustment process is asymmetric. Therefore, Enders & Siklos (2001) proposed the following asymmetric adjustment, called the threshold autoregressive TAR model:

$$\Delta e_t = I_t \rho_1 e_{t-1} + (1 - I_t) \rho_2 e_{t-1} + u_t \quad (4b)$$

where  $\rho_1$  and  $\rho_2$  are speed-adjustment coefficients and  $I_t$  is the indicator function such

that:

$$I_t = \begin{cases} 1 & \text{if } e_{t-1} \geq \tau \\ 0 & \text{if } e_{t-1} < \tau \end{cases}$$

and  $\tau$  is the threshold parameter. To satisfy the necessary and sufficient conditions of the stationarity of  $e_t$ ,  $\rho_1 < 0$ ,  $\rho_2 < 0$ ,  $(1 + \rho_1)(1 + \rho_2) < 1$  are required. The threshold parameter  $\tau$ , which is restricted to the ranges of the remaining 70% of  $e_t$  or  $\Delta e_t$  when the largest and the smallest 15% values are discarded, is selected as an unknown value so as to minimize the sum of the squared residuals obtained from (4b) and (4c) (Chan 1993). Although, Enders & Siklos (2001) proposed tests for when the threshold parameter is known ( $\tau = 0$ ) and unknown, we use an unknown threshold parameter because we do not have an a priori reason to believe that  $\tau$  is known. As an alternative adjustment process, the momentum threshold (MTAR) model is as follows:

$$\Delta e_t = M_t \rho_1 e_{t-1} + (1 - M_t) \rho_2 e_{t-1} + u_t \quad (4c)$$

$$M_t = \begin{cases} 1 & \text{if } \Delta e_{t-1} \geq \tau \\ 0 & \text{if } \Delta e_{t-1} < \tau \end{cases}$$

The MTAR model can capture the properties such that the threshold depends on the previous period's change in  $e_t$ , whether the  $\Delta e_{t-1}$  is increasing or decreasing. When the adjustment process (4b) is serially correlated, we can re-write it<sup>1</sup>:

$$\Delta e_t = I_t \rho_1 e_{t-1} + (1 - I_t) \rho_2 e_{t-1} + \sum_{i=1}^p \gamma_i \Delta e_{t-1} + u_t \quad (4d)$$

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<sup>1</sup> Although, it is possible that  $\gamma_i$  is asymmetric, we do not consider this case for the sake of simplicity, similarly to Enders & Siklos (2001).

To test for threshold cointegration, Enders & Siklos (2001) proposed two types of tests, called  $\Phi$  and t-max statistics. The  $\Phi$  statistic using an F-statistic involves procedure testing for the null hypothesis  $\rho_1 = \rho_2 = 0$  and the t-max statistic employing a t-statistic requires the test for the null hypothesis with the largest  $\rho_i = 0$  between  $\rho_1$  and  $\rho_2$ . If the null hypothesis of no cointegration is rejected, we can test for the null hypothesis  $\rho_1 = \rho_2$  by a standard F statistic because the system is stationary. In this case, the Engle-Granger model characterized by symmetric adjustment is supported.

### **3 Data and results**

#### **3.1 Data and unit root tests**

Hopefully the sources of all variables listed below are extracted from the annual reports of Saudi Arabia Monetary Agency (SAMA, report 43, 2006). The annual data base is from 1968 to 2006. The National accounts statistics break down gross domestic investment into its private and public sector components. The public investment contains investment by state-owned enterprises such as state petroleum Arabian American Oil Company ARAMCO and so on. We attempt to determine total public investment i.e. consolidated public investment, inclusive of public investment undertaken by any state-owned enterprises (from national accounts) and of state-budget investment breaking down into infrastructure and productive investment (see, figure 1).

\*\* Insert Figure 1: Private and Public Investment of GDP in Saudi Arabia \*\*

Data on real GDP has been calculated straightforwardly by implicit deflator of GDP (base 1999), both obtained from the Saudi Arabia Monetary Agency (2007). To escape the influences of inflation, all data comprised the interest rate are taken in real terms in constant 1999 prices with the appropriate deflators. All variables are not seasonally adjusted.

To test the order of integration of variables standard tests for unit root such as the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests are often used. However, these tests are not generally reliable in small samples, because of their poor size and power properties i.e. they tend to over-reject the null hypothesis when it is true and under-reject it when it is false, respectively (Harris, 2003).

The Dickey-Fuller generalised least square ( $DF^{GLS}$ ) de-trending test proposed by Elliot et al. (1996) and the Ng-Perron test following Ng and Perron (2001) have been proposed to address these problems. Ng and Perron (2001) also address the problem of sensitivity of unit root testing to choice of lag. They propose a new information criterion, the modified information criteria (MIC). The distinction between the MIC and the standard information criteria such as the Akaike and the Schwartz Bayesian criteria is that the former takes into account the fact that the bias in the sum of the autoregressive coefficients is highly dependent on the number of lags.

Table 1 displays the results of unit root tests for the null hypothesis  $I(1)$  and  $ADF^{GLS}$  is the Ng & Perron's test (2001). We chose the lag order employing the data dependent method, denoted by t-sig, to check for possible size distortions for ADF-type

tests, proposed by Ng & Perron (1995)<sup>2</sup>. We set the maximum lag  $k_{\max} = 5$ . A plot of the variables over time indicates the presence of trend in the variables (mainly in LIPR, LGDP and LCRE).

\*\* Insert Table 1A: Unit root tests with constant and trend \*\*

\*\* Insert Table 1B: Unit root tests with constant \*\*

where LIPR, LIPU, LIBG, LGDP, LCRE and ucc denote in logarithm the real private investment, the investment of public enterprises, the State budget investment, the gross disposable product, the credit to private sector and the user cost of capital, respectively.

The results indicate that the computed t-statistics are greater than the critical values i.e. the null hypothesis can't be rejected. Since neither level of LIPR, LIPU, LIBG, LGDP, LCRE and ucc are significant at a 1%, the results from Table 1A show that these variables have a unit root process. Applying the two tests on the first difference of the variables shows that the null hypothesis can be rejected mainly for  $\Delta$ LIPR,  $\Delta$ LCRE and  $\Delta$ ucc variables. The ADF-GLS test confirms that the variables are I(1). These unit root results have significant implications for the cointegration analysis.

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<sup>2</sup> t-sig selects the lag order  $k$  via top-down testing. More accurately, we estimate the equation with the maximum lag (here, the max lag is 5). We use the lag length if the absolute t-statistic of the parameters of the maximum lag is larger than 1.65 i.e. significant. If the t-statistic in the maximum lag is smaller than 1.65 i.e. not significant, we estimate the equation with the  $lag = k_{\max} - 1$ . That is, when the absolute t-statistic of the parameter of the  $lag = k_{\max} - q$  is significant at a conventional level, we employ the lag length.

### 3.2 Cointegration tests

Whether the long-run equilibrium relationship between private investment and public investment, represented by the equation of private investment, exists and therefore has significant implications for budget policy. The existence of the equilibrium relationship implies that economic policies using public investment as a policy instrument can influence fluctuations in private investment and flows of credit to private sector. This is especially important for the Saudi Arabian economy characterized by the importance of petroleum resources and their dependence from the international market and by the strategic policy to boost the private sector.

Table 2 illustrates the results of cointegration tests. Each cointegration test includes a constant and trend as a deterministic component since by the equation of private investment and by visualizing data does support a constant and trend. For the estimation of  $e_t$ , we chose the lag order by AIC and t-sig. EG and PR denote Engle & Granger's (1987) and Perron & Rodriguez's (2001) methods assuming only symmetric adjustment, respectively. These tests presuppose a linear adjustment, which is not realistic considering the friction of budget investment and the presence of transactions costs in private investment.

\*\* Insert Table 2: Cointegration tests (dependent variable: LIPR) \*\*

From two first columns of Table 2, we cannot reject the null hypothesis of no cointegration using the ADF cointegration test. Thus, there is no evidence of cointegration at the 5% or 1% significance level according to the conventional Engle & Granger (1987) ADF test. Also, we employ the Perron & Rodriguez (2001) cointegration tests with good size and power. The null hypothesis of no cointegration is only rejected at the 5 percent

level. There is no evidence of a plausible cointegrating relationship between the private investment and the public investment. The contrast between the results in Table 2 suggests that the rejections using EG test entail a Type II error.

As tabulated in Table 3, the threshold cointegration approach clearly rejects the null hypothesis of no cointegration particularly in MTAR model. For example, the  $\Phi$  and  $F$  statistics based on t-sig lag option are 11.171 and 5.409, respectively ; and the coefficients are significant at the 1% level.

\*\* Insert Table 3: Threshold cointegration tests (dependent variable: LIPR) \*\*

Parentheses show t statistics in the first two columns.  $\Phi$  denotes the tests for the null hypothesis  $\rho_1 = \rho_2 = 0$ .  $F$  shows the tests for the null hypothesis of symmetry  $\rho_1 = \rho_2$ . The coefficient  $\tau$  indicates the estimated threshold<sup>3</sup>.

The null hypothesis of  $\rho_1 = \rho_2 = 0$  can therefore be rejected, indicating that the series are cointegrated. Given that the series are cointegrated, the null hypothesis of symmetric adjustment (i.e.  $\rho_1 = \rho_2$ ) can be tested using the standard F-distribution (Enders & Granger, 1998). The simple value of  $F = 5.409$  (MTAR, t-sig) has a P-value of 0.028<sup>4</sup>. Then the null hypothesis of symmetric adjustments is rejected at the 2.8 percent

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<sup>3</sup> The test statistics of t-sig and  $\Phi$  are obtained from Enders & Siklos (2001). In the TAR and MTAR tests : one-sided (lower-tail) test of the null hypothesis that the variables are not cointegrated; the 1, 5 and 10 percent critical values equal -2.30, -1.73 and -1.52, respectively.

<sup>4</sup> The MTAR model yields the best overall fit by comparing AIC-values and t-sig values. It is therefore preferable to the TAR model for explaining asymmetric adjustment of the real private investment margin. This implies that positive discrepancies from long-run equilibrium (such that  $\Delta \hat{e}_{t-1} \geq -0.135$ ) do adjust deviations less rapidly from long-run equilibrium. Therefore, a MTAR adjustment responds to the previous changes to the negative deviation (such that  $\Delta \hat{e}_{t-1} < -0.135$ ).

level of significance. In TAR and MTAR model with t-sig criteria, when we consider  $e_t$  or  $\Delta e_t$  as a shock to real private investment, this finding suggests that adjustment is asymmetric in the sense that negative shocks to the real private investment margin revert most quickly towards the attractor i.e. long-run equilibrium, comparatively to positive shocks which also tend to the attractor but less rapidly.

From the estimated equation in Table 3, we confirm that the adjustment process is no persistent toward equilibrium above the threshold parameter ( $\tau = -0.135$ ), whereas deviations from equilibrium are almost quickly eliminated below this threshold parameter. The adjustment process toward equilibrium above the estimated threshold is almost feeble in TAR comparatively to MTAR, and that there is relatively rapid convergence in MTAR below the estimated threshold. The results mean that long-run equilibrium relationship below the threshold parameter between the real private investment and real public investment among other explanatory variables is more stable with asymmetric adjustment and implies asymmetries in real public investment changes to private investment shocks or real private investment changes to public investment shocks.

#### **4 Conclusions**

This paper has investigated the equilibrium relationship between the private investment and public investment among others explanatory variables in the Saudi economy using the threshold cointegration method, which allows for asymmetric adjustment. The obtained results show an effective stability in the private investment efforts: that the decrease in public investment boosts private investment below threshold parameter. So, the adjustment process toward equilibrium above the threshold is no persistent, but very quickly reverting below the threshold. This outcome indicates the strength of the Saudi economy against the shocks and mostly negative shocks.

The results have shown that the long-run equilibrium relationship above and below the threshold parameter between the private investment and public investment is stable and reliable with asymmetric adjustment. This finding is important for public investment policies to control the extension of private investment and the private investment effort's fluctuations.

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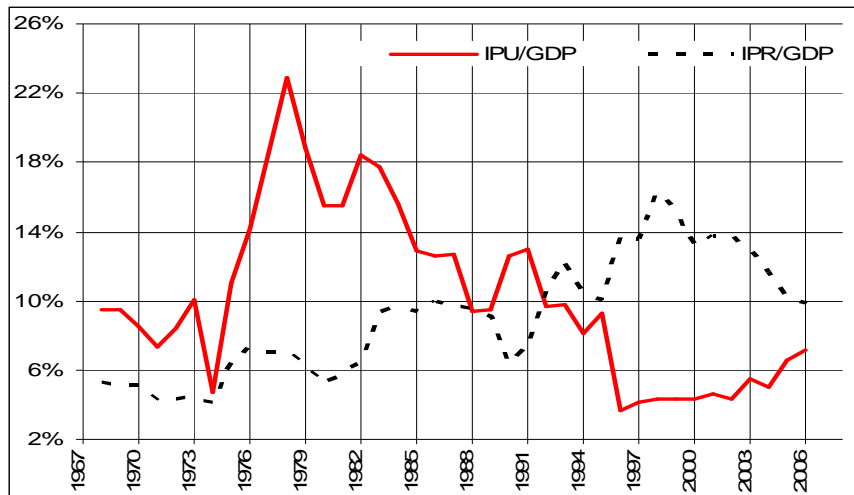


Figure 1: Private and Public Investment of GDP in Saudi Arabia

Table 1A: Unit root tests with constant and trend <sup>5</sup>

	LIPR	LIPU	LIBG	LGDP	LCRE	ucc
$ADF^{GLS}$	-1.526	-1.458	-1.547	-2.266	-1.558	-2.002
$\overline{MZ}_{\alpha}^{GLS}$	-2.887	-2.194	-2.908	-6.796	-4.026	-6.568

Table 1B: Unit root tests with constant

	$\Delta$ LIPR	$\Delta$ LIPU	$\Delta$ LIBG	$\Delta$ LGDP	$\Delta$ LCRE	$\Delta$ ucc
$ADF^{GLS}$	-4.249**	-1.780*	-2.211*	-2.065*	-4.209**	-3.113**
$\overline{MZ}_{\alpha}^{GLS}$	-16.301**	-4.906	-6.476 <sup>†</sup>	-6.874 <sup>†</sup>	-16.212**	-37.658**

<sup>5</sup> In all Tables †, \*, \*\* indicate significance at the 10, 5 and 1 percent levels, respectively. The Akaike Information Criterion (AIC) has better theoretical and empirical properties. In the ADF-GLS test: one-sided (lower-tail) test of the null hypothesis that the variable is nonstationary; at 1, 5 and 10 percent asymptotic critical values equal -3.46, -2.91 and -2.59, respectively when the model includes a constant and trend ; and equal -2.58, -1.98 and -1.62, respectively when the model includes only a constant (Rapach & Weber, 2004). For the Modified Phillips-Perron test: one-sided (lower-tail) test of the null hypothesis that the variable is nonstationary; at 1, 5 and 10 percent asymptotic critical values equal -19.95, -17.30 and -11.16, respectively when the model includes a constant and trend ; and equal -13.80, -8.10 and -5.70, respectively when the model includes only a constant (Ng & Perron, 2001).

Table 2: Cointegration tests (dependent variable: LIPR) <sup>6</sup>

	EG		PR=EG <sup>GLS</sup>	
	AIC	t-sig	AIC	t-sig
$\rho$	-0.0758	-0.0708	-0.5043*	-0.6769*
$\tau_\rho$	(-1.513)	(-1.515)	(-3.015)	(-3.123)

Table 3: Threshold cointegration tests (dependent variable: LIPR)

		$\rho_1 (\tau_{\rho_1})$	$\rho_2 (\tau_{\rho_2})$	$\Phi$ (P-Value)	$F$ (P-Value)	$\tau$
TAR	AIC <sup>†</sup>	-0.492** (-2.706)	-0.668** (-3.552)	9.061** (0.005)	0.510 (0.480)	-0.197
	t-sig	-0.837** (-2.895)	-1.348** (-4.520)	10.216** (0.004)	4.169* (0.051)	-0.197
MTAR	AIC	-0.473** (-3.111)	-0.858** (-3.628)	10.256** (0.003)	2.093 (0.157)	-0.135
	t-sig	-0.876** (-3.201)	-1.578** (-4.648)	11.171** (0.002)	5.409** (0.028)	-0.135

<sup>6</sup> In the EG's test: one-sided (lower-tail) test of the null hypothesis that the variables are not cointegrated; at the 1, 5 and 10 percent levels asymptotic critical values equal -4.02, -3.40 and -3.09, respectively (Rapach & Weber, 2004). In the PR's test: one-sided (lower-tail) test of the null hypothesis that the variables are not cointegrated; at the 1, 5 and 10 percent levels asymptotic critical values equal -3.33, -2.76 and -2.47, respectively (Perron & Rodriguez, 2001).