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Modelling and Forecasting Investment in Korea for Policy and Crisis Studies: A New Multisectoral Approach

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The paper first briefly surveys empirical work on Korea's investment. It then presents the basics of a new and flexible approach to econometric modelling of the activities of multi-sectoral open economies (Tran Van Hoa, 1992) and applies it to study private investment in Korea during the period 1970-1998. The paper then describes the fundamentals of the new two-stage hierarchical information (2SHI) estimation and forecasting theory (Tran Van Hoa, 1985, 1986a, 1993b, Tran Van Hoa and Chaturvedi, 1988, 1990, 1997) and establishes its universally superior forecasting *MSE* properties for the linear model with 2 or more independent variables and reports substantive empirical findings on elasticity estimates and ex-post forecasts of Korea's private investment over three decades including its sharp GDP downturn during the Asia crisis of 1997. Brief discussions on the foundation of current alternative estimation and forecasting methodologies in economic modelling and policy uses, on the significance of our empirical findings, and a critical comparison with results obtained from other well-known forecasting methods such as the OLS, the maximum likelihood and the positive-part Stein (or empirical Bayes) will also be provided.

JEL Classification: C3, C5, E2, F1, F3

Keywords: modelling, forecasting, investment, multi-sectoral models, MSE, Wald risks, ex-post forecasting evaluation OLS and ML, Stein estimators, 2SHI estimators, informational dominance

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1. INTRODUCTION

The standard theories of economics, international finance, transnational corporations, and within the accounting framework of the United Nations System of National Accounts (SNA) stipulate that investment plays a crucial role in influencing microeconomic decisions and macroeconomic activity, national output growth and economic development, and in shaping fiscal and monetary policy (Dornbusch and Fischer, 1990) and economic reforms in many developed, newly industrialized and especially developing countries (World Bank, 1991). Corporate and private strategies for business development and expansion in a home or host economy depend on this crucial role in a Wiener-Granger causal sense. As a result, a rigorous study and discussions of the movements or trends of these economic aggregates and their empirical relationships either in a historical context or in future predictions are amply justified. In Korea, there were 2 distinct subperiods of investment fluctuations: the fairly stable pre-1990 and the widely unpredictable post-1990 (see ICSEAD, 2001). These observed structural breaks could be attributed to external pressure and subsequent capital market liberalisation in the country by the end of 1980s. And this would make econometric modelling and accurate forecasting for Korea's investment trend and pattern in the past two decades or so more acute and challenging.

The purpose of our paper is threefold. First, it contributes to macroeconomic analysis in general and to international business, financial studies, transnational corporations, development economics and investment strategies in major Asian economies particular. It does this by rigorously investigating the causal structure and empirical forecasts of a major SNA macro aggregate, namely, investment, in a major Asian newly industrialized economy (NIE) and the second Asian member of the OECD, Korea. Once a causal effect has been established, remedies may be found for restoring investment to a level conducive to promotion of growth and other activities dependent on investment. The testable causal structure is based upon the conventional dynamic multi-equation multi-sectoral Keynesian theory and the SNA data framework.

The second purpose is methodological in nature in that the paper departs from the applied econometric modelling approaches using conventional multiple regressions, simultaneous equations, or seemingly unrelated regressions, and makes use of a fairly simple and flexible economy-wide multi-equation modelling approach. This approach is based on the calculus of differential analysis in economics (Tran Van Hoa, 1992a, 1992d) to provide the fundamental equations in the reduced form for better estimation and forecasting of investment (or other endogenous variables) in the model. The success of this new approach is further assessed via its modelling and forecasting performance.

Finally, the paper contributes to important practical applications of recent advances in the statistical theory of forecasting to better formulating forward planning policies and strategies in finance, economics, and business in a major NIE, namely Korea. It does this by providing forecasts of Korean private investment based on the empirical Bayes or hierarchical information theories (Tran Van Hoa, Tran Van Hoa, 1985, 1986a, 1993b, Tran Van Hoa and Chaturvedi, 1988, 1990) under different plausible scenarios, and comparing them to other conventional methods. More specifically, the ex post performance (or accuracy) of these forecasts in the context of average mean squared forecasting errors (MSE) or Wald risk criteria is then evaluated against more traditional forecasts based on the ordinary least squares (OLS), the maximum likelihood, or the explicit (Baranchik, 1973) positive Stein-like (Anderson, 1984) methodologies.

The implications from our paper's findings are fourfold. First, they provide empirical evidence on whether our method is conceptually more appropriate to studying major economic activities and engines of growth such as investment (domestic and foreign). Second, while the 2SHI is, in theory, universally superior to other conventional methods (OLS, ML, Stein) for a linear model with 2 or more regressors, the paper provides numerical evidence on the improved accuracy of our new forecasts of Korea's investment for better investment policy uses. Third, if the modelling and forecasting success of our approach is relatively superlative – in terms of its empirical fit and accurate turning-point predictions – its superiority is further enhanced. Fourth, if, based on the same model and dataset, a substantial improvement is achieved by the 2SHI method in relation to other conventional procedures currently in use, then our findings will, in addition, point to a new direction of rigorous forecasting methodology for finance, economics, and business analysts in their everyday or long-term strategic corporate and individual planning applications to investment or other endogenous activities of interest in the model.

2. MULTI-SECTORAL ECONOMETRIC MODELLING OF INVESTMENT IN KOREA

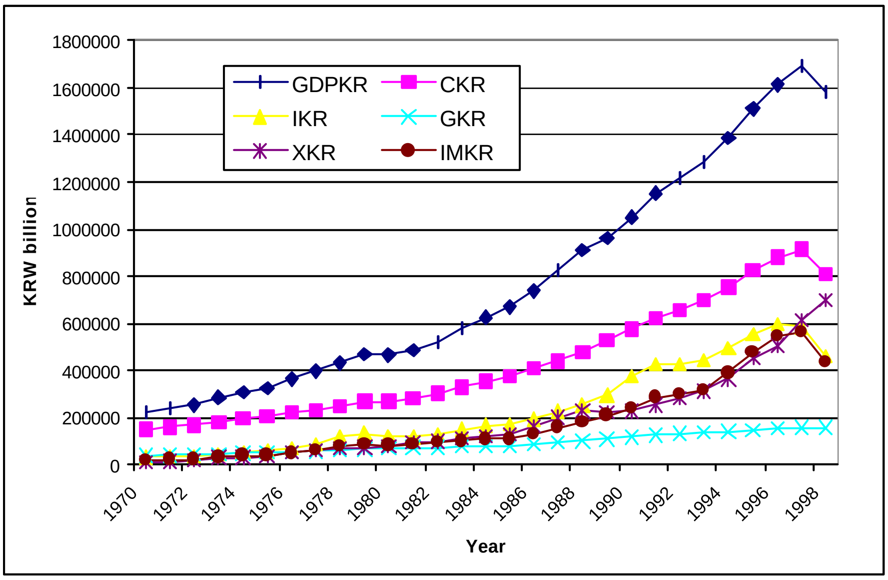
The annual movements of Korea's main macro aggregates: GDP, private consumption, gross fixed investment, government expenditure, exports, and imports (all at 1995 prices), are depicted in the Figure 1 below. The Figure shows a very strong trend in all but one variables under study, starting at the take-off stage in 1970 and peaking in 1996 for investment and in 1997 for GDP, consumption, and imports. All these activities show a very sharp decline even in aggregates in 1998 as a result of the 1997 Asia crisis. Exports and government expenditure continued, on the other hand, to grow for the whole 30 years but the latter at a lower stationary rate. The low proportion of government expenditure to GDP especially in the recent years, reveals the lesser part (share) the Korean government had been playing in the economy. Suddenly high volumes of exports were achieved for 1980 (before the second oil crisis) and 1991-92 after market liberalisation.

Modelling and forecasting Korea's investment poses a real challenge for a number of reasons. First, in Korea, the pace of deregulation of international capital flows proceeded in manner closely linked to macroeconomic developments. The government had always been reluctant to allow liberalisation of Korea's financial system to move too fast, fearing that an inflow of foreign funds would push up the nominal and real exchange rates and undermine competitiveness with its trading rivals (Smith, 1998). Three principal changes (the limit on foreign ownership raised to 15%, borrowings for capital good imports permitted, and constraints on the ownership of foreign currency deposits eased) between 1993 and 1995 however were responsible for net capital inflow explosion (as mentioned earlier). Second, despite progress in the deregulation of capital flows, Korea's regulations remained extensive for a country whose share of international trade was very large. Third, there were two great crisis turning points in investment statistics in Korea during 1981-2000 (late 1989 and 1997) attributed by some authors to the yen appreciation, trade friction between Japan an Asian NIEs and the US and the European Union, and increasing wages in Japan and the Asian NIEs (Seo and Suh, 1999).

The challenging situation above (and other economic, non-economic or policy factors) may have explained why studies of Korean investment have been limited in number, scope and methodologies. For example, most of previous studies on Korea's investment were either focused on a macroeconomic or microeconomic analysis of a descriptive kind (eg, Smith, 1998, Kwon and Suh, 2001, and Asian Development Bank, 2001) or on modelling, by a single equation approach, the impact of foreign direct investment on trade or growth from the OLI (ownership-location-internalisation) theoretical underpinning of Dunning and other authors (eg, Seo, 1998, and Seo and Suh, 1999). Studies on Korea's investment and even on Korea's economy were not even covered in the 1999 OECD country member report. In view of this neglect and also of Korea's importance in world economy and world trade under increasing globalisation however, a serious study of its investment in a multi-equation multi-activity framework is fully justified.

It is well known that an empirical study of the Korean economy's major activities (such as investment) can involve a descriptive analysis of the graphs of these macro aggregates, their means and standard deviations, their shifts over time, and their turning points and cycles. But a study involving the interaction between investment and the other major economic activities in the Korean economy is more realistic and therefore more appropriate. We adopt the economy-wide multi-sectoral approach because, first, of the inherent Marshallian nature of economic activities in which all are interrelated or interdependent as they should be, and second, of the now well-known Haavelmo theorem on simultaneous-equation inconsistency and bias.

Figure 1 Major Trends in Korea's Economy in 1970-1998



Source: World Bank World Tables (2000).

In an economy with interdependent sectors and activities, investment could be argued to be dependent on many varied internal and external, economic and non-economic factors in a linear, nonlinear, or mixed form. Consider for illustration in this paper a simple well-known generic five-equation Keynesian macroeconomic model of the Korean economy in the linear form as

$$C_t = \alpha 11 + \alpha 12 Y_t + \alpha 13 C_{t-1} + u1_t \quad (1)$$

$$I_t = \alpha 21 + \alpha 22 Y_t + \alpha 23_{t-1} + \alpha 24 R_t + \alpha 25 R_{t-1} + u2_t \quad (2)$$

$$X_t = \alpha 31 + \alpha 32 Y_t + \alpha 33 YW_t + \alpha 34 PW_t + \alpha 35 XR_t + u3_t \quad (3)$$

$$IM_t = \alpha 41 + \alpha 42 Y_t + \alpha 43 YW_t + \alpha 44 PW_t + \alpha 45 XR_t + u4_t \quad (4)$$

$$Y_t = C_t + I_t + G_t + X_t - IM_t \quad (5)$$

where *C* = private final consumption expenditure, *Y* = gross domestic product or GDP, *I* = private gross fixed investment, *G* = government expenditure, *X* = exports of goods and services, *IM* = imports of goods and services, *YW* = US income (as a proxy for world income), *PW* = general price deflator in the US (as a proxy for world prices), and *R* = US prime rate (as a proxy for world interest rate). The a's denote the structural parameters, and the *u*'s the error terms. All value variables are expressed in terms of their constant 1995 prices, therefore filtered of the inflationary effect.

The model (1)-(5) is a simple dynamic macroeconomic model (Pindyck and Rubinfeld, 1991) for an open economy and takes into account (a) a partial adjustment process in consumption behaviour encompassing the hypotheses of relative and permanent income, liquid assets, wealth, and life cycles in the sense of Duesenberry, Friedman, and Modigliani, (b) a flexible accelerator investment behaviour, augmented by foreign capital borrowings (see for further detail Tran Van Hoa and Harvie, 2000) and user's costs, (c) trade openness through exports and imports regulated by foreign and domestic demand conditions and price relativities (via the exchange rates) and (d) relevance of the government sector expenditure (a feature prominent in many contemporary Asian economies).

In the model, consumption, investment, exports, imports and GDP are endogenous, and there are 9 exegoneous and predetermined variables.

It can be verified that, using the order condition for identifiability or mathematical consistency in the theory of econometrics, the investment equation (2) in the model is over-identified. As a result, it can be written, instead of its linear form given traditionally in (1)-(5), in its complete differential form (see Allen, 1960) in the reduced form as (see Tran Van Hoa, 1992a and 1992d, Harvie and Tran Van Hoa, 1993)

$$I\%_t = a11 + a12C\%_{t-1} + a13Y\%_{t-1} + a14\%_t + a15\%_{t-1} + a16YW\%_t$$

$$+ a17PW\% + a18XR\% + a19G\%_t + e1_t \tag{6}$$

where *I*%, *C*%, *Y*%, *R*%, *YW*%, *PW*%, *XR*%, and *G*% indicate the rate of change of *I*, *C*, *Y*, *R*, *YW*, *PW*, *XR* and *G* respectively. The *a*'s indicate the reduced form parameters, and e1 is the new error term.

Equation (6) characterizes the investment relationship from the five-equation macroeconomic model given in Eqts (1)-(5). By conventional definition, the parameters from this equation are in fact either static (or dynamic) elasticities associated with either current (or lagged) variables included in it.

The derivation of (6), based on the total differentiation of an arbitrarily functional relationship, is simple and, more importantly, consistent with the procedure usually adopted for the neoclassical macroeconomic models of the applied or computable general equilibrium Johansen kind. In these neo-classical models, the endogenous and exogenous variables in the economy are linked by *a* (usually first order) approximate transmission mechanism in terms of the elasticities. There are however at least five important differences between our investment equation given in (6) above and the investment specification from applied or computable general equilibrium Johansen-class models

First, in our case, the important linking elasticities have to be estimated for the model as a whole using economic time series data and possibly other extraneous (prior) information such as policy switches or external non-economic factors. Our equation given in (6) thus is completely data-based, although clearly we do not preclude the use of prior or extraneous information (in the form of an oil or financial crisis or a major war for example) in the equation in other theoretical or judgemental contexts.

Secondly, in view of the above arguments, our model is capable of accommodating sub- and add-factors as well as structural change and other institutional considerations (for a discussion supporting the use of these factors in macroeconomic models, see Johansen, 1982).

Thirdly, our equation must be mathematically consistent as required by the identifiability conditions for complete systems of structural simultaneous equations in the theory of econometrics.

Fourthly, by its construct, our modeling approach encompasses a wide class of linear, nonlinear or mixed multi-equation econometric models in which the exact functional form of each of the individual structural equations is, as usual, unknown or needs not be specified.

Finally, for an important group of economic variables whose first differences in logs are approximately equivalent to the rates of change, our equations by their construct include as the special cases the Granger-Wiener short term causality if these rates of changes are $I(0)$ and the co-integration or long-term equations of the Engle-Granger (1987) class (see Tran Van Hoa, 1993c, and Harvie and Tran Van Hoa, 1993, for further detail) if the rates of change are $I(1)$. Our approach also avoids the awkward situation of using log-changes in applied econometric studies encountered by many econometricians when the variables involve measurements of deficits (eg, government budget) or negative current account in national accounts or negative real rates of interest (nominal rate of interest is lower than inflation rate) in finance.

To evaluate the performance of (a) the investment equation in this macroeconomic model and (b) our forecasting methodology using official data from Korea in recent years, we have fitted the equation (6) to data for the period 1970 to 1998, covering the damaging Asia crisis of 1997. This will optimally produce the necessary elasticity estimates. These estimates are then used in a comparative study, which is based on stochastic simulation to measure the relative *MSE* performance or operational accuracy of our modelling investment equation and also of our new forecasting approach in relation to other current methodologies. The new methodology and its well-known characteristics are briefly described below.

3. ALTERNATIVE METHODOLOGIES IN ESTIMATION AND FORECASTING

The investment equation in differential and reduced form as given in (6) can be written more generally with a sampling size T and k independent variables (possible causes) in matrix notation as

$$\underset{(Tx1)}{y} = \underset{(Txk)}{Z} \underset{(kx1)}{ß} + \underset{(Tx1)}{u} \tag{7}$$

where y = I% or Y%, Z = the rate of changes of the exogenous and predetermined variables (both static and dynamic), $\boldsymbol{b}$ = the parameters, and u the disturbance satisfying all standard statistical assumptions.

To estimate (7) which is essentially a general linear model (7) for structural or behavioral analysis or for direct forecasting and policy analysis (see Pindyck nd Rubinfeld, 1991), we can use the OLS, or, at a more efficient level, any of the explicit (Baranchik, 1973) Stein or Stein-rule methods as described below.

More specifically, using (7), the basic and most well known method to produce estimates and forecasts of y (or I %) is the OLS estimator of $\boldsymbol{b}$ (denoted by b) and is written as

$$b = (Z'Z)^{-1}Z'y \tag{8}$$

A more sophisticated and efficient method is the explicit Stein estimator of $\boldsymbol{b}$ (Baranchik, 1973) that is given by

$$\boldsymbol{b}s = [1 - c(y - Zb)'(Y - Zb)/b'Z'Zb]b = [1 - c(1 - R^2)/R^2]b \tag{9}$$

where c is a characterizing scalar and defined in the range $0 < c < 2(k-2)/(T-k+2)$, and R^2 is the square of the sample multiple correlation coefficient.

A still more efficient method is the explicit positive-part Stein estimator of $\boldsymbol{b}$ (Anderson, 1984) which is defined as

$$\boldsymbol{b} + s = [1 - \min\{1,\ c(y - Zb)'(y - Zb)/b'Z'Zb\}]b$$

$$= [1 - \min\{1,\ c(1 - R^2)/R^2\}]b \tag{10}$$

A new method to obtain estimates and forecasts of b in (7) with better properties has been proposed (see Tran Van Hoa, 1985, Tran Van Hoa and Chaturvedi, 1988 and 1990). It is in a class of explicit improved Stein-rule or empirical Bayes [also known as two-stage hierarchical-information (2SHI)] estimators for some linear regression models. This estimator includes the explicit Stein and the double k-class (Ullah and Ullah, 1981) estimators as subsets (Tran Van Hoa, 1993b). Other applications of the Stein, Stein rule, and 2SHI estimators to linear regression models with non-spherical disturbances and to Zellner's seemingly unrelated regression model have also been made (see Tran Van Hoa *et al.*, 1993a, in the case of regressions with nonspherical disturbances, and Tran Van Hoa, 1992b, and 1992d, in the case of seemingly unrelated regressions).

The explicit 2SHI estimator is defined as

$$bh = \left[1 - c(1-R^2)/R^2\right\} - c(1-R^2)/\left\{R^2(1+c(1-R^2)/R^2\right\}\Big]b \qquad (11)$$

and its positive-part counterpart (Tran Van Hoa, 1986a) is given by

$$b+h = \left[1 - \min\left\{1,\ c(1-R^2)/R^2\right\} - \left\{1/\left((R^2/c(1-R^2))+1\right)\right\}\right]b \qquad (12)$$

While all the estimators given above can be applied to the general linear model (7) for structural and forecasting analysis, their relative performance in terms of historical, ex post or ex ante (Pindyck and Rubinfeld, 1991) forecasting *MSE* can differ. Thus, it is well-known that, in *MSE* and for $k \geq 3$ and $T \geq k + 2$, bs dominates (that is it performs better in forecasting *MSE*) b, and bs is dominated by $b+s$ (Baranchik, 1973; Anderson, 1984). However, it has also been demonstrated (Tran Van Hoa, 1985; Tran Van Hoa and Chaturvedi, 1988) that, in *MSE*, bh dominates both b and bs, and more importantly, $b+h$ dominates $b+s$ (Tran Van Hoa, 1986a).

A further important path-breaking result of the 2SHI theory has recently been proved (see Tran Van Hoa and Chaturvedi, 1997): the dominance of the 2SHI over the OLS and Stein exists anywhere in the range $0 < c < 2(k\text{-}1)/(T\text{-}k)$. This indicates that the 2SHI method produces better (in terms of smaller Walk risk or generalized Pitman nearness) estimates and forecasts even if the estimating and forecasting equation has only one independent variable in it. *The condition for the optimal Stein dominance in the linear equation up to now requires that* $0 < c < 2(k-2)/(T-k+2)$ (see Anderson, 1984).

While some application of these forecasting methodologies to predictions of economic activity in some developed countries such as Australia (see Tran

Van Hoa, 1992d) has been made, the extent of the significance of the *MSE* dominance, or equivalently, the informational gain or relative forecasting success between the alternative estimators above has not been investigated explicitly within an open trade theoretical framework and an empirical context using more recent economic data for the major economies in East Asia. This issue is taken up in the study below for one of the fastest growth economies in the world in recent years but with highly fluctuating investment and being very sensitive to foreign trade and capital flows in the region (see Tran Van Hoa and Harvie, 2000).

Another interesting feature of our study is that, since all data are annual and have as usual a small sample size, our study is therefore designed to look at the finite sample performance of alternative forecasting methods.

Finally, since the poor quality of economic data from the Asian countries and other less developed countries (LDC) economies is well known, one by product of our study is that we in fact investigate the performance of the alternative forecasts in the case of serious measurement errors on the variables of the macromodel of an economy however it is defined.

The substantive findings for Korea's investment reported below are based on the five-equation macroeconomic model described earlier in (1)-(5), and the appropriate estimating equation to produce elasticity parameters or the forecasting equation to produce policy impact is given in (6) for investment. In addition, a number of well known forecasting methods that are currently popular among quantitative economists is used to compare their relative performance for decision analysis.

4. ALTERNATIVE FORECASTS AND THEIR PERFORMANCE

In our study, we have fitted the investment equation as given in differential and reduced form (6) of the model (1)-(5) to annual official data collected for Korea. The original dataset is from 1960 to 1998, but the effective (i.e., after allowing for missing or statistically incompatible data) sample period is 1972 to 1998, giving, when the dynamic (lag) structure is taken into account, a sample size of up to 27 observations for each variable. In our comparative study, only the OLS or ML, the positive-part Stein, and the positive-part 2SHI forecasts of Korea's investment are used.

The data are in real terms at the constant 1995 prices and obtained from the 2000 World Bank World Tables OECD and East Asia databases, using Australia's data express (DX) extracting and transforming procedures. The performance of our reduced form investment equations is determined solely from their goodness of fit, correct turning point predictions and ex post forecasting *MSE*.

Other research strategy of our study includes a number of important features:

First, to investigate the possible accuracy improvement or informational gain under different situations from the data, the ex post forecasts (Pindyck and Rubinfeld, 1991) of investment from our macroeconomic model are derived rather pragmatically, for a lack of larger samples, for 2 (short term), 4 (medium term) and 6 (long term) years only ahead. These are called Subsamples 1, 2, and 3 respectively. In other words, for our investment equation which has 27 annual observations and 9 elasticity parameters to be estimated, the ex post forecasts are made respectively 2, 4 and 6 years ahead from 1992. The consistency of our ex post forecasts (which are based on the same historical simulation period), if existent, describes to some extent the possible presence of rationality (ie, the forecasts match the data generating process) in our forecasting investment equations.

Secondly, for each of these subsamples, the *MSE* of the forecasts from (6) is computed from a stochastic simulation and is based on 100 (smaller or larger simulations yielded similar results) statistical trials. In stochastic simulation, both the estimated parameters and the disturbances are allowed to vary from trial to trial (see Pindyck and Rubinfeld, 1991, for further detail). The distributions used to generate these parameter and disturbance trial-to-trial variations are based upon their OLS-based (Monte Carlo) sample distributions with 500 repetitions.

Finally, in the case of the disturbance or error term distribution, the simulation for each subsample takes respectively the value of s^2, $10s^2$, and $100s^2$, where s^2 is the sample disturbance variance. This strategy is adopted to investigate the impact of the size of the disturbance variances (or the size of the measurement errors on the possible causes or the misspecification of the investment function) on the relative performance of the various forecasting methodologies in our investment equation. This kind of analysis is particularly applicable to data from the LDCs, as is well known.

Thus, in our empirical study, the ex post forecasting *MSE* is obtained, by stochastic simulation, for a total of 9 sets of investment forecasts in differential and reduced form, different from each other in terms of the forecasting sample size and $\boldsymbol{s}^2$ (the disturbance variance).

The relative performance of the OLS, positive-part Stein $\boldsymbol{b}+s$, and positive-part 2SHI $\boldsymbol{b}+h$ estimators for each of these equations and for

Korea between 1992 and 1998 is given in Table 1. Relative performance between say the OLS and the positive-part Stein is defined formally as $R(b/\boldsymbol{b}+s)=100[MSE(b)/MSE(\boldsymbol{b}+s)-1]$, and dominance or informational gain in ex post forecasting *MSE* of $\boldsymbol{b}+s$ over b exists whenever ex post forecasting $R(b/\boldsymbol{b}+s)\geq 0$, with equality somewhere in the parameter space. Similar results are used for other comparisons $R(b/\boldsymbol{b}+h)$ and $R(\boldsymbol{b}+s/\boldsymbol{b}+h)$.

It can be further verified that, for the forecasting equation of the functional form defined in (6) or (7), when historical and future values of Z (the possible causes) are known, dominant ex post forecasting *MSE* implied dominant ex ante forecasting *MSE. This extension is useful for policy analysis into the future.*

For ex post forecasting, the relative performance of the OLS, $\boldsymbol{b}+s$, and $\boldsymbol{b}+h$ estimators for each of these models is also expressed in terms of its standard criteria such as mean per cent errors, RMS per cent errors, and per cent improvement in ex post forecasting *MSE* or informational gain (see Pindyck and Rubinfeld, 1991). Only the informational gain or forecasting accuracy improvement is given in Table 1.

The relative performance in ex post forecasting *MSE* between say the OLS-based forecasts and the positive-part Stein-based forecasts, as reported in Table 1, is in fact defined as

$R(b/\boldsymbol{b}+s)=100[(MSE(yb-y)/MSE(ys-y)-1)]$ with $MSE(yb-y)$

Table 1 Improved Modeling and Forecasting Investment in Korea Results of Stochastic Simulation, 1972-1998

Average R^2									
	0.873	0.706	0.710	0.863	0.728	0.736	0.865	0.746	0.724
OLS-based disturbance variance or measurement errors									
	$s1^2$		***$s2^2$***		***$s3^2$***				
	83.1579		831.579		8315.79				
Estimation period	1972 to 1992								
Forecasting period									
	1993 to 1994 (short term)			1993 to 1996 (medium term)			1993 to 1998 (long term)		
	$\sigma1^2$	$\sigma2^2$	$\sigma3^2$	$\sigma1^2$	$\sigma2^2$	$\sigma3^2$	$\sigma1^2$	$\sigma2^2$	$\sigma3^2$
Ex Post Forecasting Relative MSE – Informational/Accuracy Gain (%)									
R(ML/S)	18.76	50.30	42.00	17.80	49.76	40.96	21.24	47.19	43.69
R(ML/H)	39.23	96.54	89.54	37.21	106.5	92.08	44.88	105.4	93.78
R(S/H)	17.23	30.76	33.48	16.48	37.92	36.26	19.50	39.59	34.86

Note: *b*=OLS, *ßs*=positive-part Stein (STEIN), *ßh*=positive-part 2SHI. *R*(*ml*/*s*)=*R*(*b*/*ßs*)= 100[*MSE*(*b*)/*MSE*(*ßs*)-1], where *MSE*(*b*) = *E*(*b*-*ß*)'(*b*-*ß*) with *ß* calculated from the OLS estimates of each equation using 500 repetitions (with the error terms only random from trial to trial), and used as the true parameter vector. Similarly for *ßh* and *ßs*, i.e., *R*(*ml/h*)=*R*(*b*/*ßh*) and *R*(*s*/*h*)=*R*(*ßs*/*ßh*). Relative efficiency in ex post forecasting *MSE* of say *ßh* over *ßs* exists whenever *R*(*s*/*h*) = *R*(*ßs*/*ßh*) ≥ 0. σ^2 = OLS-based disturbance variance. In our stochastic simulation study, all results are based on 100 statistical trials and c is arbitrarily set $c = (k-2) / (T-k+2)$. All data are from the 1997 World Bank World Tables *DX* database. For the derivation of the *I*% equation above, see (6) in text. The parameter estimates of this equation are obtained, as the mean parameters from 100 stochastic simulations with the equation variances equal the actual residual variance σ^2.

being the *MSE* of the forecasting errors based on the OLS estimates, and $MSE(ys - y)$ being the *MSE* of the forecasting errors based on the positive-part Stein. The calculation of $MSE(yh - y)$ is similar.

5. DO WE GAIN MORE FORECASTING ACCURACY FOR BETTER POLICY ANALYSIS ON INVESTMENT IN KOREA?

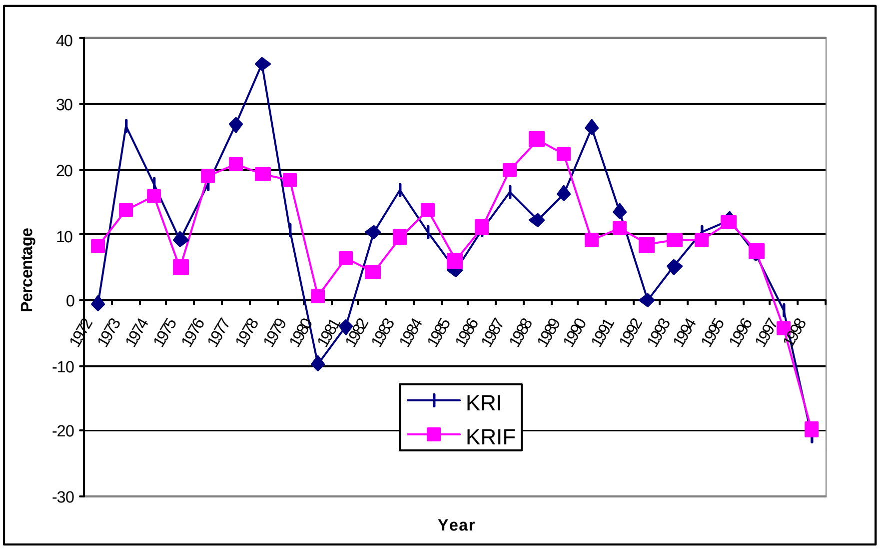
The OLS estimates of the reduced form investment equation (6) and two other similarly specified equations, namely consumption and growth, fitted to Korea's annual data for 1972 to 1998 have been obtained and their historical forecasts for this period plotted in Figure 2. Similar forecasts for private consumption are given in Figure 3 and for GDP growth in Figure 4. Only the estimates of investment are given below

$$I\%_t = -2.22 + 1.73C\%_{t-1} - 1.10Y\%_{t-1} - 0.01R\%_t + 0.05R\%_{t-1}$$

$$+ 0.93YW\%_t + 1.81PW\% + 0.88XR\%_t + 0.40G\%_t \qquad (6')$$

$R^2 = 0.60$, Adjusted $R^2 = 0.42$, $F = 3.36$, $DW = 1.69$

Figure 2 Korea's Actual and Forecast Investment (1972-1998)



Judged from conventional statistical tests, the historical forecasts of Korea's investment are efficient and emulate well its actual fluctuations (peaks and troughs) during the period under study (see Figure 2). Of special interest to us is the ability of our estimated model to accurately mimic the turning points of the observed investment data (especially the activity leading to the economic meltdown since 1997), even though we conceded earlier that our model is simply an illustration of our modelling and forecasting methodologies.

Also from the reported results in (6′), investment in our study seems positively affected by lagged consumption, lagged world income, world prices, Korea's exchange rates, and government expenditure. But it is negatively affected by lagged GDP and both current and lagged US interest rates. The strongest and significant positive influences on Korea's investment are world prices and exchange rates. This seems to show the volatility of the Korean economy that can be attributed to principally external factors outside Korea's controls and the importance of the large share of its international trade (Smith, 1998). The findings also show the relevance of part of the OLI approach (ie, via GDP and exchange rates) to studying Korea's investment (Seo and Suh, 1999). More importantly, they point out further forces that have been overlooked by the OLI approach but they are inherent and crucial in understanding investment behaviour in Korea in the past few decades. These are the government sector, world demand and world prices, US interest rate movements, and domestic private consumption.

The superiority of our multi-sectoral and flexible approach can also be empirically evaluated and measured also in terms of its better elasticity estimates and forecasts of Korea's investment in the context of the MSE criterion. More importantly, it is the ability of our forecasts to accurately foreshadow the exact downturn in investment (and output growth – see Figure 4 - and private consumption – see Figure 3) during the whole period under study (1972-1998) especially during and immediately after the Asia crisis of 1997 that indicates that a multi-sectoral model of this kind and functional form is far better, for practical policy analysis, than its alternative models of investment such as the OLI approach. Our further discussion below on the findings of our new approach is focused on more numerical

Figure 3 Korea's Actual and Forecast Private Consumption (1972-1998)

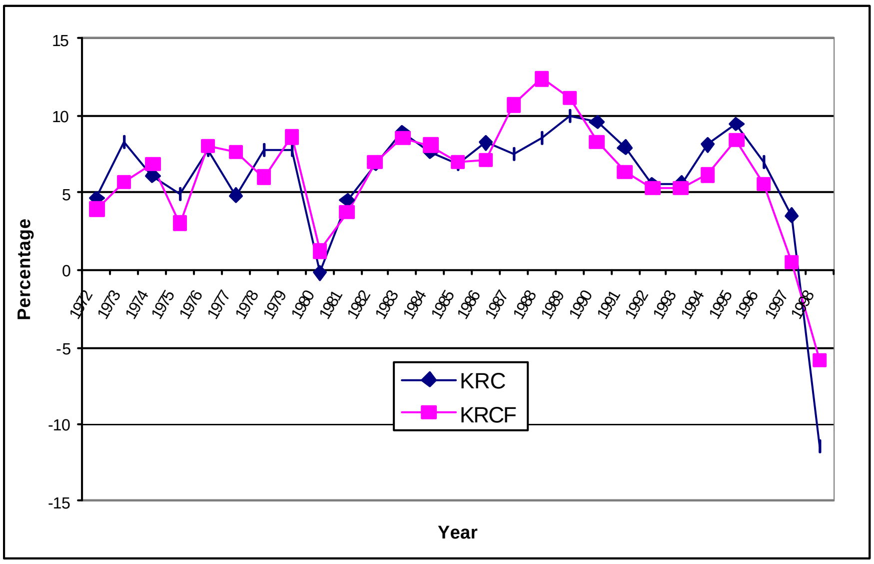
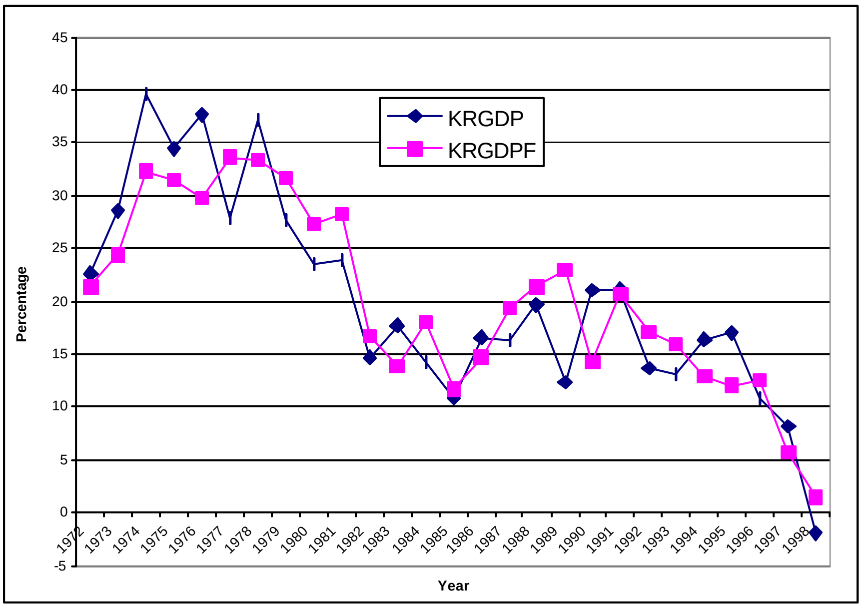


Figure 4 Korea's Actual and Forecast Growth (1972-1998)



detailed analysis of Korea's 2SHI investment forecasts and their informational gain or forecasting accuracy relative to other conventional estimation and forecasting methods (OLS or ML and Stein).

We note that our 2SHI estimation and forecasting method described earlier uniformly dominates in average MSE or under Wald risk the OLS, ML and Stein methods for all linear models having 2 or more RHS variables and for any finite sampling sizes, regardless of whether these variables are measured with or without errors, stochastic or non-stochastic. The discussion is based on the simulation results for Korea's investment ex post forecasts under a number of plausible scenarios for the short, medium and long terms.

From the empirical results of stochastic simulation given in Table 1, we observe that the average R^2 values of our 9 estimated investment equations are fairly high for the actual disturbance variance (from 86.3% to 87.3%). When substantial (i.e., 10 and 100 times its actual value) measurement errors were injected into our data, the goodness-of-fit value still ranges well from 70.1% to 73.6%.

From Table 1, and in terms of comparative forecasting accuracy and improvement, all values of the relative forecasting *MSE* criteria [i.e., $R(ml/s)$, $R(ml/h)$ and $R(s/h)$] for the 9 sets of investment forecasts for Korea, are greater than zero. In other words, the positive-part Stein-based forecasts of investment uniformly dominate (or perform better than) the OLS-based forecasts. More spectacularly and significantly, the positive-part Stein-based forecasts of investment which have been claimed in the statistical literature to be unbeatable are in turn uniformly dominated by the positive-part 2SHI forecasts. Our findings establish the optimal hierarchy for selection of an appropriate forecasting theory for making better forward planning investment strategies.

Some other interesting forecasting and methodological features about the observed investment behaviour and trends in Korea for the period 1972 to 1998 are briefly described below (detailed comments on the investment behaviour and trends as well as trade and business opportunities from our empirical results will be reported elsewhere).

The estimated investment equation for Korea during the historical estimation period 1972-1992 has the highest R^2 value among the 9 equations in our study (at 87.3%). This indicates some measure of success of our multi-sectoral econometric modelling approach for the available data.

Using our 2SHI methodologies for forecasting investment in the short (two years), medium (4 years), and long term (6 years) for Korea, the informational gain or improved accuracy can be as high as 106.54% in relation to the OLS and 50.30% in relation to the positive-part Stein. The gain increases with the size of the measurement errors on investment. This establishes the superiority of our methods over other traditional methods especially with economic and finance data where measurement errors are suspected to be large in practice.

An outstanding finding from our comparative study here is that our modelling and forecasting methodologies are able to produce better medium and long term ex post forecasting results than their short term counterpart. Usually, the opposite is true in empirical studies of this kind.

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