A SUPPLY SIDE APPROACH FOR ESTIMATING A NEO-CLASSICAL FIXED INVESTMENT MODEL FOR THE SOUTH AFRICAN ECONOMY

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Paper presented at the Third Annual Conference for Econometric Modelling in Africa.

at

The University of Pretoria.[1]

June 1998

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ABSTRACT

Investment behaviour is influenced by a number of variables. A change in macro-econometric parameters can affect investment behaviour in a number of ways. The purpose of this study is to report the theory and estimation of an investment model for the South African economy.

The model estimated in this study is mainly based on the neo-classical investment theory as part of the estimation of a consistent supply side, macro-econometric model for the South African economy. Equations for capital, fixed investment and company savings were constructed and estimated.

1. INTRODUCTION

Investment modelling has to form an integral part of any macro-econometric model. Such a model can be used to analyse possible supply side policies, and supply side theory in general. Supply side theory is concerned with the decision making process of the firm. Investment behaviour is influenced by a number of variables, such as changes in tax rates and interest rates. People will change their savings patterns as a result of tax changes, which will again contribute to secondary changes in investment behaviour. Eventually, all these changes affect aggregate supply.

It is the purpose of this study to report on the theory and estimation of an investment model for the South African economy. The model estimated is mainly based on the neo-classical investment theory as part of the estimation of a consistent supply side, macro-econometric model for the South African economy. Equations for capital, fixed investment and company savings are constructed and estimated.

2. SUPPLY SIDE ECONOMIC THEORY

What is (really) meant by the concept of supply side economics? According to Evans (1981: 19), supply side economics can formally be defined as the branch of economics that deals with those factors effecting the productive capacity of the economy.

Arthur Laffer (1982), defined supply side economics as follows: "Supply side economics is little more than a new label for standard neo-classical economics. In layman's terms supply side economics provides a framework of analysis that relies on personal and private incentives. When incentives change, people's behaviour changes in response. People are attracted towards positive incentives and repelled by the negative." The role of government in such a framework is carried out by the ability of government to alter incentives and thereby affect the behaviour of society.

Truu and Contogiannis (1987: 260) said that the term supply side economics came to be associated with the policy proposal of making large tax cuts, designed to increase the effective supply of both labour and capital and, therefore, the output of final goods and services.

3. SUPPLY SIDE ECONOMIC POLICY EFFECTS

According to Evans (1981: 253), a balanced supply side program, which includes personal tax rate cuts, corporate tax rate cuts, government spending cuts and a decrease in government regulations will result in the following economic events:

i. A reduction in the tax rate on personal income will serve as an incentive for individuals to save and raise the rate of return on assets held by that individual.
ii. Higher savings will lead to lower interests rates and higher investment.
iii. A reduction in corporate tax rates[3] will increase investment and the net of tax rate of return.
iv. As a result, higher investment leads to improved productivity, resulting in an increase in output while keeping labour and capital input constant. This would in turn lead to a decrease in the inflation rate.
v. The transfer of resources from the public to private sector, accomplished by a reduction in the growth in government spending, will increase overall productivity.
vi. Higher productivity, and therefore production, is needed to accommodate the increase in demand induced by the tax cuts, thus leading to balanced growth and equilibrium.

[2] This can be a direct or indirect reduction by means of some investment tax credit.

vii. Lower tax rates will result in more modest demands for wage increases since real income has risen by virtue of the tax cuts.

viii. A tax reduction and higher productivity will decrease inflation, leading to an increase in real disposable income and hence increases in consumption, production and employment.

ix. Lower tax rates will also motivate workers to improve work effort and other individual incentives, leading to an improvement of quality of work. The resulting gains will lead to even lower inflation.

x. Lower inflation will improve net exports, thereby strengthening the exchange rate.

xi. The increase in production capacity due to lower taxes will also lead to higher export production output, which will yet again provide for additional strength to the exchange rate and less import inflation.

A supply side approach to tax policy will probably result in improved savings, investment and eventually also improve levels of aggregate supply. Because of the real growth gains, the tax base will increase and, hence offsetting any potential decline in overall revenue caused by the tax rate cuts. In other words, because of this feedback effect, the budget deficit will not be as large as many have predicted. The increase in savings can also serve as a means to finance the deficit without increasing money supply.

4. THE NEO-CLASSICAL INVESTMENT THEORY

There are more than one way to formulate a theory of investment behaviour based on the neo-classical theory of capital accumulation. Reduced to its barest essentials, the theory requires only that capital accumulation be based on the objective of maximising the utility of a stream of consumption. This basic assumption may be combined with any number of technological possibilities for production and economic possibilities for transformation of the result of production into a stream of consumption.

According to Jorgenson (1996), the essentials of a theory of capital accumulation that meets the basic objectives are as follows:

i. The firm maximises the utility of a consumption stream subject to a production function relating the flow of output to flows of labour and capital.

ii. The firm supplies capital services to itself through the acquisition of investment goods; the rate of change in the flow of capital services is proportional to the rate of acquisition of investment goods less the rate of replacement of previous investment goods.

The result of the productive process is transformed into a consumption stream under a fixed set of prices for output, labour, investment goods and consumption goods. These prices can be defined as spot and forward prices for each commodity, or as current prices, combined with future prices adjusted by a normalisation factor, which can be identified as an interest rate. All these prices and rates are taken as fixed by the firms.

Under these conditions the problem of maximising utility can be addressed in two stages. First, a production plan that will maximise the productive enterprise should be chosen. Secondly, consumption is distributed over time to maximise utility subject to the present value of the firm. According to Jorgenson (1996), this is not the only approach to the neo-classical theory, and many more are available in the literature.

In the neo-classical literature there are two basic models that represent the relationship between flows of investment goods and flows of capital services, namely a model of inventories and a model of durable goods. The basis for the distinction between inventories and durable goods lies in the relationship between the initial inputs and the various outputs from the stockholding process.

Some assumptions are made about these outputs, namely

i. outputs generated by certain investment inputs are either perfectly complementary or perfectly substitutable - this assumption, however, can be highly restrictive;
ii. investments for production, acquired at different times, are perfect substitutes, and
iii. the replacement or depreciation rate over time is distributed exponentially and therefore replacement is proportional to accumulated stock of investment goods at a specific time.[3]

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[3] This assumption is one among many others, see Jorgenson (1996: 189) for more.

There is a justification for the use of the exponential distribution. It arises from the theory that replacement approaches an amount proportional to the accumulated stock of capital, whatever the distribution of replacement for an individual piece of equipment, provided that the capital stock is constant or growing at a constant rate. The exponential distribution is used to derive the user cost of capital as one of the most important variables in a neo-classical investment function.

4. THE COST OF CAPITAL

The pioneer of the neo-classical cost of capital theory, Jorgenson (1963), defines the cost of capital as the cost the firm incurs as a consequence of owning an asset. The cost of capital transforms the acquisition price of an asset into an appropriate rental price. This cost depends on the rate of return and depreciation. The rate of return is the opportunity cost of holding capital goods rather than financial assets. Depreciation arises from the decline in the value of capital goods with age.

The neo-classical theory of capital accumulation is formulated in two alternative yet equivalent ways. First, the firm may accumulate capital to obtain capital services from itself. The objective of the firm is profit maximisation, subject to the firms technological limitations. Secondly, the firm may rent the assets in order to obtain a capital service.[4] In this case the objective of the firm is to maximise its current profit, defined as gross revenue less the cost of inputs less the rental value of capital. The

[4] The firm may rent assets either from another firm or from itself.

rental can be calculated by using the relationship between the price of new capital goods and the discounted value of future services received from these goods.

According to Jorgenson (1993), in the absence of direct taxes, this relationship takes the form

$$q_t = \int_t^{\infty} e^{-(r)(s-t)} c(s) e^{-\delta(s-t)}\, ds,$$

where *r* is the discount rate, *q* the price of capital goods, *c* the cost of capital services and δ the rate of replacement. The time of acquisition is given by *t* and time *s* is the time during which capital services are supplied.

Differentiating this with respect to *t* gives $c = q(r+\delta) - \dot{q}$, which is the rental price of capital services supplied by the firm to itself. Under static expectations about the price of investment goods, the rental price reduces to $c = q(r+\delta)$.

To extend the formula to allow for taxation, Jorgenson (1993), defines a depreciation formula *D(s)*, which gives the proportion of the original cost of an asset of age *s* that may be deducted from taxes. Jorgenson also assumes a tax credit *k* that may be deducted from investment expenditure. If the tax rate is constant over time at rate *u*, the equality between the price of investment goods and the discounted value of capital services is

$$q_t = \int_t^{\infty} e^{-r(s-t)} \left[(1-u) c(s) e^{-\delta(s-t)} + u(1-k) q(t) D(s) \right] ds + k q_t\,.$$

Denoting the present value of the depreciation on one rand's investment by *z* gives

$$z = \int_0^\infty e^{-rs} D(s)\, ds\,.$$

The rental value of capital under static expectations then becomes

$$c = q(r+\delta)\frac{(1-k)(1-uz)}{1-u}\,.$$

There are at least three depreciation formulae that can be applied when calculating *z*.[5] Thus, there is no difference between Jorgenson's and Biorn's formulation of the user cost of capital. Both allow for taxation, time value of money and depreciation.[6]

After calculating the cost of capital it can be used as one of the most important determinants in a neo-classical investment function. By including this variable, any effect of a change in tax, interest rates or depreciation can be studied. Through this variable a tax reduction, for example, will influence investment behaviour and eventually aggregate supply.

The effect of tax policy on investment behaviour enters the investment function through the rental value of capital (cost of capital). A change in taxes affects the rental value of capital. This results in a change in the desired level of capital. Such a

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[5] See Jorgenson (1993: 4) for a brief discussion of the three methods.

[6] Also see, among others, Rosen (1985: 439) and Van der Walt (1997: 105) for more general formulations of the user cost of capital.

change leads to net investment (or disinvestment), bringing capital stock up (or down) to its new desired level.

The neo-classical investment function can therefore be written as, $I_t = K_t - K_{t-1}$, where $K_t = f(c, y, fc)\lambda$ and *c* is the cost of capital, *y* is the output level, *fc* is financial conditions and λ is other explanatory variables.

5. AN EMPIRICAL NEO-CLASSICAL INVESTMENT MODEL FOR SOUTH AFRICA

5.1 INTRODUCTION

This section employs the theory discussed previously, and its purpose is to set up a model that can represent the investment situation in South Africa. To do this, the model should be based on sound economic and statistical theory.

The first part of this section will take a closer look at the empirical model. Once the model is set up, the data generating process follows. The latter includes tests for stationarity and the order of integration. The model is subsequently estimated using the Engle and Yoo three step procedure.[7]

The last part of this section takes a look at the results obtained from a dynamic simulation (expost forecast over the period of estimation). All the diagnostic tests, regressions and simulation results are discussed from section 5.5 onwards.[8]

5.2 SETTING UP THE MODEL

Combining the theory with expansive research on the situation in South Africa leads to a model for gross fixed investment. This model consists of two functions which form a system of equations. The first regression function deals with fixed investment whereas the second deals with company savings. The latter enters the first function through the variable *fc*, which allows, among others, for company savings.

After expansive research and the investigation of many alternatives, fixed investment can be written as

$$fi = f\left(gdp\_fac, ucc2, fc, capt, cpi, pp, sanction\_dum\right).$$

Thus fixed investment (*fi*) is a function of the following:

- Gross domestic product at factor cost (*gdp_fac*).

[7] Extensive work was done on the method used to estimate this model, as well as the test for co-integration. See among others the work of Engle and Yoo (1987) and Verwoerd (1997).

[8] A list of variables used is given in Appendix A.

- User cost of capital (*ucc2*), calculated as

$$ucc2 = dipi * \frac{(\ell i\_r + 0.2)}{(1 - tc\_rate\_ppi)},$$

where *dipi* is a domestic investment price index, ℓi_r[9] is the long term real interest rate, 0.2 is the depreciation rate[10], and *tc_rate_ppi* is the company tax rate deflated with the production price index[11].

- Financial conditions (*fc*), which enters the model as an identity, is the finance needed to generate new investment. The calculation of *fc* is

$$fc = sc + sp + sg + dp + cig + captin,$$

where *sc* is company savings, *sp* is private savings, *sg* is government savings, *dp* is the nominal value (as opposed to percentage) of depreciation, *cig* is change in gold and foreign reserves and *captin* is net capital inflow.

- Capital stock (*capt*).
- Consumer price index (*cpi*).
- Production price index for manufacturing goods (*pp*).
- Sanction dummy (*sanction_dum*). From 1986 to 1994 the performance of the South African economy was heavily affected by international sanctions. This had a substantial effect on investment in these years and hence the estimation of the

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[9] The prefixed "ℓ" in this case does not indicate a logarithmic transformation.

[10] The *2* in *ucc2*, refers to a 20% depreciation rate, assuming companies apply linear depreciation over a period of five years.

[11] Tax rate equals corporate taxes as a percentage of the gross domestic product (Lucas: 1993).

model. The dummy was introduced to minimise distortions caused by this problem.

The second function, company savings, enters the model as part of the variable (identity) specified above as financial conditions (*fc*). Theoretically company savings can be written as, $cs = f(y, w, p)\lambda$, where y is the output level, w is wages, p is company profits and λ is a set of other explanatory variables. Research has shown that company savings can be written as

$$sc = f(gos\_at, union\_pres\_ind, R\$).$$

Thus company savings (*sc*) is a function comprising of the following:

- Gross operating surplus after taxes (*gos_at*), which is simply calculated as the gross operating surplus minus taxes, (company profits after allowance for depreciation and taxes).
- Union pressure index (*union_pres_ind*). The labour unions in South Africa play an important role in some of the decisions made by companies, especially wage negotiations. This put extreme pressure on, among other things, company savings. For this reason the index was introduced, and calculated as

$$union\_pres\_ind = unp * 0.15 + unm * 0.05 + dependrat * 0.05 + res\_wsu * 0.75,$$

where *unp* is the union power calculated as the percentage union members, *unm* is the union militancy calculated as the percentage number of working days lost due to strikes and other militant actions, *depenrat* is the rate of dependent family members, and *res_wsu* represents the ratio of skilled wages to unskilled wages.[12]

- Rand-dollar exchange rate (*R$*).

5.3 MODEL SUMMARY

The model therefore consists of two stochastic functions, one for fixed investment and another for company savings, as well as an identity for financial conditions.[13] The identity unites the two equations into one model.

The model can be represented as follows:

$$fi = f\left(gdp\_fac, ucc2, fc, capt, cpi, pp, sanction\_dum\right)$$

$$\uparrow$$

$$fc = sc + sp + sg + dp + cig + captin$$

$$\uparrow$$

$$sc = f\left(gos\_at, union\_pres\_ind, R\$\right)$$

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[12] Skilled; population with matric or higher qualification. Unskilled; population with less than matric qualification.

[13] Note that the identity for financial conditions is the relationship I=S, or put differently, total investment = company savings + private savings + government savings + depreciation + change in gold reserves + net capital inflow.

5.4 DATA SOURCES

The necessary data was obtained from the South African Reserve Bank's Quarterly Bulletin, the Central Statistical Service (CSS) and the Development Bank of South Africa (DBSA). Annual data from 1970 to 1995 was used to estimate the parameters of the model and, where necessary, monthly and quarterly data were converted to annual figures. Where appropriate, all data were transformed to 1990 figures. For series affected by inflationary considerations, consistency was achieved by deflating data at the rate of the production price index over the period of estimation. The model was estimated using the supply side approach, which explains the relevance of production price inflation rather than consumer price inflation for the sake of deflating the relevant series.

5.5 TESTS FOR STATIONARITY

The model estimated was a log-linear model, which means that the *ℓog* of a variable was the subject for estimation. The most important reason behind choosing a log-linear model is the fact that the estimates obtained are coefficients of elasticity, rather than coefficients of marginal effects. Logarithmic transformations also help to overcome problems faced when dealing with non-linear relationships and non-stationarity. Transformed variables are denoted by an "*ℓ*" preceding the original variable.

To determine the order of stationarity, the following tests have to be carried out rigorously:

i. Data plot. This is only a graphical approximation and an informal indication whether a given series is stationary.

ii. Correlogram. If the auto-correlation factors of a data series are positive for small lags, decline and then start increasing in a negative direction as the lag increases, it is an indication of a non-stationary time series. If the auto-correlation factors, however, taper off to zero, the data series may in fact be stationary (Verwoerd, 1997: 8).

iii. Augmented Dickey Fuller test. Unit root tests are important to examine the stationarity of a time series. A unit root test is a test on the coefficient of the lag-dependent variable in a regression. Coefficients that differ significantly from zero indicates stationarity.

iv. Obtaining the spectrum of the series.

Table 5.1 gives a summary of the variables' ADF test statistics, critical values, and orders of integration.

Table 5.1: ADF test for unit root.

Variable	ADF Statistic I(d)	Critical Value 5% I(d)	Order of Integration I(d)
ℓgdp_fac	-2.2424	-1.9546	I(1)
ℓucc2	-2.6666	-1.9574	I(1)
ℓfc	-4.6960	-1.9566	I(1)
capt	-3.1895	-3.5943	I(1)
ℓcpi	-4.2562	-1.9574	I(2)
ℓpp	-3.8817	-1.9546	I(2)
sanction_dum	-2.8507	-1.9546	I(1)
ℓgos_at	-5.2005	-2.9969	I(1)
ℓunion_pres_ind	-3.0973	-1.9566	I(1)
ℓR$	-3.0054	-1.9566	I(1)

After the order of integration was determined the model was estimated using the Engle and Yoo three step procedure. If all variables are integrated of the same order the regression results in stationary residuals.

5.6 FIXED INVESTMENT FUNCTION, THREE STEP PROCEDURE

From section 5.2 the investment function can be written as

$$fi = gdp\_fac^{\alpha} ucc2^{\beta} fc^{\chi} e^{\delta capt} e^{\varepsilon}.$$

Taking ℓogs on both sides gives the function

$$\ell fi = \alpha \, \ell gdp\_fac + \beta \, \ell ucc2 + \chi \, \ell fc + \delta capt + \varepsilon ,$$

where ε is an error term. Given the fact that fixed investment is a flow variable taking ℓogs assumes that disinvestment will never occur in South Africa.

This semi-log model was used to estimate the parameters $\alpha, \beta, \chi,$ and δ using Engle and Yoo's three step co-integration technique.

5.6.1 STEP ONE: CO-INTEGRATION REGRESSION

The first step was to estimate the Engle and Granger long term coefficients of the semi-log model presented above using ordinary least squares. Table 5.2 gives a summary of the estimation results obtained.

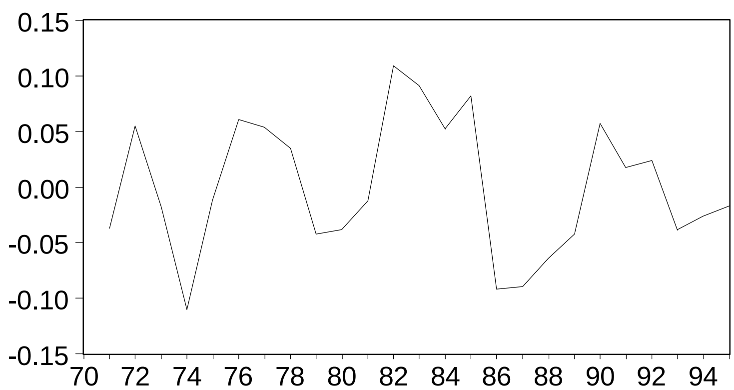
Table 5.2: First step estimation results, dependent variable: ℓfi

Variable	Coefficient	Standard Error	t-Statistic	Probability
ℓgdp_fac	0.304720	0.101035	3.015980	0.0066
ℓucc2	-0.150542	0.045329	-3.321065	0.0032
ℓfc	0.573198	0.113768	5.038323	0.0001
capt	8.12E-07	3.36E-07	2.416444	0.0249

R-squared	0.773187	*F-statistic*	23.86245
Adjusted R-sq	0.740785	*Prob (F)*	0.000001

An ADF test was used to determine, in normal fashion, whether the residuals (e_1) obtained from the above regression were stationary. A data plot of these errors is given in figure 5.1.

Figure 5.1: Data plot of e_1.



The ADF test statistic was -3.631057, which is a clear indication that the residuals are stationary, and the variables in the regression can therefore said to be co-integrated.

5.6.2 STEP TWO: ERROR CORRECTION MODEL

In the second step an ECM (error correction model) was constructed to estimate the short-run or dynamic adjustment process towards the long-run equilibrium.

The estimation results of this step are summarised in table 5.3.

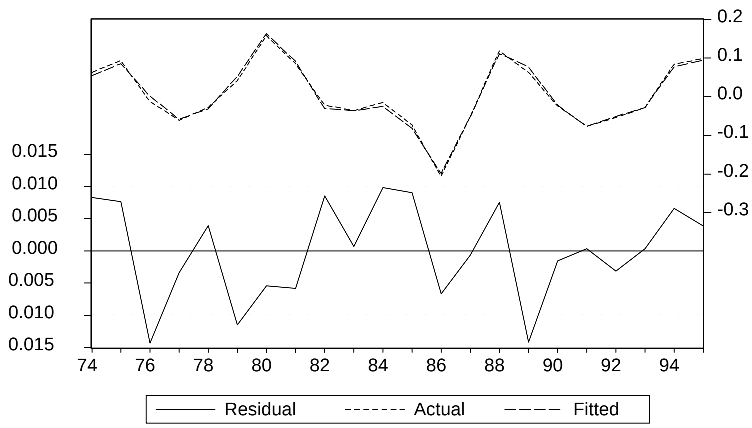
Table 5.3: Second step estimation results, dependent variable: $\nabla^1(\ell\text{fi})$

Variable	Coefficient	Standard Error	t-Statistic	Probability
e(-1)	-0.396226	0.134762	-2.940195	0.0124
$\nabla^1(capt)$	1.56E-05	2.56E-06	6.078411	0.0001
$\nabla^1(capt(-1))$	-1.28E-05	2.88E-06	-4.459868	0.0008
$\nabla^2(\ell cpi)$	-0.302935	0.139500	-2.171576	0.0507
$\nabla^2(\ell cpi(-2))$	-0.731413	0.178400	-4.099857	0.0015
$\nabla^2(\ell pp(-1))$	-0.586886	0.117480	-4.995611	0.0003
$\nabla^1(sanction\_dum)$	0.003415	0.001359	2.512768	0.0273
$\nabla^1(\ell gdp\_fac)$	-0.432222	0.176019	-2.455551	0.0303
$\nabla^1(\ell fc)$	0.166899	0.066056	2.526636	0.0266
c	-0.027921	0.009091	-3.071225	0.0097

R-squared	0.992011	*F-statistic*	165.5628
Adjusted R-sq	0.986019	*Prob (F)*	0.000000

The notation ∇^d(*variable*(-t)) denotes the d^{th} order difference of *variable*, lagged by t periods, where t is taken as zero where omitted, and ∇ is the backwards difference operator. The ECM includes both long and short term effects. A data plot of the actual and fitted values obtained from this regression is given in figure 5.2.

Figure 5.2: Actual and fitted values of $\nabla^1(\ell fi)$.



Before the third step was executed, a number of diagnostic tests were performed on the ECM.[14] Table 5.4 summarises all the test results obtained.

[14] See Verwoerd (1997) for a discussion of the possible diagnostic tests.

Table 5.4: Diagnostic tests results.

Purpose of Test	Test	Test Statistic	Probability
Normality	Jarque-Bera	JB = 1.444891	0.485563
Heteroscedasticity	ARCH	nR^2 = 0.338824	0.560509
Heteroscedasticity	White	nR^2 = 17.68722	0.476430
Serial correlation	Breuch-Godfrey LM	nR^2 = 1.202040	0.548252
Specification	Ramsey reset, F-statistic	LR = 1.316178	0.310870
Parameter stability	CUSUM & $CUSUM^2$	Both provided stability	

5.6.3 STEP THREE: ADJUSTED COEFFICIENTS

In this step the Engle and Yoo technique was applied to adjust the coefficients and t-statistics to their true values.

The results from the third regression and the adjusted coefficients are summarised in table 5.5.

Table 5.5: Third step estimation result, adjusted coefficients.

Variable	Coefficients	Variable	Engle and Granger Coefficients	Engle and Yoo Adjusted Coefficients	Adjusted t-Statistic
0.396*ℓgdp_fac	-0.017489	ℓgdp_fac	0.304720	0.287231	8.04501
0.396*$\ell ucc2$	0.007794	$\ell ucc2$	-0.150542	-0.142748	-7.68743
0.396*ℓfc	0.023403	ℓfc	0.573198	0.596601	16.13699
0.396*$capt$	-3.00E-08	$capt$	8.12E-07	7.82E-07	4.739394

The final model was constructed after completion of the Engle and Yoo third step technique. Construction entailed combining steps one and two, and applying the adjusted coefficients calculated in step three.

The final model for ℓfi ,combining both the long- and short-run characteristics, can be written as:

$$
\begin{aligned}
\ell fi = {} & 1.56\,\mathrm{E}{-}05\big(capt - capt(-1)\big) - 1.28\,\mathrm{E}{-}05\big(capt(-1) - capt(-2)\big) \\
& -0.302935\big(\ell cpi - 2\ell cpi(-1) + \ell cpi(-2)\big) - 0.731413\big(\ell cpi(-2) - 2\ell cpi(-3) + \ell cpi(-4)\big) \\
& -0.586886\big(\ell pp(-1) - 2\ell pp(-2) + \ell pp(-3)\big) + 0.003415\big(sanction\_dum - sanction\_dum(-1)\big) \\
& -0.432222\big(\ell gdp\_fac - \ell gdp\_fac(-1)\big) + 0.166899\big(\ell fc - \ell fc(-1)\big) - 0.027921 \\
& -0.396226 e_1(-1) + \ell fi(-1),
\end{aligned}
$$

where,
$$
\begin{aligned}
e_1(-1) = {} & \ell fi(-1) - 0.287231 \ell gdp\_fac(-1) + 0.142748 \ell ucc2(-1) \\
& -0.596601 \ell fc(-1) - 7.82\,\mathrm{E}{-}07\, capt(-1).
\end{aligned}
$$

The final result for fixed investment fi, is then obtained by taking the exponent of ℓfi.

5.7 COMPANY SAVINGS, THREE STEP PROCEDURE

From section 5.2, company savings can be written as

$$cs = Agos\_at^{\alpha} union\_press\_ind^{\beta} e^{\varepsilon} .$$

Taking *ℓogs* on both sides gives

$$\ell cs = a + \alpha\, \ell gos\_at + \beta\, \ell union\_pres\_ind + \varepsilon ,$$

where a is a constant and ε is the error term. The function was estimated using nominal terms. A log-linear model applied to derive estimates for the parameters α and β using Engle and Yoo's three step co-integration technique.

5.7.1 STEP ONE: CO-INTEGRATION REGRESSION

The first step was to estimate the Engle and Granger long term coefficients of the semi-log model presented above using ordinary least squares. Table 5.6 gives a summary of the estimation results obtained.

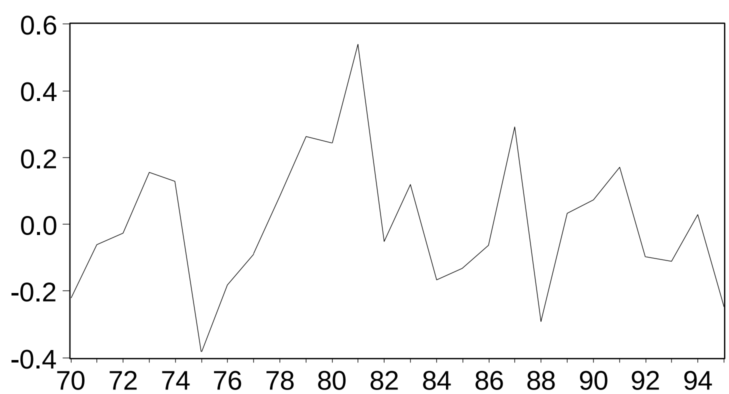
Table 5.6: First step estimation results, dependent variable: ℓcs

Variable	Coefficient	Standard Error	t-Statistic	Probability
ℓgos_at	2.251027	0.117374	19.17821	0.0000
ℓunion_pres_ind	-5.853409	0.729214	-8.027010	0.0000
constant	-15.96598	1.340709	-11.90861	0.0000

R-squared	0.978672	*F-statistic*	527.7099
Adjusted R-sq	0.976818	*Prob (F)*	0.000000

As for fixed investment, an ADF test was used to determine whether the residuals (e_1) obtained from the above regression were stationary. A data plot of these residuals is given in figure 5.3.

Figure 5.3: Data plot of e_1.



The ADF test statistic was -2.835734, from which it is clear that the residuals are stationary and the variables in the regression model are co-integrated.

5.7.2 STEP TWO: ERROR CORRECTION MODEL

In the second step an ECM (error correction model) was constructed to estimate the short-run or dynamic adjustment process towards the long-run equilibrium. The estimation results of this step are summarised in table 5.7.

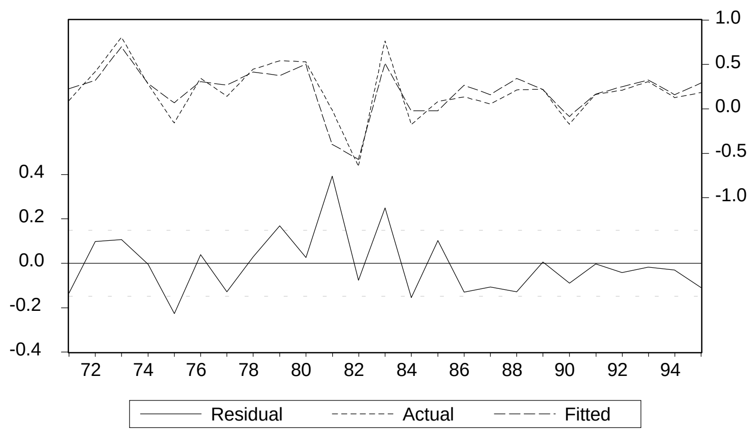
Table 5.7: Second step estimation results, dependent variable: $\nabla^1(\ell cs)$

Variable	Coefficient	Standard Error	t-Statistic	Probability
e(-1)	-0.751778	0.152252	-4.937710	0.0001
$\nabla^1(\ell gos\_at)$	2.407679	0.227693	10.57425	0.0000
$\nabla^1(\ell union\_pres\_ind)$	-3.136299	0.697903	-4.493892	0.0002
$\nabla^1(\ell R\$)$	-0.713831	0.232294	-3.072965	0.0058

R-squared	0.798219	*F-statistic*	27.69112
Adjusted R-sq	0.769393	*Prob (F)*	0.000000

The same notation as for fixed investment applies: ∇^d(*variable*) denotes the d^{th} order difference of *variable*. A data plot of the actual and fitted values obtained from this regression is given in figure 5.4.

Figure 5.4: Actual and fitted values for $\nabla^1(\ell cs)$.



As before, a number of diagnostic tests were performed on the ECM before the third step was executed. These tests and their results are summarised in table 5.8.

Table 5.8: Diagnostic tests results.

Purpose of Test	Test	Test Statistic	Probability
Normality	Jarque-Bera	JB = 5.229047	0.073203
Heteroscedasticity	ARCH	nR^2 = 0.691034	0.405813
Heteroscedasticity	White	nR^2 = 9.095533	0.334301
Serial correlation	Breuch-Godfrey LM	nR^2 = 6.010673	0.049522
Specification	Ramsey reset, F-statistic	LR = 2.851012	0.082642
Parameter stability	CUSUM & $CUSUM^2$	Both provided stability	

5.7.3 STEP THREE: ADJUSTED COEFFICIENTS

In this step the Engle and Yoo technique was applied to adjust the coefficients and t-statistics to their true values. The results from the third regression and the adjusted coefficients are summarised in table 5.9.

Table 5.9: Third step estimation result, adjusted coefficients.

Variable	Coefficients	Variable	Engle and Granger Coefficients	Engle and Yoo Adjusted Coefficients	Adjusted t-Statistic
0.751*ℓgos_at	-0.004863	ℓgos_at	2.251027	2.246164	40.85652
0.751*$\ell union\_p$	-0.221887	$\ell union\_p$	-5.853409	-6.075296	-28.17789

The final model was constructed after completion of the third step Engle and Yoo technique as discussed before.

The final model for ℓcs, combining both long- and short-run characteristics, can be written as:

$$\begin{aligned}\ell cs = {} & 2.407679(\ell gos\_at - \ell gos\_at(-1)) \\ & -3.136299(\ell union\_pres\_ind - \ell union\_pres\_ind(-1)) \\ & -0.713831(\ell R\$ - \ell R\$(-1)) - 0.751778\,\mathrm{E}(-1) + \ell cs(-1),\end{aligned}$$

where,

$$\begin{aligned}e_1(-1) = {} & \ell cs(-1) + 2.246164\ell gos\_at(-1) \\ & +6.075296\ell union\_pres\_ind(-1) \\ & +15.96598.\end{aligned}$$

The final estimate for company savings, is then obtained by taking the exponent of ℓcs.

5.8 DYNAMIC SIMULATION

An initial dynamic simulation was performed on the two models independently as a indication of the goodness of fit of the models. The models were subsequently subjected to sensitivity testing by changing (shocking) all variables (one at a time) with an increase of 10%. For a model to be stable and robust, shocks applied to the model should result in consistent long-run multiplier effects. Over time, the difference between the shocked simulated value and the simulated value without the shock must ideally result in approximately 10% of the original coefficient of the shocked variable.

After the two functions have passed the sensitivity tests, they were combined into one model using the identity for financial conditions. This model (see section 5.3) was simulated and tested for stability once again, resulting in a final investment model which may be applied to policy analysis and forecasting.

5.8.1 FIRST DYNAMIC SIMULATION

The two models were simulated independently over the period 1975 to 1995. Figures 5.5 and 5.6 represent the results obtained.

Figure 5.5: Simulation results, actual fixed investment (FI) and predicted fixed investment (FIPO).

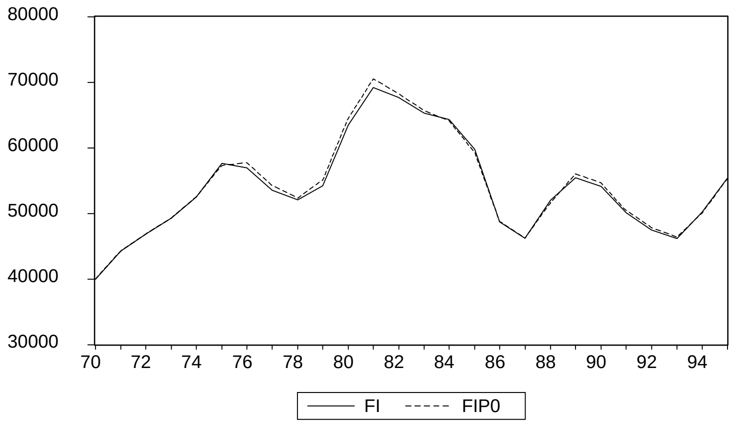
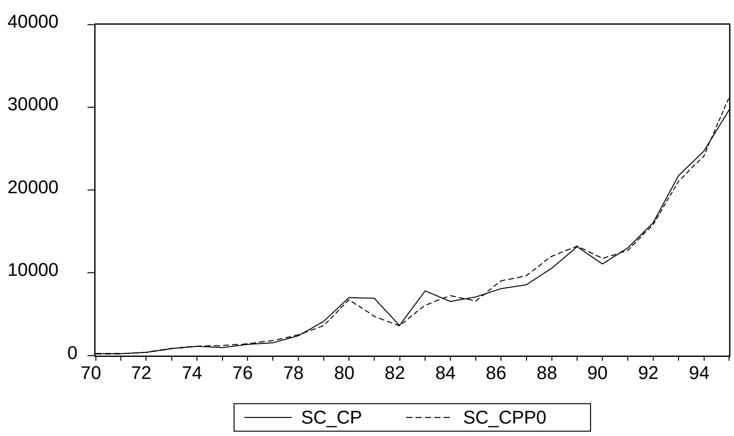


Figure 5.6: Simulation results, actual company savings (SC_CP) and predicted company savings (SC_CPPO).



The initial dynamic simulation suggest satisfactory goodness of fit and stability. The mean absolute errors obtained from these simulations were 0.007419 and 0.174860 for investment and company savings respectively. Although the mean absolute error for company savings is not very satisfying, the final model combining the two functions delivered better results.

5.8.2 SENSITIVITY TESTS

A typical sensitivity test will be to shock the explanatory variables in the model, one at a time, with an across the board increase of 10%. As described in section 5.8, the shock must result in a convergence of the dependant variable to 10% of that of the estimated coefficient of the shocked variable, i. e. 10% of the multiplier effect.

Figure 5.7 illustrates the effect of a 10% increase in capital on fixed investment. The initial effect of the shock in 1975, as well as the subsequent convergence to the original estimation can clearly be seen on the graph.[15] At the end of the period, in 1995, the difference between the originally simulated values and the shocked simulated values of *fi* converged to 10% of the multiplier as a result of the 10% shock in capital. Similar results were obtained when exposing all other variables (both short and long term) to cognate treatment. Note that shocks on the short run variables, should result in a convergence of the dependant variable to its original long-run equilibrium. A summary of the long term variables are provided in table 5.10.

[15] Although the shock had less effect on logarithmically transformed variables, they also converged with time, albeit less dramatically.

Table 5.10: Difference between actual and predicted values - 1995, dependent variable, fi.

Variable	Coefficient	10% of Coefficient	% Difference in 1995
ℓgdp_fac	0.287231	0.028723	0.02775
ℓucc2	-0.142748	-0.014274	-0.01351
ℓfc	0.596601	0.059660	0.05850
capt	7.82E-07	0.06102*	0.07918

* This elasticity was calculated as the ratio of the marginal investment function to the average investment function.

Figure 5.7: Simulation results with 10% increase in capital, with FIP0 the original values and FIP4 the shocked values, dependent variable fi.

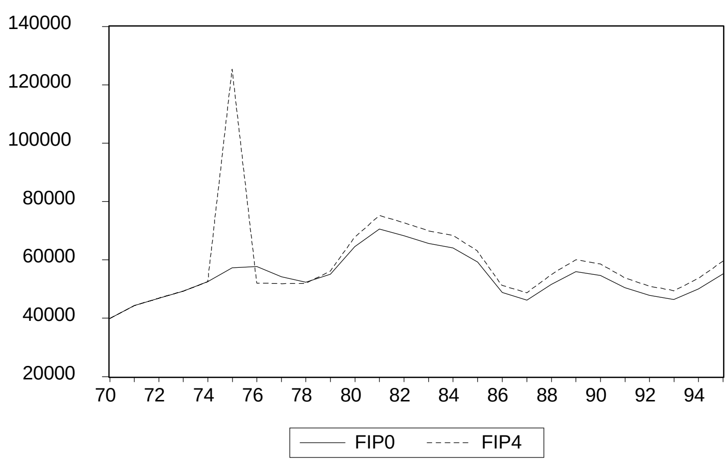


Figure 5.8: Simulation results with 10% increase in cpi, with FIP0 the original values and FIP5 the shocked values, dependent variable fi.

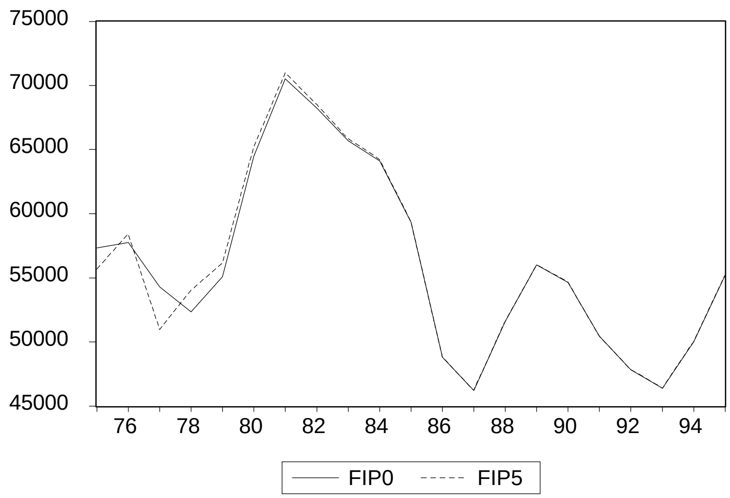
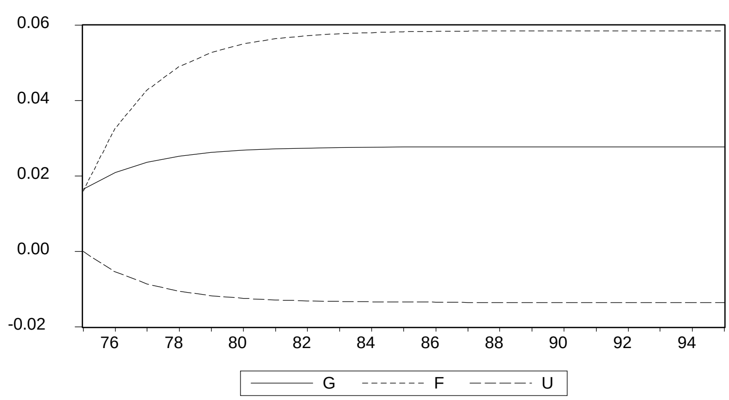
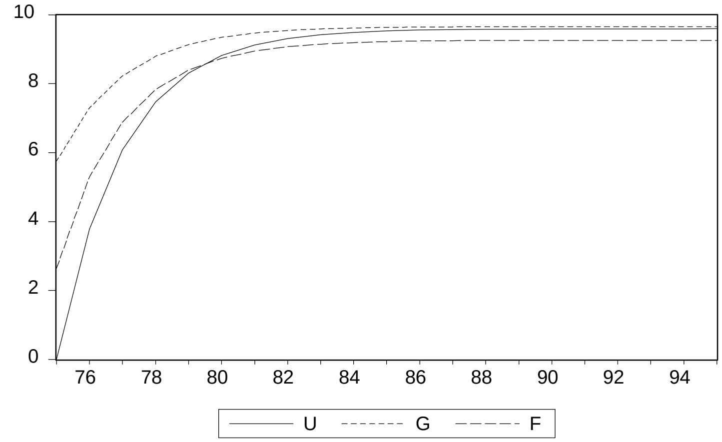


Figure 5.9: Dynamic effect of a 10% increase in long term variables, convergence to 10% of coefficient, dependent variable, fi. [16]



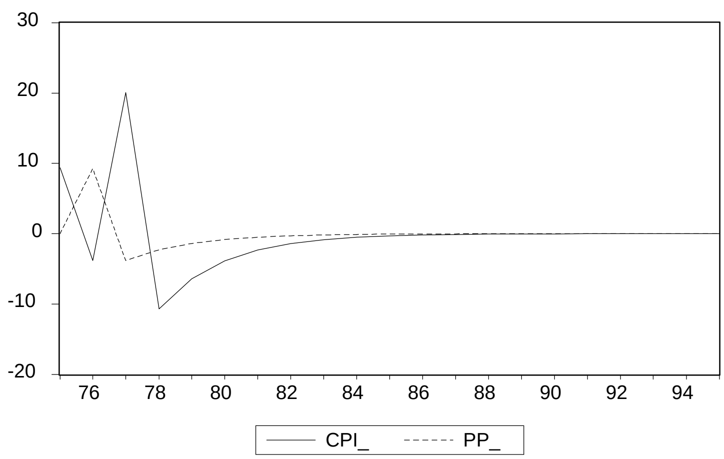
where G is gross domestic product at factor costs, F is financial conditions and U is the user cost of capital.

Figure 5.10: Dynamic effect of a 10% increase in long term variables, 10% of coefficient, dependent variable, fi.



where G is gross domestic product at factor costs, F is financial conditions and U is the user cost of capital.

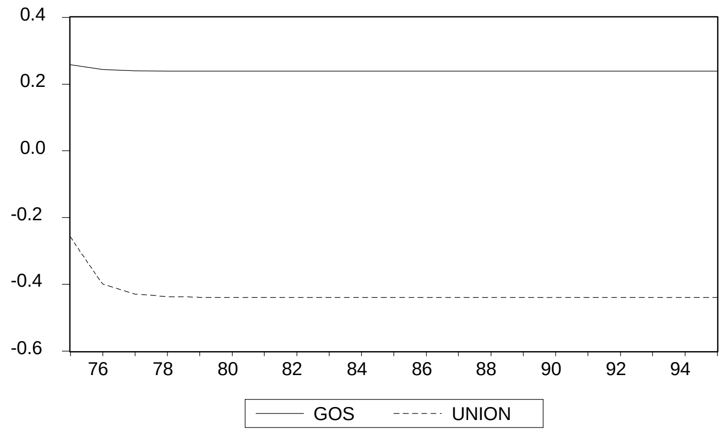
Figure 5.11: Dynamic effect of a 10% increase in short term variables, 10% of coefficient, dependent variable, fi.



Similar results were obtained for company savings. These results are illustrated in figures 5.12, 5.13 and 5.14, and summarised in table 5.11.

[16] Note that capital was not subjected to a logarithmic transformation and as such the scale of the graph in figure 5.9 did not apply naturally to the variable *capt*, which was therefore excluded from the illustration.

Figure 5.12: Dynamic effect of a 10% increase in long term variables, converge to 10% of coefficient, dependent variable, cs.



where GOS is gross operating surplus after tax and UNION is the union pressure index.

Figure 5.13: Dynamic effect of a 10% increase in long term variables, 10% of coefficient, dependent variable, cs.

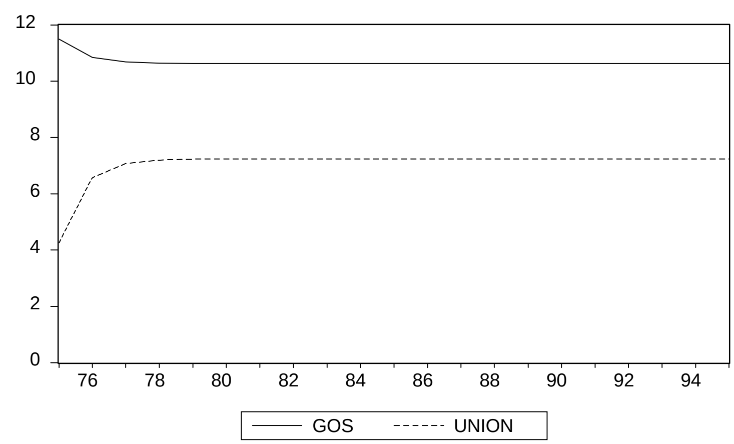


Figure 5.14: Dynamic effect of a 10% increase in short term variables, 10% of coefficient, dependent variable, cs.

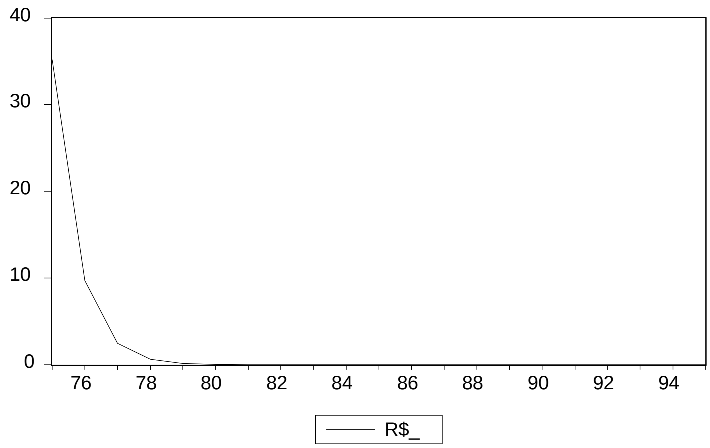


Table 5.11: Difference between actual and predicted values - 1995, dependent variable, cs.

Variable	**Coefficient**	**10% of Coefficient**	**% Difference in 1995**
ℓgos_at	2.246164	0.22461	0.23870
ℓunion_pres	-6.075296	-0.60752	-0.43956

The only variable behaving less predictable when shocked is *union_pres_ind*. One possible explanation for this is the fact that it consists of a number of elements which behave differently when shocked, and that each of these should be considered independently.

5.8.3 FINAL SIMULATION

Following satisfying results from sensitivity testing, the inclusion of *fc* (as an identity) in the model, is substantiated. So, instead of simulating separate models for fixed investment and company savings as before, an extended model to simulate fixed investment would be to include company savings in the fixed investment function via the identity of *fc*.

The system of equations can be written as follows:

$$fi = f\left(gdp\_fac, ucc2, fc, capt, cpi, pp, sanction\_dum\right)$$

$$\uparrow$$

$$fc = sc + sp + sg + dp + cig + captin$$

$$\uparrow$$

$$sc = f\left(gos\_at, union\_pres\_ind, R\$\right)$$ [17]

Figure 5.15 represents the results from the final simulation. The mean absolute error obtained in this case was 0.011376, which is rather satisfying considering the high mean absolute error of 0.174860 for company savings in the earlier simulation.

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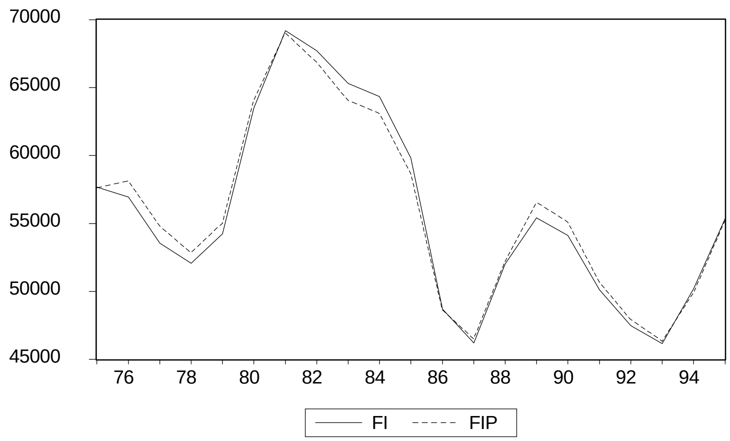
[17] A list of variables used is given in Appendix A.

Figure 5.15: Simulation results, actual fixed investment (FI) and predicted fixed investment (FIP), including the identity fc.



The final model was shocked again and similar results were obtained as before. Thus the inclusion of the identity did not influenced the stability of the model.

Due to some controversy concerning the trade-off between economic adequacy and statistical adequacy, an alternative function for modelling fixed investment was introduced. The alternative function estimates the ratio of investment to capital. A summary of this model is given in Appendix B.

6. CONCLUSION

It can be concluded that the model described in this study gives a sufficient description of fixed investment behaviour over the period 1970 to 1995. The model significantly incorporates both supply side theory and supply side policy effects, by means of variables such as the user cost of capital. Ideally, further research should be conducted for the period 1996 to 1998, as well as investigations verifying the adequacy of applying the model to policy analysis and forecasting.

The performance of the specified model, its equations and parameters, established itself as a robust mechanism for estimating investment behaviour as an integral part of a macro-econometric model for the South African economy.