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Estimation of the Euler Investment Equation for Thailand

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Abtract. *This paper employs the dynamic Arellano-Bond GMM estimator to estimate the basic Euler investment equation of the type used by Bond and Meghir (1994) to investigate the role of cash flow, sales and indebtedness to firms' investment. The Euler investment equation includes both positive and negative investments. Thus, disinvestments can also be examined. The model is tested on firm-level panel data for a sample of selected companies in the Stock Exchange of Thailand for the period before the global subprime debt crisis. The results demonstrate that the important role of cash flow and sales in the determination of private fixed investment expenditure and show that indebtedness would have a negative impact on investment decisions.*

Keywords: *Capital Market, Euler Equation, Investment, Financial Constraint, Panel Data, JEL Classification: O16, C22, D21, E22, C23*

1. Introduction

This research uses an Euler investment approach to model an empirical model of firms' investment behaviour. The Euler investment equation derived from the first order condition for the capital stock has been increasingly used for modelling investment recently. Although econometric research on investment has extensively used aggregate data[1], this paper will not attempt to use aggregated data at the industry, sector or macroeconomic levels. Firm-level data of investment for a sample of selected companies in the Stock Exchange of Thailand for the period before the global subprime debt crisis are used to improve testing results. The pooling of cross sections and time series data significantly improves the way researchers quantify economic relationships between firms' investment and a number of firms' characteristics. Each type of series provides information lacking in the other, so a combination of both results in more accurate and reliable estimates than what would be achieved by one type of series alone.

There are very few studies on Thai firm-level investment. The most notable studies of these are those research works that are based on the comprehensive firm level data collected from a regional survey led by the World Bank of over 3000 manufacturing establishments in four East

[1] See Chirinko (1993, 1996) and Caballero (1999) for comprehensive surveys of recent work on aggregate investment.

Asian countries affected by the economic crisis in 1997: Indonesia, Korea, the Philippines, and Thailand for the period from 1996-1998.[2] Though the data set is much more comprehensive and provides much richer information for a comparative study of firm investment behaviour in the concerned countries, it provides a panel of data over much shorter period than the one used by the current research. Very few research results have been documented and they mainly try to explain the causes of the East Asian Financial Crisis in 1997 (See, for example, Claessens, Djankov and Xu 2000, and Dollar and Hallward-Driemeier 2000).

It is also worth mentioning another research on firm-level investment of the problem countries in the 1997 crisis, which is quite relevant to our research. Driffield and Sarmistha (2003) analyse the financial pattern of corporate investment in Indonesia, Korea, Malaysia, and Thailand using the Worldscope data-set for an unbalanced panel of listed firms during the period 1989-97.

Given the lack of research on firm-level investment in Thailand, the World Bank project and Driffield and Sarmistha (2003) are the only useful sources that can be used to compare with the results of our work. Driffield and Sarmistha (2003) examine firm investment behaviour before the 1997 Economic Crisis, and the World Bank project covers the period during and after the Crisis.

Arellano and Bond GMM dynamic panel data estimator is used to analyse our empirical models. This approach is attractive because the estimated Euler investment equation is based on explicit microeconomic foundations for investment behaviour (Bond and Meghir, 1994). Empirically, it has been applied mainly to panel data for individual firms (Blundell et al., 1992; Bolton, 2011; Hubbard, 1994; Leahy and Whited, 1996; Scaramozzino 1997, Bloom, 2009; Bloom et al., 2011), but there is no reason in principle why it cannot be used for pure time series aggregate data (Abel, 1984; Bachmann et al., 2013).

The following session analyses the basic Euler investment equation. Section 3 describes the collected data and estimated methodology. Session 4 provides the regression results and the final session concludes the research with implications for further research direction.

2. The Basic Euler Investment Model

The basic Euler Equation Model of the type used by Bond and Meghir (1994) is constructed on the basis of the net revenue function adjusted by a symmetric adjustment-cost function, which is linearly homogeneous in investment and capital. Imperfect competition is allowed with price elasticity of demand assumed to be constant and greater than unity. Adjustment cost is defined by the loss in total output. The net output function, specified by a constant return to scale production function net of adjustment cost, is linearly homogeneous in capital and labour.

[2] See Hallward-Driemeier (2001) for detailed description of the data set.

The specification of our model is very similar to that of Bond and Meghir (1994). The basic difference is the use of $\frac{I_{it}}{K_{it-1}}$ as the dependent variable instead of $\frac{I_{it}}{K_{it}}$. Thus, investment is normalised by fixed capital stock at the end of the previous period and other lagged independent variables are normalised by K_{it-2}. Lagged capital stock, used as a normalization factor, is also widely used in investment literature (see, for example, Scraramozzino, 1997). This choice of variables does not change the main regression results. Detailed derivation of the empirical model is given in Bond and Meghir (1994). For the sake of brevity, only the final empirical specification of investment without financial constraints is specified here as follows.

$$\frac{I_{it}}{K_{it-1}} = \beta_1 \frac{I_{it-1}}{K_{it-2}} - \beta_2 \left(\frac{I_{it-1}}{K_{it-2}}\right)^2 - \beta_3 \frac{CF_{it-1}}{K_{it-2}} + \beta_4 \frac{S_{it-1}}{K_{it-2}} - \beta_5 \left(\frac{B_{it-1}}{K_{it-2}}\right)^2 + d_t + v_i + \varepsilon_{it}$$

where β_i's, the estimated coefficients are assumed to receive positive values so that the associated signs are assumed by Bond and Meghir to be the correct signs by model construction. The coefficient on the lagged investment rate, β_1, is assumed to be positive and greater than one. The coefficient on the lagged investment squared is negative and greater than one in absolute value. The coefficient on lagged cash flows, $\frac{CF_{it-1}}{K_{it-2}}$, measured by the earnings plus depreciation, which is also assumed to equal the net output minus other variable input costs (labour), is assumed to be negative under the assumption of no financial constraints. Firms are not liquidity constrained and can raise as much capital as required at a given cost. Positive coefficient on cash flows would suggest the contrary, firms are liquidity constrained and marginal profitability is an important determinant of investment. The output term, $\frac{S_{it-1}}{K_{it-2}}$, controls for imperfect competition and is eliminated from the Euler equation under perfect competition. The coefficient on the output term should normally be positive and imply either imperfect competition or relax the homogeneous production function assumption for a decreasing production function. The debt term is included to control for the relationship between investment and borrowing decision. The coefficient on debt capital ratio squared is expected to be negative if bankruptcy cost is high. It can also be positive if tax-incentive is important. In the case of the Modigliani-Miller debt irrelevance, the coefficient is insignificant and can be eliminated.

Other factors that have not been included may have some impact on investment. For this model, the error component can be broken down into the time specific effect, firm specific effect, and common variation across firms over time. For example, the measurement errors caused by inflation or fluctuations caused by changes in interest rates and foreign exchanges over time, which are common to all firms, need to be controlled for. During a turbulent period, the fluctuations can be expected to be wide. Time dummies can be included to capture these time specific effects, d_t. Firm heterogeneity, characterised by factors such as firm size, capacity utilization, technology specific, liquidity constraints, etc. can be captured by υ_i, which is assumed to be independent and identically distributed (iid) over the individual firms with variance σ_υ^2. The combined variation over time and across firms in all factors not included in the specified model is captured by ε_{it}, which is assumed to have finite moments and to be iid over the whole sample with variance σ_ε^2.

Since the lagged values of the dependent variable are included in the right hand side, our model has a dynamic specification. Firm heterogeneity and endogeneity can be potentially problematic for model specification as the lagged values of the dependent variable included in the right hand side of our model is expected to correlate with the firm specific effects. υ_i and other independent variables are potentially correlated with υ_i as well. To reduce endogeneity, all independent variables have been lagged for one period so that the dependent variable in the following period cannot affect the independent variables of the previous period. Heterogeneity is reduced by dividing the dependent and all explanatory variables by total fixed capital. This specification is standard in investment literature. In addition, Arellano and Bond (1991) suggested transforming the original dynamic equation into first differences so that firm specific effects, υ_i, can be removed and the model can be estimated by instrumental variable.

3. Data Description

The Stock Market of Thailand is formed with a full-fledged institutional structure and accounting firm-level data are only available on Thomson Reuters Datastream in 1989. We choose the time frame before the global subprime debt crisis to avoid the impact of credit booming and investment surge just before the global crisis and prolong credit crunch and economic bust after the global crisis. The data collected include all 283 listed firms on the Stock Exchange of Thailand from 15 December 1989 to 15 December 2002, extracted from Thomson Reuters Datastream. After taking differences and lags, the data suitable for regression is reduced to a series of 9 periods (1994-2002). We include all firms but ones operating in banking, financial, and insurance sectors from the sample because we are interested only in fixed asset investment of firms operating in real sector. Lags, differences and adjustment for serial correlation also reduce the number of firms included. All the data including suspended firms are used to avoid loss of valuable information. The final sample includes 283 firms, with the total of 1980 observations for 9 years (1994-2002).

Table 1: Data Definitions and Descriptions

Variables		**Description**
S_{it}	Total sales	The amount of sales of goods and services to third parties relating to the normal activities of the company.
K_{it}	Total fixed assets – net	Net tangible fixed assets as shown by the company on the face of the balance sheet. It can include investment property if shown by the company as part of their tangible fixed assets.
D_{it}	Depreciation	Includes provisions for amounts written off, and depreciation of tangible fixed assets.
E_{it}	Earned for ordinary	Net profit after tax, minority interest, pre-acquisition profits and preference dividends attributable to ordinary shareholders. It is before any extraordinary items after tax.
B_{it}	Total Debt	The total of all long and short term borrowings, including any subordinate debt and 'debt like' hybrid finance instruments.
I_{it}	$= K_{it}-K_{it-1}$	Investment measured by the changes in total net fixed asset between two consecutive periods.
CF_{it}	$=E_{it} + D_{it}$	A measure of cash flows, which include the ordinary earning and Depreciation

Source: Thomson Reuters Datastream's Company Accounts

Our panel is highly unbalanced due to firms' entry and exit during the sampling periods. This phenomenon is very common especially with firm data. Unlike the panel data set collected by the World Bank after the 1997 Financial Crisis (Hallward-Driemeier, 2001), which may be heavily subject to survival bias, the use of unbalanced panel data allows the use of much larger sample and lessens the impact of self-selection of firms in the sample. Arellano and Bond GMM estimator can accommodate unbalanced panels with minor changes. For example, Arellano and Bond GMM estimator adjusts the instrument matrix for unbalanced data and missing observations by dropping the rows for which there are no data and zeros are filled in the columns where missing data would be required.

It is not easy to determine firm investment. Accounts data basing on balance sheets can only show the aggregate figures at the end of the fiscal year. It is not possible to differentiate different types of investments. Firms' attitudes towards new investment to increase capacity[3] and replacement investment to maintain current capacity are very different. New investment can be better defined using the net of new capital purchase and sale of existing capital minus the normal depreciation.

For our data set, data on sale of capital is not available so we opt for another approximate measure of investment. Investment is defined as the difference between the net fixed assets of two consecutive years. For the purpose of our research, we are more interested in the investment, which is likely to be irreversible. Therefore, working capital and current asset is not of great

[3] Capacity in our notion includes investments in new plants or the expansion of capacity of current plants

interest for our purposes. Capital expenditure in terms of fixed assets is appropriate to serve our goals. In Thomson Reuters Datastream, net fixed assets refer to the fixed assets net of normal depreciation so our investment measure takes only new investment to expand capacity into account. The explanatory variables chosen for our investment models are based on the evidence of previous company investment research using Euler investment equation. *Table 1* lists all the variables used in this study with their descriptions.

4. Empirical Findings

We use the dynamic Arellano-Bond GMM estimator to estimate the basic Euler investment equation of the type used by Bond and Meghir (1994). The study of firm investment behaviour, especially business fixed investment, is crucial to our understanding of economic activities. The Euler investment equation includes both positive and negative investments. Thus, disinvestments can also be examined.

Arellano and Bond (1991) developed a Generalized Method of Moments (GMM) estimator for dynamic panel data, which can be used to estimate the Euler investment model. The advantage of the Arellano-Bond GMM estimator is that the consistency of the estimates does not depend on first-order autocorrelation in the first-differenced idiosyncratic errors. However, the absence of second-order autocorrelation in the first-differenced idiosyncratic errors is still required to ensure consistency of the estimators.

Table 2 presents the estimated results using STATA's Arellano-Bond dynamic panel data estimator command. Both one-step and two-step estimates are reported for the basic Euler investment equations with and without time dummies. None of the regressions exhibit second-order autocorrelation. However, the one-step Sargan statistics do reject the overidentifying restrictions, which would pose specification issues. Fortunately, the Monte Carlo simulation results by Arrellano and Bond (1991) suggests a strong tendency for Sargan tests to reject too often in the presence of heteroskedasticity. The two-step Sargan statistics are insignificant and suggest the specification of our models is appropriate.

Table 2: Basic Euler Investment Equation

$\Delta \frac{I_{it}}{K_{it-1}}$	(a.i)† (one step)	(a.ii)† (two steps)	(b.i)†† (one step)	(b.i)†† (two steps)
$\Delta \frac{I_{it-1}}{K_{it-2}}$	.0760 (.0599)	.0761** (.0083)	.0953 (.0618)	.0947** (.0093)
$\Delta \left(\frac{I_{it-1}}{K_{it-2}}\right)^2$	-.0006 (.0005)	-.0006** (.0001)	-.0008# (.0004)	-.0008** (.0001)
$\Delta \frac{CF_{it-1}}{K_{it-2}}$	.0738* (.0310)	.0573** (.0048)	.0799* (.0332)	.0713** (.0059)

$\Delta \frac{S_{it-1}}{K_{it-2}}$	-.0519** (.0207)	-.0474** (.0024)	-.0517* (.0224)	-.0504** (.0027)
$\Delta \left(\frac{B_{it-1}}{K_{it-2}} \right)^2$	-1.38e-06 (1.84e-06)	-2.14e-06* (9.47e-07)	-4.08e-07 (1.65e-06)	-2.07e-06* (9.71e-07)
m_1	-2.25*	-2.13*	-2.26*	-2.13*
m_2	-0.45	-0.25	-0.01	0.02
z_1	22.21(5)**	684.28(5)**	12.14(5)*	616.93(5)**
z_2	36.37(7)**	204.50(7)**	-	-
Sargan	222.24(35)**	30.55	223.82(35)**	42.86

(** Significance at 1%; * Significance at 5% level; # Significance at 10% level)

† Time Dummies are included; †† Time Dummies are not included

Sample: Period: 1994-2002; Number of firms: 283; Total number of observations: 1980 (Unbalanced panel; some observations are missing due to firms enter and exit, some others are lost in regressions due to lags and differences)

Estimated using Arellano and Bond GMM estimator: Basic instruments: $\frac{I_{it-2}}{K_{it-3}}$, $\left(\frac{I_{it-1}}{K_{it-2}}\right)^2$, $\frac{CF_{it-1}}{K_{it-2}}$, $\frac{S_{it-1}}{K_{it-2}}$, $\left(\frac{B_{it-1}}{K_{it-2}}\right)^2$ (under assumption of strictly exogenous covariates, see Arellano and Bond (1991) for detail). Heteroskedasticity-robust standard errors in brackets except for two steps, where the usual standard errors are reported. m_1 and m_2 are Arellano and Bond tests for first-order and second order serial correlation in the residuals of first differences, asymptotically distributed as $N(0,1)$ under the null hypothesis of no serial correlation. $z_1(k)$ is a *Wald* test of joint significance of the reported coefficients while $z_2(k)$ is a *Wald* test of joint significance of the time dummies, both asymptotically distributed as $\chi^2(k)$ under the null hypothesis of no relationship. *Sargan* is a test of the overidentifying restrictions, asymptotically distributed as $\chi^2(k)$ under the null hypothesis that over-identifying restrictions are valid. The reported *Sargan* is obtained without general heteroskedasticity option for the Arellano and Bond command in STATA as the Sargan statistics is only valid in the case of iid errors and is not asymptotically robust to general heteroskedasticity. *Sargan* test over-rejects in the presence of heteroskedasticity. Arellano and Bond recommend using one-step results for inference on coefficients.

Comparing the one-step and two-step estimated coefficients, we can see that they are quite similar and the asymptotic standard errors associated with the two step estimates are generally much lower than those associated with one-step estimates. Arrellano and Bond (1991) suspect the improvement in precision may reflect a downward finite-sample bias and suggest using the one-step estimates for inference. Thus, in subsequent regressions, we will only report the one-step estimates with their White adjusted robust stand error estimates. The Sargan tests are reported at the end of each table for inference on the specification of the models.

Columns (a) and (b) of the table give the estimation results for the basic Euler equations with and without time dummies. The results are very similar for the two equations, except that all estimated coefficients tend to be biased upwards, showing partly the growing trends that are normally present in time series data, and partly, the adjustment for inflation.

Except for the estimated coefficient on the output term, represented by the ratio of total sales to capital stock, all other coefficients have the same sign as reported coefficients in Bond and Meghir (1994). However, most of the estimates are insignificant. Debt is irrelevant both in the present model and all other subsequent regressions. The non significance of the lag of investment capital ratio and its squares is surprising, which may suggest high correlation among explanatory variables or model specification. Both coefficients on cash flow and output are incorrectly signed as compared to theoretical specification. The positive coefficient on cash flow is however consistent with other empirical findings, suggesting liquidity constraints can be an important factor on firm investment (or disinvestments) decisions. Firms rely on cash flows to finance their investments and profitability will lessen its reliance on external finance. Negative coefficient on the output term is difficult to explain. It can suggest indications of either over-investment (if sales decline) or under-investment (if sales increase) or technology heterogeneity in production functions among firms. If none of these are true, then misspecification is suggested.

5. Concluding Remarks

We have developed an investment model for a sample of Thai listed firms on the Stock Exchange of Thailand over the period from 1994-2002. Like other research, notably Bond and Meghir (1994), Blundell *et al* (1992), Leahy and Whited (1996), Scaramozzino (1997) and others, we use the full sample of all firms but ones operating in banking, financial, and insurance sectors with available data using the Arellano-Bond GMM dynamic panel data estimation method.

Two factors found significant for the basic Bond and Meghir's Euler equation and its extension are cash flows, sales. Cash flows are also documented to be positive and significant in other research (Bond and Meghir, 1994), indicating liquidity constraints and profitability. However, the negative significant coefficient on sales has a wrong sign and is difficult to interpret. An explanation that can be offered is that, during our testing period, the capacity utilisation of firms in Thailand is very low and firms have the tendency to disinvest regardless of sales position.

During the sample period, the Thai economy experienced the hardest ever economic crisis in the region in 1997 and studies by the World Bank (Dollar and Hallward-Driemeier, 2000; Hallward-Driemeier, 2001) suggest average low capacity utilisation. Thus, disinvestments should prevail either through actual sales of capital goods or the postponement of scheduled investment to wait for further market information. Firms are adverse to immediate investment at a given level of uncertainty. High uncertainty may induce firms to wait further before committing to new investments. In fact, the market turmoil during this period can be a factor that discouraged investments. On the contrary to the findings of Driffield and Sarmistha (2003), who examine firm investment behaviour in Thailand during the period before the 1997 Economic Crisis and find evidence of overinvestment, our findings suggest uncertainty depresses investment. Firms, *ceteris paribus*, make less investment than it otherwise would do. However, the period that is examined by Driffield and Sarmistha (2003) is immediately before our sampling period; firms therefore may adjust from high overinvestment to a lower investment level during the period characterised by high uncertainty.

In conclusion, it can be said that there are always various different approaches that can be used to explain the way firms make their investment decisions. The findings of this research are significant in that they have helped to develop a robust empirical investment model for Thailand, which will serve as a benchmark for future research on investment in Thailand, a task that hardly anyone was interested in before the onset of the East Asia Financial Crisis in 1997.

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