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by

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Aggregate business fixed investment*

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Abstract

An aggregate business fixed investment error correction model (ECM) is estimated with Icelandic data. The user cost of capital increased considerably in the 1980s as capital markets in Iceland were liberalised and interest rates were adjusting. From the 1990s and onwards, however, the user cost has been decreasing steadily. And the relative price of business investment has been downward trending since the 1980s. A high Q ratio over the period portrays an increased demand for capital. The first order condition of capital for profits which is derived for a constant elasticity of substitution production function has minor long-run role for the user cost. Investment and capital, and investment, value added and the user cost do, however, give expected estimates of cointegration coefficients. In the short-run dynamics of the ECM, gearing, Q and profit ratios move with investment. Official figures show an unprecedented capital decrease in the 1990s in Iceland. The possibility of mismeasured technology investment is explored briefly.

Keywords: Aggregate investment, capital stock, cointegration, user cost of capital, information technology.

JEL Classification: E22, E27.

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1 Introduction

Fixed investment is an important factor of national accounts mainly because of its share of gross domestic product (GDP) (in levels and volatility) and its implications for economy growth. These characteristics can make investment the main source of economic growth forecast bias. In this paper the focus is on business investment which fell sharply in the 1990s. Official estimates of the capital stock indicate that it decreased in the years 1993-1995. Such a decrease has not been observed before in Iceland.

Traditional aggregate investment models for US and UK data have been claimed as inadequate. Tevlin and Whelan (2000) and Bakhshi et al. (2003) use business sector data to compare traditional aggregate investment equations to disaggregated equations. The disaggregated equations split investment between computing equipment and non-computing equipment. Such effects are likely to have a role in Iceland but because of data unavailability the Tevlin and Whelan procedure is pursued here only with a general discussion.

Ellis and Price (2003) augment a long-run investment relation under assumptions from Bean (1981) and use cointegration in their investment model. The Ellis and Price model and a modified version of it are estimated in this paper with annual data. The results for the long-run relations are that there is little role for the user cost of capital in a traditional capital-output first order condition equation over the sample period. However, when the capital stock is replaced by investment, the user cost has a significant role consistent with a constant returns to scale Cobb-Douglas production function. Variables such as gearing, Q and profit ratios are added to a general dynamic error correction investment model.

The rest of the paper is organised as follows. Section 2 provides the theoretical and empirical foundation. Short-term explanatory variables are discussed in addition to the long-run relationships that are hypothesised to exist. A data overview is provided for the main variables. Section 3 presents estimation results and Section 4 contains the conclusions. Detailed data information is in Appendix A.

2 Theory and data

2.1 Investment theory

Early investment theory produced empirical models of capital stock adjustment (see discussion in Caballero (1999)). In these models the current business capital stock (K_t) is a function of past capital stock deviations from optimal capital stock (K_t^*), exogenous production and, sometimes, user cost of capital (C). The optimal capital stock often derived for a representative profit maximising firm with constant returns to scale and constant elasticity of substitution production technology. The most simple cases (accelerator models) ignore the cost of capital and derive maximising conditions of the Keynesian form

$$K_t^* = \alpha Y_t \tag{1}$$

where Y is value added.

Business fixed investment (I)[1] in such capital adjustment models is then a residual based on the estimated capital stock and depreciation rate. An example of such a model is

$$I_t = f(K_t, \delta_t),\ \Delta K_t = g(K_{t-1}, Y_t, C_t) \tag{2a}$$

where f and g are investment functions which can contain distributed lags of their parameters and, δ_t is the depreciation rate. An equation that estimates g with the capital stock as the dependent variable forecasts *net investment* (ΔK_t) but not *gross investment* (I_t) which is the variable of interest. To produce gross investment forecasts from g the net investment forecast has to be plugged into f, usually the perpetual capital equation,

$$K_t = I_t + (1-\delta_t)K_{t-1}, \quad I_t = f(K_t, \delta_t) = \Delta K_t + \delta_t K_{t-1} \tag{2b}$$

assuming a declining geometric depreciation pattern. One problem with this simple stock adjustment procedure is that measured and derived capital stock and physical depreciation

[1]Investment is the sum of *fixed investment* and *inventory investment* (stockbuilding).

data are subject to considerably more uncertainty than investment data.[2,3]

The user cost of capital (C) is the economic cost of capital for firms. The cost varies between projects and changes with expectations. Define the user cost (real cost of capital) with the Hall-Jorgenson representation as a function of the corporate interest rate, relative investment goods price, depreciation and the tax effect on investment,[4]

$$C_t = \frac{p_t^I}{p_t^Y}\left(r_t + \tau_t^p + \delta_t\right)\frac{(1-A_t)}{(1-\tau_t^i)}. \tag{3a}$$

where r is the real interest rate available to the firm, τ^p is the business property tax rate, τ^i is the business income tax rate and A is the present value of tax savings investment allowances. The tax savings term is calculated with

$$\begin{aligned} A_t &= \tau_t^i\left(\delta_t + \frac{\tilde{\delta}_{t+1}}{(1+r_t)} + \frac{\tilde{\delta}_{t+2}}{(1+r_t)^2} + \cdots\right) = \tau_t^i \frac{\delta_t}{1-(1-\delta_t)/(1+r_t)} \\ &= \frac{\tau_t^i(1+r_t)}{1+r_t/\delta_t} \end{aligned} \tag{3b}$$

and represents the present discounted value of depreciation tax savings on a unit of investment divided by the effective tax rate.[5] At time $t+j,\ j \geq 1,\ \tilde{\delta}_{t+j} = (1-\delta_t)^j\delta_t$ is the depreciation per unit of capital invested at time t. The fraction $(1-A)/(1-\tau^i)$ is a tax policy factor which is neutral when the fraction is one, stimulating when the fraction is less than one and discouraging when the fraction is greater than one.

The initial capital stock models were improved with capital instalment costs (see references in Hayashi (1982)) and/or steady state assumptions. The resulting models

[2]An empirical example in the spirit of (2a) is Breece and Cassino (1998) for the forecasting and policy system of The Reserve Bank of New Zealand. Breece and Cassino divide business fixed investment into (*i*) buildings, (*ii*) machinery and (*iii*) computers. The capital stock adjusts to the long-run desired ratio of capital stock and production.

[3]See Chirinko (1993) and Caballero (1994) for a discussion of capital stock measurement problems.

[4]See Hall and Jorgenson (1967), King and Fullerton (1983) and OECD (1991). The formula is obtained by setting the price of capital equal to the present value of capital services. In continuous time the Leibniz integral rule can then be used for the derivative of this equality with respect to time. The p^Y term in (3a) comes from net worth maximisation and is sometimes not included in C.

[5]The second step in (3b) is obtained with a standard result for geometric series.

usually had gross investment as a dependent variable or the *investment rate* (I/K) instead of the capital stock. Bean (1981) uses the steady state approach with a constant elasticity of substution (CES) production function and constant returns to scale which yields a first order condition[6]

$$k_t = a + y_t - \sigma c_t \tag{4a}$$

where lower case variables denote log values. Setting $\gamma_t^K = \Delta K_t / K_{t-1}$, rearranging the perpetual capital in (2b) gives[7]

$$k_{t-1} = i_t - log(\gamma_t^K + \delta_t). \tag{4b}$$

For the long run, (4a) and (4b) can be combined to give

$$i = b + y - \sigma c \tag{4c}$$

where $b = a + log(\gamma^K + \delta)$ is assumed stationary in the long run.

Modern investment models are usually based on intertemporal optimising conditions. The following is an example of such a model. Firms invest as if their objective is

$$V(A_t, k_t, w_t) = \max_{\{k_{s+1}, b_{s+1}\}_{s=t,\cdots,\infty}} \left\{ \sum_{s=t}^{\infty} \left(\frac{\zeta}{R} \right)^{s-t} \left[d_t + \frac{(1-\zeta)}{\zeta} w_t \right] \right\} \tag{5a}$$

$$\text{s.t.} \quad d_t + p^K (k_{t+1} - (1-\delta) k_t) + c(i_t) + b_t = A_t y_t + b_{t+1}/R, \tag{5b}$$

$$b_{t+1} \leq e p^K k_{t+1}, \tag{5c}$$

$$d_t \geq 0, \tag{5d}$$

$$0 < \zeta < 1 \tag{5e}$$

[6]A simple example is $Y = [\alpha K_t^\phi + (1-\alpha) N_t^\phi]^{\frac{1}{\phi}}$, $\partial Y / \partial K = \alpha (Y/K)^{1-\phi}$. Using the static profit maximising condition $\partial Y / \partial K = C$ gives $K = (\alpha / C)^{\frac{1}{1-\phi}} Y$, $k = \sigma log(\alpha) + y - \sigma c$ where $\sigma = 1/(1-\phi)$.

[7]From (2b), $\gamma_t^K K_{t-1} + \delta_t K_{t-1} = I_t$, $k_{t-1} = i_t - log(\gamma_t^K + \delta_t)$.

where V is the present value of the firm, A is a technology shock, w is net worth, $c(i_t)$ is a capital adjustment cost function, p^K is the price of capital, b is one period debt, k is the capital owned by the firm, R is the gross business interest rate, e is a borrowing constraint constant, ζ is the probability that the firm will continue operating next period and d is dividend payments to shareholders (see Kiyotaki (1998), Hauksson (2005) and Caggese (2003)). The standard Tobin's Q model is a special case of the model in (5) where the optimising condition becomes

$$I_t/K_t = \gamma_0 + \gamma_1 (V_t^M / P_t^I - 1). \tag{6}$$

The ratio V^M/P^I is the marginal Q per unit of capital where V^M is the marginal value of capital and P^I is the price of investment. This model is not estimated directly in this paper but an earnings variable is included in an error correction regression under the assumption that credit constraints are relevant for business investment as captured by the credit constraint in (5c). This model also supports including a Q variable in the regression.

The basic Q model in (6) is too simple for empirical time series. The main simplifications of (6) are that it assumes no credit frictions and convex adjustment costs. One way to capture non-convex adjustment costs is the discrete choice model solved in Cooper and Haltiwanger (2003),

$$V(A,K) = max\{V^b(A,K), V^s(A,K), V^i(A,K)\},\ \forall (A,K) \tag{7}$$

where b refers to the representative business value function for the action of net buying capital, s refers similarly to the value function of net selling capital and i refers to the value function of inactivity (to only recover depreciation).[8]

Another concern is the ignorance of trending depreciation rates and investment goods prices in investment forecasting models. Tevlin and Whelan (2000) note that a sharp increase in computer investment has led fixed investment in the late 1990s. They argue that because of this, traditional models of investment are not as suitable as before.

[8]This approach is in the spirit of the (S,s) model. The (S,s) model states that firms keep their capital within a lower and an upper bound: when capital reaches the lower bound they invest.

Tevlin and Whelan disaggregate business investment into computing and non-computing. They mention two main reasons for this disaggregation to be useful: first, replacement investment[9] increases with increased computing capital stock. Second, investment has become more sensitive to the user cost of capital since computing capital usually has higher depreciation rates. Bakhshi et al. (2003) use the Tevlin and Whelan (2000) framework but in addition estimate an error correction model (ECM).

Simple empirical alternatives or generalisations of the models introduced in this section simply add variables in first differences to linear regression equations. If the new variables are significantly different from zero that can be taken as an indicator of a failure of the model, or as an indicator of the importance of the additional variables. One such example is provided by Blanchard et al. (1990) who estimate models with the first differenced investment rate as the dependent variable and regressors such as $\Delta log(Q)$, $\Delta log(D/K)$ and $\Delta(\Pi/K)$ where Q is Tobin's (average) Q, D is dividend payments, Π is profits and Π/K is return on capital (ROC).

Figure 1 shows an example of a decision mechanism for investment of a representative business sector. The rectangles in the diagram represent the main hypothesised decision factors of business fixed investment. The arrows which represent directed relations are an example of interactions between the decision factors. Some are only relevant in the short run. Higher values of variables in rectangles with a '+' should have a positive effect on investment and reverse for '-'. A higher exchange rate means that fewer domestic units are needed to buy one unit of foreign currency.

2.2 Data

This subsection contains empirical observations for the main issues from the investment theory presented in Subsection 2.1. Appendix A contains data source information.

Since 1979, when production per unit of capital has been high (low), investment per unit of capital has overall been high (low). Figure 2 shows the log ratios of investment and production to capital as well as the logs of capital and production. The variability in the ratios is considerable in the sample period, in particular in the 1990s. In the long run,

[9]Replacement investment replaces depreciated capital stock (δK_t).

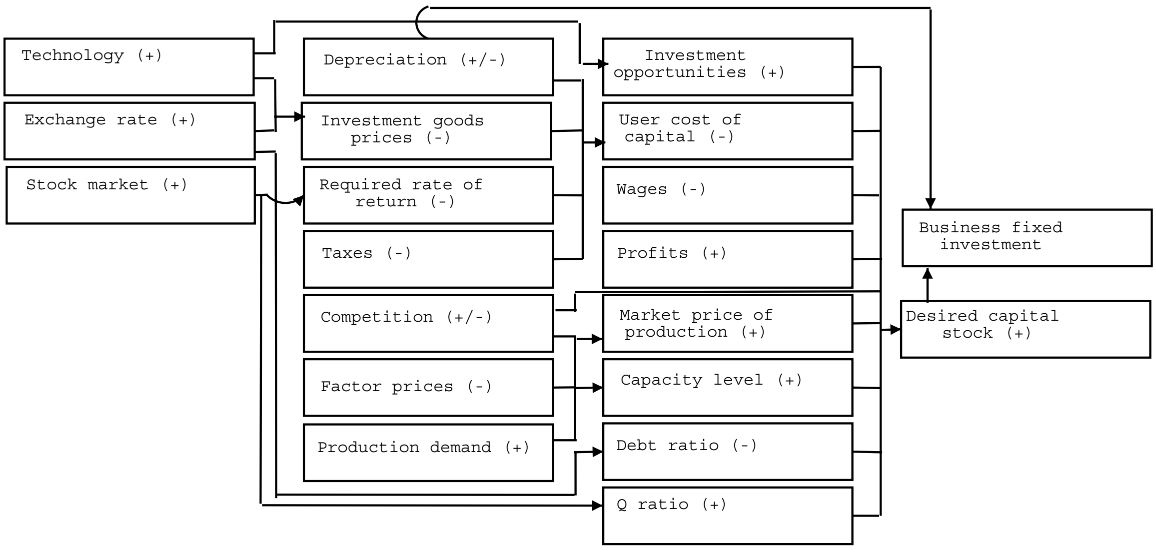

Figure 1: Business investment mechanism example.

the capital and production series seem to exhibit co-movement in addition to a common trend in the series. The National Economic Institute (1991) has a detailed overview of investment in Iceland over 1945-1989.

2.2.1 The 1993-1995 fall in the capital stock

There is a fall in official estimates of business capital stock in the first half of the 1990s. As Figure 3 illustrates, such a business capital decrease has not been observed in previous recessions, at least not since 1945. Investment was lower than depreciation and this caused the fall in the capital stock. For example, five major business sectors which make up around 50% of business capital had a capital decrease in this period. The fisheries industry had a capital decrease in 1990-1991, 1993-1995, 1997 and 2001, agriculture in 1989-1996 and 2002-2003, energy in 1992-1996, metal smelting in 1992-1995 and 2002-2003 and transport in 1992-1997 and 1999.

The energy investment is determined generally on political principles and often associated with large metal smelting investment projects. The metal smelting investment

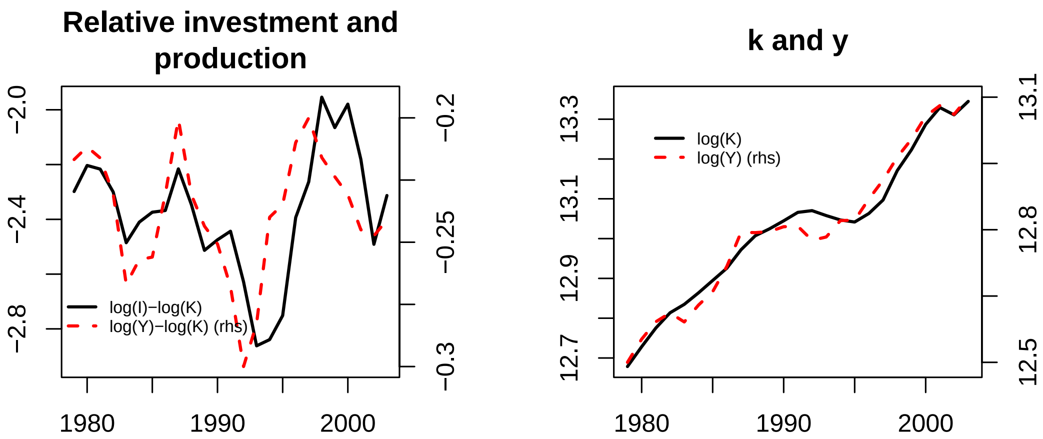

Figure 2: Investment, production and capital in log scales 1979-2003.

mainly depends on external conditions such as the price of aluminum. Metal smelting and energy investment's average share of business investment over 1980-2002 is around 10% but in 1992-1995 the share was 2-4%, reaching its lowest point in 1994.

It is likely, however, that official investment figures are lacking some of the information technology (IT) investment as it had been very low in the past and new methods were needed to measure it.[10] But many indicators support the measured decline in the capital stock. Fisheries investment reached a two decade bottom,[11] GDP growth was low in the previous years, interest and unemployment rates were high and financial markets were not so developed that firms could fully exploit the stock market financing route. And as discussed by Zoega (2002), the liberalisation of capital markets caused a jump in the required rate of return which was followed by a wave of bankruptcies while the economy was adjusting. See further discussion in Pétursson (2002).

The decline in the capital stock in the 1990s supports the use of the discrete choice model in (7). This model allows estimation of different investment policy functions depending on whether capital is decreasing, unchanged or increasing. But it is not

[10]For example firms were perhaps registering a large share of IT investment as costs. Similar arguments may apply for intangible capital like advertising and research.

[11]There was a fundamental structural change in the fisheries sector in 1983 which increased fisheries investment for some years.

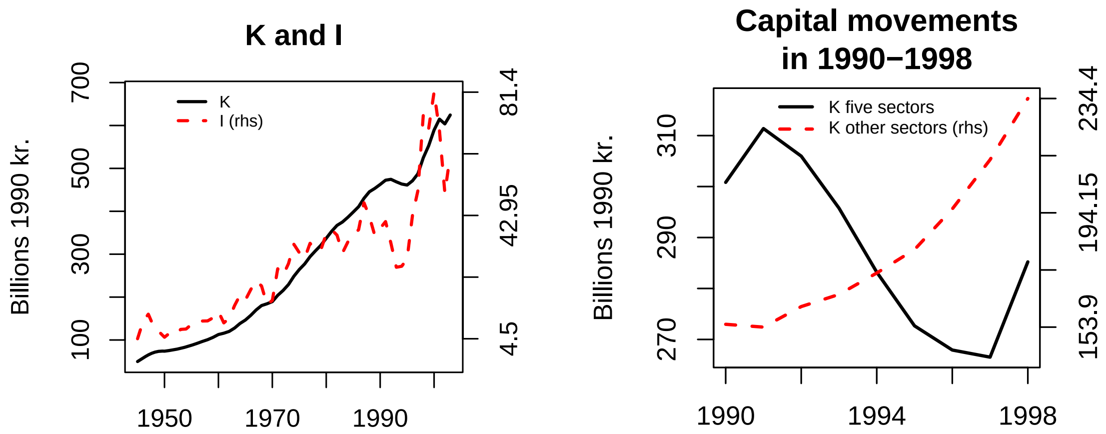

Figure 3: Left side shows business capital stock (K) and investment (I) over 1945-2003 in 1990 billions of kronas. Right side shows K over 1990-1998 split into two halves. One half is for five major business sectors' capital stock and the other half shows the rest.

straightforward to estimate the model for such a short time series as used here. Instead a dummy variable is used for the estimation results presented in Section (3).

2.2.2 IT investment

With increased technology many investment goods will become cheaper and with a high growth rate of technology the investment goods will tend to depreciate faster. Figure 4 shows the development of the ratio between business investment and GDP prices. For the last two decades investment goods prices have been trending downwards relative to production prices. The relative price of investment to wages has similarly been downward trending for the last two decates. This trend in the ratio of investment prices and wages should cause a shift in production factors from labour to capital.

Figure 4 also shows the development of the computer price index to consumer price index ratio 1995-2003. The downward trending prices of computers and other IT investment should explain a part of the price decrease in aggregate investment.[12]

[12]Information technology (IT) refers to computer hardware and software.

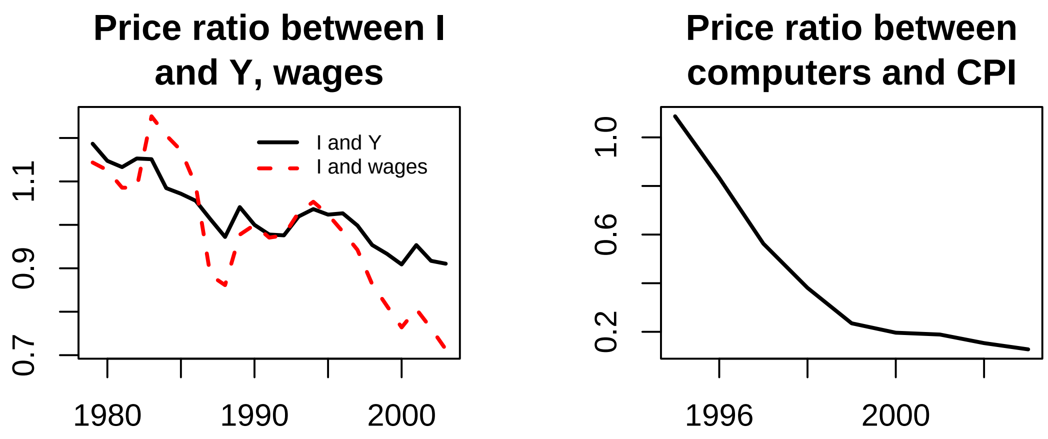

Figure 4: Relative price of business investment to gross domestic product (GDP) and wages 1979-2003 and relative price of computers to the consumer price index (CPI) 1995-2003.

Statistics Iceland (2004) estimate that around 60% of all employees in Iceland use computers regularly and 99% of firms have a computer with an internet connection. Within some sectors and in larger firms with 100 or more employees, almost all employees regularly (on average at least once a week) use a computer at work. This high rate of computer usage along with the downward trending prices of computers and high depreciation rates of computers could have considerable implications for business investment behaviour. Because of the lack of IT investment data in Iceland, approximations have to be used to estimate the IT share of business investment. Available demand side figures are aggregates for office machinery and computers. Fairly detailed supply side figures are available for 2001-2002 but can currently only be estimated further backwards using IT sector turnover data.

Figure 5 shows business investment categories 1997-2002 and two estimates of IT investment share in 1991-2002.[13] Computers are included in the office category (left figure) but this category also includes other investment goods and some software

[13]Categories not shown in the figure are motor vehicles for industrial use (average 1997-2002 share 3%), ships, aircraft and pertaining equipment (average share 8%), machinery tools for quarrying and construction (average share 30%) and other (average share 3%).

investment might be missing. One estimate of IT share of business investment (right figure) is conservative and the other is non-conservative. The non-conservative one assumes that official estimates of software investment are only a third of the actual software investment. See data description in Appendix A. This software assumption is from Oulton (2001) who argues that UK software investment at current prices is at least three times the official figure. Oulton also estimates the UK information and communications technology (ICT) share of GDP at around 3% in 1998. This share would mean that the share of ICT in Icelandic investment in 1998 is around 28% and underestimated in official figures by around 20 percentage points.

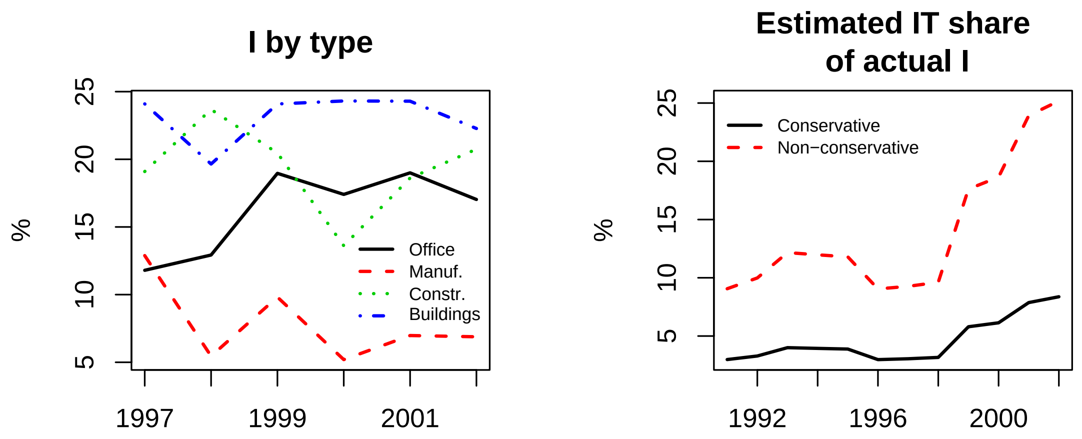

Figure 5: Four categories of business investment 1997-2002 and estimates of IT share of business investment 1991-2002. The categories of investment shown are: Office machinery and computers (Office), manufacturing machinery and equipment (Manuf.), construction other than buildings (Constr.) and buildings.

2.2.3 User cost of capital

The user cost of capital is the minimum expected real rate of return that investment projects must provide in order to be feasible for investors. According to the traditional neoclassical first order condition for maximum profits in (4a) where σ is the elasticity of production factors substitution, an x percentage point increase in C will decrease the demand for

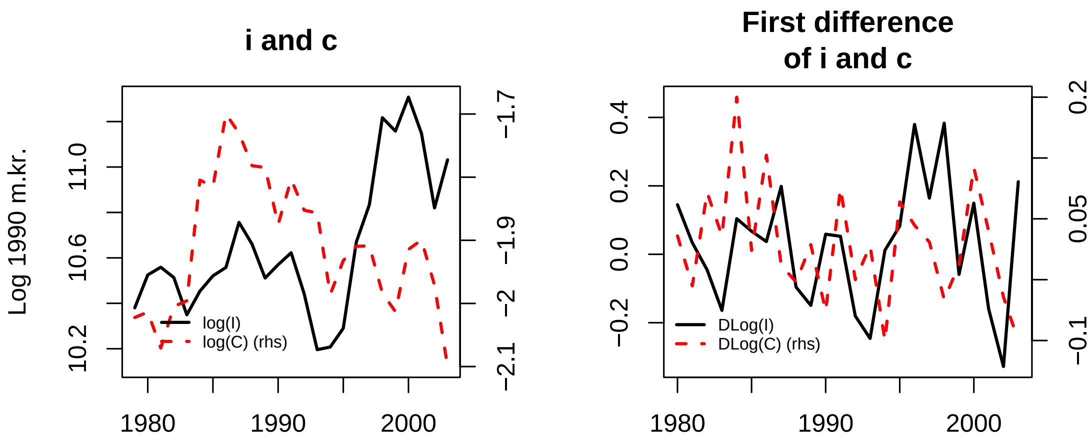

Figure 6: User cost of capital (C) in log levels and first differences 1979-2003.

capital by $x\sigma$ percentage points in the long run. If for example $\sigma = 0.5$ then an increase in C by two per cent should decrease capital demand by one percentage point.[14] Figure 6 contains the estimated business real user cost of capital series. Figure 7 has estimates of r, τ^p and the two policy series included in the user cost. A rise (fall) in the tax savings series $(1-\tau^i)$ should stimulate (discourage) investment. The tax savings series represents present value tax savings for each investment unit. Similarly a fall (rise) in the policy series $(1-A)/(1-\tau^i)$ should stimulate (discourage) investment.

The sample period in this paper is generally 1979-2003. The main reason for this short period is that a longer user cost and Q series are hard to construct because of data unavailability and the young age of Icelandic financial markets.

2.2.4 Gearing, Q and ROC

Corporate gearing of nonfinancial firms can be defined as $G_t = D_t/W_t$ where D is debt and W is wealth. Figure 8 shows an estimate of gearing for the 1979-2002 period as well as

[14] The parameter σ indicates how easily the mix of production factors can be modified while keeping production constant. Or in other words, the parameter indicates how much the ratio between investment and production responds to changes in the user cost of capital (Ellis and Groth, 2003). When $\sigma = 1$ the first order condition becomes identical to the Cobb-Douglas production function case.

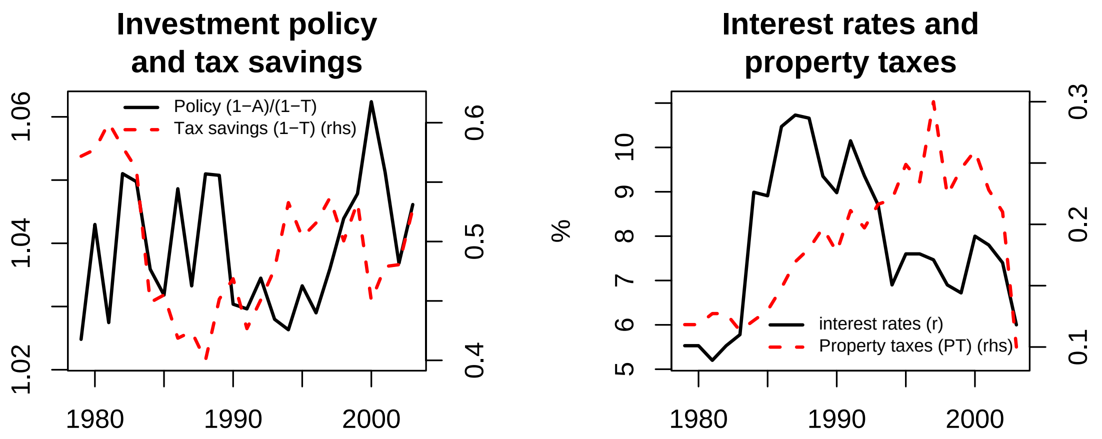

Figure 7: Investment policy and interest rates.

investment in levels and first differences. From Figure 8 there is co-movement between capital gearing and investment. This should, however, be interpreted with care because of measurement problems affecting the available data (see data description in Appendix A). Also, causality is not entirely clear between the variables. Figure 8 could indicate that investment causes gearing to rise or gearing causes investment to decrease. In addition, the relationship seems to vary between periods as Hall (2001) concludes for UK data.[15] The gearing ratio peaked in the late 1990s which indicates a positive shift in credit opportunities for firms.

Figure 9 shows investment and a simple estimate of the Iceland business average Q for 1981-2001. The figure indicates a co-movement between the two variables. The standard Q investment model as in equation (6) predicts a positive response of investment to the Q ratio. Investment has a positive correlation with the Q ratio with a zero or one period lag.

Figure 10 shows the first difference of I and return on capital (ROC) with earnings before taxes (ET) in the numerator. The figure also has a comparison between ROC ratios with different profit measures. The timing of movements is almost identical for the profit measures over the second half of the sample period but around 1990 there are

[15]Cuthbertson and Gasparro (1995) estimate the cointegration relation between investment, the Q ratio, output and gearing.

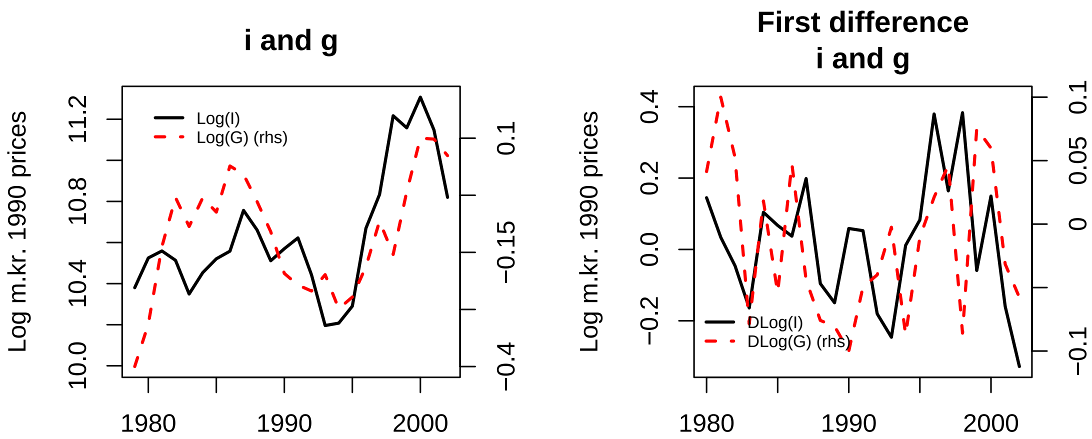

Figure 8: Investment and gearing 1979-2002 in levels and first differences.

some differences. Over the sample period there is a positive response of investment to the *ROC* ratio with a lag. Profit measures could influence investment through the Tobin's Q effect because of market expectations or through cash flow which affects available funds for investment if investment is debt-constrained as assumed in (5). Another possible link between profit and investment is that it is a special case of the accelerator model.[16] If profit is viewed as a stable function of output then the role of profit for investment can be the same as the role of output.

The observed co-movement of investment with the Q and the ROC ratios are similar to the Blanchard et al. (1990) results for US investment.

3 Econometric analysis

Following Ellis and Price (2003), the estimated long run relations are between $\{k, y, c\}$, between $\{k, i\}$ and between $\{i, y, c\}$ from (4a), (4b) and (4c). Note that the third cointegration relation is implied by the other two and from Figure 2 it is clear that the ratio I/Y has very similar movements over the sample period as I/K. These long-run relations

[16]See the discussion in Junankar (1972). In short, the basic accelerator model assumes a linear relation between optimal capital stock and production as in (1).

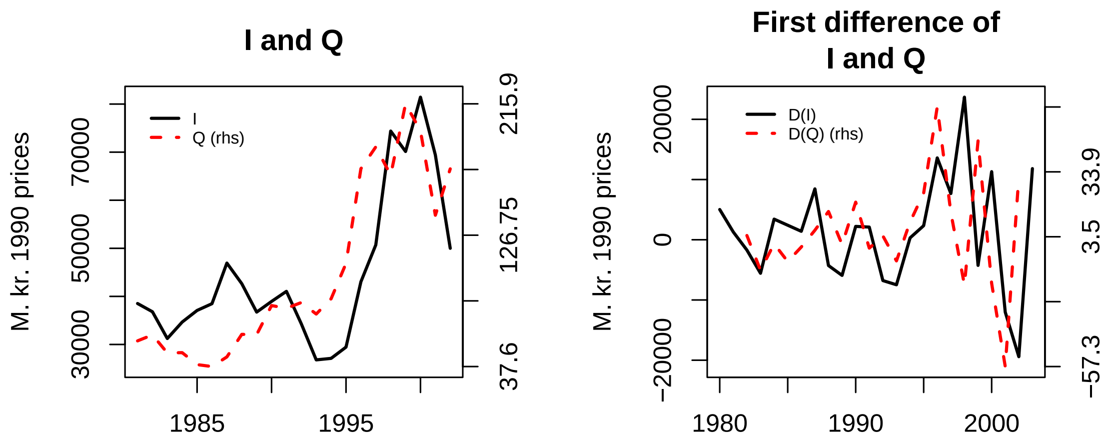

Figure 9: Investment and Tobin's Q ratio in levels and first differences 1981-2002.

are then used in a vector error correction model (VECM) and an ECM with additional short-run regressors. The general VECM estimated is

$$\Delta x_t = \Phi D_t + \Gamma(L)\Delta z_t + \alpha\beta'(L)x_{t-1} + \varepsilon_t \tag{8}$$

where $x = (k, y, i, c)'$, z is a regressor matrix which could include variables such as gearing, profit measures and a Q ratio with lags in addition to lags of the x elements, D is a vector of deterministic elements such as constants, α is a factor loading matrix and β is a matrix of cointegration vector coefficients. Put

$$\alpha\beta' x_{t-1} = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \\ \alpha_{41} & \alpha_{42} \end{pmatrix} \begin{pmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} \end{pmatrix} \begin{pmatrix} i \\ k \\ y \\ c \end{pmatrix}_{t-1}, \tag{9a}$$

$$\Gamma(L)\Delta z_t = \sum_{i=1}^{s} \Gamma_i \Delta(i,k,y,c)'_{t-i} + \sum_{i=0}^{s} \Gamma_{i+s+1}\Delta(g,Q,ROC)'_{t-i} \tag{9b}$$

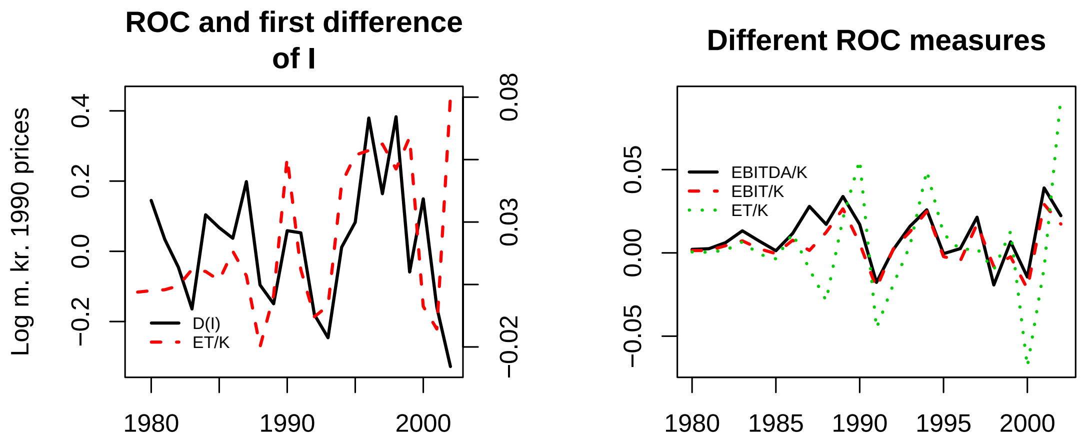

Figure 10: Left figure shows the first difference of business fixed investment 1979-2002 and level values of return on capital (*ROC*). Right figure shows first differences of nominal values of three different ROC measures.

where D contains constants and the dummy variable $D9395$ which takes the value one in 1993-5 and zero otherwise. When using the modified FOC in (4c), (9a) reduces to

$$\tilde{\alpha}\tilde{\beta}'\tilde{x}_{t-1} = \begin{pmatrix} \tilde{\alpha}_1 \\ \tilde{\alpha}_2 \\ \tilde{\alpha}_3 \\ \tilde{\alpha}_4 \end{pmatrix} \begin{pmatrix} \tilde{\beta}_1 & \tilde{\beta}_2 & \tilde{\beta}_3 \end{pmatrix} \begin{pmatrix} i \\ y \\ c \end{pmatrix}_{t-1} . \tag{10a}$$

Table 1 contains Phillips Perron (PP) test statistics for unit roots in the data. p values are in square brackets. All the variables appear to have a unit root except K which seems

k	Δk	$\Delta^2 k$	y	Δy	c	Δc	i	Δi
-2.0	-2.5	-4.7	-2.0	-3.5	-1.5	-5.2	-2.0	-3.8
[0.58]	[0.37]	[0.01]	[0.57]	[0.06]	[0.75]	[0.01]	[0.57]	[0.04]

Table 1: Unit root tests calculated with the ts package in R, the test regression includes a constant and a linear trend. Critical values of the PP test are -3.8 ($\alpha = 1\%$), -3.0 (5%) and -2.65 (10%).

to have a non-stationary first difference. But when extending the period backwards from 1980 to 1945 the Phillips Perron test does not reject a unit root in the capital stock. Figure 11 shows plots of c, $k-y$, and $i-y$. The figure indicates that there could be some long-run negative effect of the user cost on the capital production and investment production ratios. The long-run ratio between investment and capital seems stationary from Figure 2.

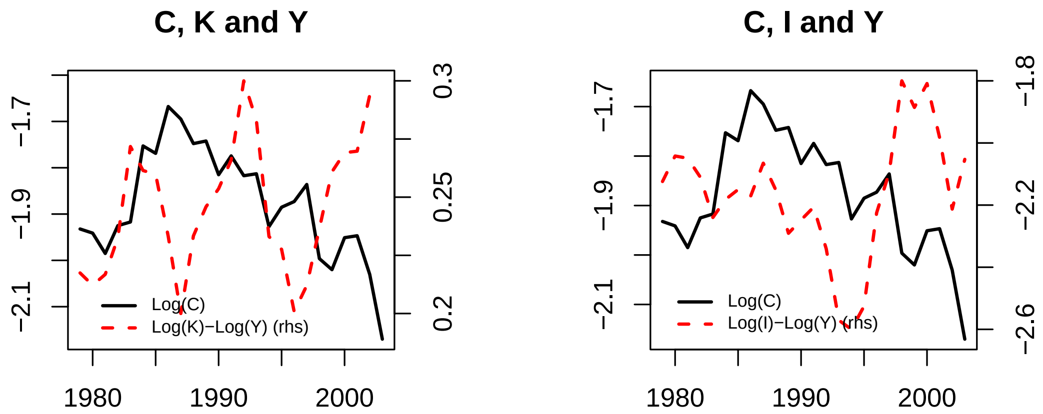

Figure 11: Cointegration variables.

Table 2 contains cointegration tests for the cointegrating variables. From the table it is evident that there is one cointegrating vector in each of systems (9) and (10). These cointegration tests assume a linear trend in the data. But excluding this trend implies two vectors in (9). The theory in Subsection 2.1 implies one vector in (10) and two vectors in (9). A dummy variable $D9395$ with value one in 1993-5 and zero otherwise is included in the tests. Without this dummy variable the results of the cointegration test change. This dummy variable captures the potential measurement problem in the national accounts data, the fall in metal smelting and energy investment and the structural break from privatisation.

3.1 Cointegration vectors

The three cointegrating vectors are estimated with the Granger Engle (GE), dynamic ordinary least squares (DOLS) and Johansen procedures but only the estimates of Johansen

	Trace statistic	Max-Eigen statistic
H_0	$\{k,i,y,c\}$	
$r=0$	82.75*	58.49*
$r\leq 1$	24.27	15.36
$r\leq 2$	8.91	7.72
H_0	$\{i,y,c\}$	
$r=0$	99,14*	59.32*
$r\leq 1$	39.83	30.04
$r\leq 2$	9.79	8.4

Table 2: Cointegration tests for unit roots in the data. r is the number of cointegrating vectors. $*$ denotes a rejection of the null at 5% significance level. Dummy variable $D9395$ included in the test.

are reported here.[17] The Johansen procedure uses the full VECM model but the other two only use the restricted single equation version where Δi is the dependent variable.[18] To choose the cointegration test lag structure, AIC (Akaike information criterion) and BIC (Bayesian information criterion) tests can be used as indicators. Considering these indicators as well as the sample size, data frequency and t values, two lags (in first differences) are used for Johansen.

Table 3 gives the estimated cointegrating vector coefficients (the β_{ij}'s; as well as standard errors) with no restrictions and with non-zero restrictions on some of the coefficients according to the investment theory in Subsection 2.1.

The standard first order condition from (4a) does not have much role for the user cost of capital. Both the unrestricted and the restricted versions give estimates of σ with a reversed sign.[19] The capital investment cointegration vector from (4b) estimate gives unrestricted estimates of the i coefficient close to the expected value of 1. The likelihood ratio (LR)

[17]Full results are available on request from the author. DOLS and GE do not give results less consistent with the theory than the Johansen procedure. Overall the results from the three tests are similar.

[18]For example for the cointegration variables $\{i,y,c\}$ and $p=1$ the DOLS model becomes $i_t=\zeta_0+\zeta_1 y_t+\zeta_2 c_t+\zeta_3\Delta y_{t+1}+\zeta_4\Delta y_t+\zeta_5\Delta y_{t-1}+\zeta_6\Delta c_{t+1}+\zeta_7\Delta c_t+\zeta_8\Delta c_{t-1}+\varepsilon_t$ where ζ_2 is $-\sigma$.

[19]However, the DOLS procedure estimates σ with a correct sign but not significantly different from zero. Caballero (1994) argues that there can be a downward bias in the estimate and suggests a correction method but this method is not pursued here.

test for the restrictions of the VECM in (9) has a probability value of 0.05 and thus barely does not reject the restrictions.

Unrestricted			**Restricted**		
k	*y*	*c*	*k*	*y*	*c*
1	-1.01	-0.06	1	-1	-0.05
<...>	<0.02>	<0.04>	<...>	<...>	<0.04>
k	*i*		*k*	*i*	
1	-0.82		1	-1	
<...>	<0.03>		<...>	<...>	
i	*y*	*c*	*i*	*y*	*c*
1	-1.19	0.54	1	-1	0.56
<...>	<0.12>	<0.23>	<...>	<...>	<0.26>

Table 3: Cointegration vectors for the VECM in (8) with (9) and (10). Left side shows only normalised vectors and right side also shows vectors with coefficients restricted. Standard errors are between inequality brackets (<>). Unadjusted [adjusted] sample period of the estimation is 1979-2003 [1982-2003]. Three dots (...) indicate not available or not applicable. Dummy variable $D9395$ is included in the estimation.

In contrast, using only the modified first order condition cointegration vector from (4c) gives estimated coefficients fairly consistent with the Cobb-Douglas case of $\sigma = 1$. The user cost of capital coefficient (σ) is estimated 0.56 which is lower than implied by a Cobb-Douglas production function. The GE procedure gives an estimate of 0.46 but DOLS has an estimate for σ of 0.63 with one lag and 1.13 with two lags. The LR test for the restriction of the y coefficient to be 1 has a probability value of 0.1 and thus does not reject the restriction. Further, restricting σ to be 1 and restricting the α coefficients of y and c to be zero gives a probability value 0.05, and 0.52 when the dummy variable is excluded. This justifies Cobb-Douglas restrictions on the cointegrating vector in the model in (9) and a conditional ECM version of it as pursued in Subsection 3.2.

Considering the cointegrating estimation results, the traditional FOC in (4a) is not used further. Only the implied cointegrating vector $i = \text{const} + y - c$ is used in the ECM estimation in Subsection 3.2. Figure 12 shows the residuals of the restricted GE cointegrating vector with and without a 1993-5 dummy variable. The residual series appear to have stable means but not stable variances without the dummy variable.

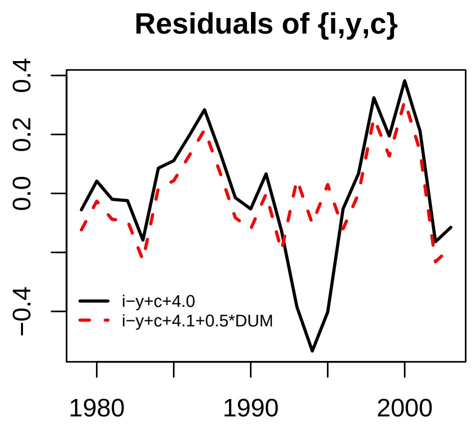

Figure 12: Cointegration residuals.

3.2 A conditional ECM for investment

The model is now reduced to a single equation ECM. Equations (8) and (10) give the general ECM. After excluding lags or variables based on t values, expected signs of coefficients, adjusted R^2 ($\bar{R}^2$), AIC and BIC, the ''simple'' dynamic investment equation (11) emerges. In this regression the coefficient of earnings is not significantly different

$$\begin{aligned} \Delta i_t \;=\; & -\underset{(-4.3)}{1.88} + \underset{(2.0)}{0.23}\,\Delta i_{t-1} + \underset{(7.0)}{4.14}\,\Delta y_t + \underset{(1.4)}{0.97}\,\Delta ROC_{t-1} + \underset{(1.7)}{0.13}\,\Delta Q_{t-1} \\ & -\underset{(-2.5)}{0.76}\,\Delta g_t - \underset{(-4.2)}{0.45}\,[i_{t-1} - y_{t-1} + c_{t-1}] - \underset{(-3.3)}{0.2}\,DUM9395_t. \end{aligned} \tag{11}$$

$\bar{R}^2$	0.87
Standard error of regression	0.07
Jarque Bera normality test	1.14 [0.56]
LM test for serial correlation (one lag)	4.63 [0.03]
Unadjusted period [adjusted]	1979-2003 [1982-2002]

from zero by standard significant levels. But earnings is kept in the equation based on the belief that credit constraints affect business investment. Under other specification of the ECM and with a previous data set used in estimation the coefficient was significant.[20] A Breusch Godfrey LM test for serial correlation in (11) with one lag has a probability value 0.03 which does not indicate serial correlation in the residuals. The Jarque Bera test for normally distributed residuals has a probability value 0.56, thus the null of normal distributed disturbances is not rejected. Cumulative sum (CUSUM) and CUSUM squared tests show stable patterns of the equation residuals over the whole sample period.

The first log difference of gearing is potentially a cause of an endogeneity bias. But a Wu-Hausman test rejects this bias. There is some correlation between Δg_t and Δg_{t-1}, and very low correlation between Δg_{t-1} and the residuals from (11). Thus the lagged log difference of gearing is used as an instrument in the auxiliary regression of the Wu-Hausman test.[21] The auxiliary regression residuals enter the ECM with a t value of -0.9. Therefore, these residuals are not significantly different from zero.

Table 4 contains an overview of the single equation cumulated response of investment in equation (11) to a 1% shock to the regressors. Earnings effects (ROC) and the Q ratio and gearing (G) peak after one year and then decay to a zero effect. Similarly, gearing (G) effect peaks simultaneously and then decays to a zero effect. Production peaks simultaneously and then settles to the long-run effect after approximately ten years. Investment response to a user cost shock steadily builds up to the long-run effect with a slight oscillation.

[20] A major revision of the capital stock data was made by Statistics Iceland in early 2005. After the revision the 1993-1995 dummy variable is not as important statistically as before. Further revised investment, capital stock and production figures are due to be published in the autumn of 2005. Here a modified capital stock series is used in the estimation, see K description in appendix A.

[21] The auxiliary regression is the model in (11) in addition to the instrument.

Years	Y	ROC	Q	G	C
Simultaneous	4.2	0.0	0.00	-0.8	0.0
One year ahead	3.8	0.4	0.13	-0.6	-0.5
Two years ahead	2.9	0.3	0.10	-0.3	-0.8
Long run	1.0	0.0	0.00	0.0	-1.0
50% of LR effect after	overshoots	...	...	...	1 year
90% of LR effect after	overshoots	...	...	...	3 years

Table 4: Cumulated shock response of investment from equation (11). Overshoots means that the short-run cumulated response overshoots the long-run response.

4 Conclusions

The main conclusions are the following.

1. Business investment was very volatile and there was a decrease in the capital stock in the 1990s. The explanations for this are probably both a structural change in the data generating process and measurement errors. These data characteristics cause estimated equations to provide a better fit for the 1979-2003 period if a dummy variable for 1993-1995 is included.

2. There has been a downward trend in investment goods relative prices. In particular in technology investment goods prices.

3. The business required rate of return and property taxes as a fraction of capital have been falling in recent years after peaking in the 1990s.

4. The basic first order condition for maximum firm profits did not comply well with sample data. However, a modified version of the condition produces results compatible with standard economic theory. In particular, it is not rejected that the elasticity of substitution is equal to one, consistent with the Cobb-Douglas production function.

5. In the short run, gearing, Q and earnings ratios have significant comovement with business investment. The profit ratio is least significant of the three ratios.

The analysis here has considerable data uncertainty. Results should be considered in light of this. Aggregation and price quantity decomposition are examples of factors that cause measurement errors. Structural changes can also affect the analysis: most notably, financial markets and technology developments in this instance.

A Data description and data

This appendix contains a data description and a datatable with the main dataset used in the research.

Name: C. *Short description:* Real user cost of capital. *Source:* Relative price of investment and depriciation rates from Statistics Iceland. Interest rate from the Central Bank of Iceland. Tax figures for 1980-1997 from the National Economic Institute, Búskapur hins opinbera and 1998-2002 figures from the Central Bank of Iceland. *Frequency and period:* Annual 1979-2002. *Detailed description:* C is an estimate of the effective marginal ‘‘tax rate’’on business capital income. C is calculated with a Hall-Jorgenson like formula as in (3a),

$$C_t = \frac{p_t^I}{p_t^Y}\left(r_t + \tau_t^p + \delta_t\right)\frac{(1-A_t)}{(1-\tau_t^i)} \tag{12}$$

where p^I is the investment goods price index, p^Y is the GDP deflator, τ^p is a property tax term calculated as the ratio between business property tax payments and the current value capital stock, δ is the annual average business capital depreciation rate, τ^i is the effective corporate income tax rate calculated as the ratio of corporate tax payments to operating surplus, A is the present value of tax savings investment allowances calculated as in (3b), r is the sum of indexed 3-5 year required return on government bonds and the additional private sector required return, set fixed here as 2%.[22,23]

[22]See Table 5 in Mayes and Young (1993) for comparison. Caballero (1994) uses the same fixed risk premium.

[23]Ellis and Price (2003) and OECD (1991) represent r with a weighted real long-run average business required rate of return (real long-run weighted average cost of capital).

Name: G. *Short description:* Business gearing (leverage). *Source:* Primary data from the National Economic Institute 1979-1997, Atvinnuvegaskýrslur. Statistics Iceland 1998-2002. *Frequency and period:* Annual 1979-2002. *Detailed description:* The movement of the ratio is more accurate than the level. The estimate is based on a (variable) sample. Offical debt figures for 1979-1985 exclude some essential sectors and are adjusted using the 1986 share of these sectors of the total. The data proxies all domestic business excluding the financial sector. Gearing is defined as $G_t = D_t/\hat{K}_t$ where debt (D) is total debt excluding equity and ($\hat{K}$) is current value capital stock derived in the same way as K.

Name: I. *Short description:*. Business fixed investment. *Source:* Statistics Iceland. *Unit:* Millions of kronas at 1990 prices. *Frequency and period:* Annual 1979-2003. *Detailed description:* For annual data there are three periods of different definitions of business investment (1945-1990, 1990-1997, 1997-current). The 1997-2003 nominal values are used directly and prior nominal values have the correct relative movements between years (chain-linked). Quantity index figures 1979-1997 are used directly and 1998-2003 figures are chain-linked. The same procedure is used for Y.

Name: IIT. *Short description:* Business information technology investment. *Source:* Primary data from Statistics Iceland. *Unit:* Millions of kronas current prices. *Frequency and period:* Annual 1990-2002. *Detailed description:* Little data for business IT investment has been published in Iceland. Results from a Statistics Iceland survey for 2001-2002 investment are used and backcasted to 1990 using turnover figures from the IT service sector. Bakhshi and Thompson (2002) report that UK IT investment is estimated from the supply side. Here detailed disaggregated turnover figures are used for 2002 and backcasted using turnover of software service/computer firms 1990-1997 (# 848 in Statistics Iceland publications) and turnover in computers and computer services (# 72 in Statistics Iceland publications) for 1998-2001. The non-conservative estimate is proxied with the sum of 3*(large software systems) + large computers + maintainence and services + small systems + workstations + related equipment. The conservative estimate is proxied with 0.65*[non-conservative estimate - 2*(large software systems) -

(2/3)*(maintainance and services) - (1/3)*(small systems + related equipment)]. 65% of IT investment is assumed in the conservative estimate to belong to the business sector and 35% to the government sector. The conservative estimate also assumes that one third of IT maintenance services and two thirds of small computers and software projects is investment. The components of small systems, workstations (desktop computers) and related equipment are all less than 130,000 kronas in value. Tax regulations permit IT investment valued at 130,000 kronas or less to be posted as expenses instead of investment. The ESA national accounts standard, in contrast, views IT purchases valued at 500 euros or higher (around 45,000 kronas) to be investment. As a result, accounting figures would not sum up to the national account figures.

Name: K. *Short description:*. Business Capital Stock. *Source:* Primary data from Statistics Iceland. *Unit:* Millions of kronas at 1990 prices. *Frequency and period:* Annual 1979-2003. *Detailed description:* I construct K in two main steps. For annual data there are three different base year periods (1945-1990, 1990-1997, 1997-current). In step 1 the 1997-2003 nominal values are used directly and prior nominal values have the correct relative movements between years (chain-linked). Quantity index figures 1979-1997 are used directly and 1998-2003 figures are chain-linked. 1997-2004 real depreciation ratios from Statistics Iceland are chain-linked backwards using implied depreciation from the real K and I series assuming the perpetual capital flow equation. In step 2 the final K is derived with real I and the depreciation from step 1. Thus the K series differs from the Statistics Iceland series. Using the original Statistics Iceland series improves the empirical results in Section 3 but the implied depreciation series in 1997-2004 is then incorrect. The nominal capital stock $\hat{K}$ is obtained by multiplying the price index of K from step 1 with K from step 2.

Name: Q. *Short description:* Q ratio. *Source:* Stock price figures from the Iceland Stock Exchange and VIB before 1993. Dwelling prices are from Fasteignamat ríkisins (The Land Registry of Iceland). *Unit:* Ratio, normalised to having average one. *Frequency and period:* Annual 1981-2001. *Detailed description:* A simple accounting measurement of

Q (see Thoroddsen (1991)) is

$$
\begin{aligned}
Q &= \frac{\text{market price of equity}}{\text{book value of equity}} = \frac{\text{book amount of stocks} \times \text{stock price}}{\text{book value of equity}} \\
&= \frac{\text{stock price}}{\text{book value of equity} \Big/ \text{book amount of stocks}}. \qquad (13)
\end{aligned}
$$

A general empirical implementation of the marginal Q in (6) is the average Q defined as $Q_t = V_t/\hat{K}_t$ where V is the financial value of the firm and $\hat{K}$ is current value capital derived in the same way as K. See Blanchard et al. (1990), Cuthbertson and Gasparro (1995) and Tobin and Brainard (1977) for other empirical measurements. Book value figures of stock are not available in Iceland for the period 1988-1997 and thus market value of equity is difficult to estimate for that period. Because of this data unavailability the aggregate Q used here is a simple implementation with only the stock price index in the numerator, normalised to having average one. Quarterly stock prices are estimated as a centred average[24] of closing monthly market figures. Annual figures are fourth-quarter figures. The stock price index is compiled from the HMark index from 1987 to 1989, the VIB index from 1990 to 1992 and ICEX-15 from 1993. Before 1987 the price index is backcasted with the housing per square metre price index for the Reykjavík area.[25]

Name: ROC. *Short description:* Return on capital. *Source:* Profit figures 1979-1997 from the National Economic Institute, Atvinnuvegaskýrslur and 1998-2002 from Statistics Iceland. *Unit:* Ratio. *Frequency and period:* Annual 1979-2002. *Detailed description:* The *ROC* ratio is constructed with $ROC_t = \text{Profit}_t/\hat{K}_t$ where profit is current book value profits before income and property taxes, and for data availability reasons it also excludes extraordinary income and costs. I call this profit measure profit from regular operation (earnings before direct taxes, ET). $\hat{K}$ is the current value estimate of the capital stock derived in the same way as K. In the return on capital ratio Benito and Young (2001) use

[24] Calculated as $\frac{1}{6}M_{-1} + \frac{2}{6}M_0 + \frac{2}{6}M_1 + \frac{1}{6}M_2$ where M_i is the month i figure within each quarter and M_0 is the first month figure of the quarter.

[25] Dwellings prices used because an Icelandic ''stock exchange market'' did not begin operation until 1987. For similar reasons Pétursson (2001) backcasts the oportunity cost of money in Iceland in the 1980s with a time-varying weight between long-term interest rates and inflation.

return defined as profit before interest and tax payments (earnings before interest and direct tax payments, EBIT) for similar purposes to those here. Another example of an earnings measure is gross operating surplus (earnings before interest, direct taxes, depreciation and amortisation, EBITDA). Blanchard et al. (1990) subtract all taxes from earnings and use the net earnings measure of after-tax profit for forecasing investment.

A.1 Data in table format

Table 5 presents the main data set used in this paper. In June 2005 figures for 2002-2003 were still not available from Statistics Iceland for G, Q, E.

	C **×100**	**G** **×100**	**I**	**K**	**Q** **×100**	**ROC** **×100**	**Y**
1979	12.9	69.8	32209.6	320765.4	...	2.28	262698.1
1980	13.0	75.7	37233.9	337141.4	...	2.37	277767.6
1981	12.3	87.6	38519.1	353389.2	55.00	1.97	289634.0
1982	13.1	96.2	36805.4	367190.8	59.07	2.28	295858.4
1983	13.2	91.1	31235.9	375019.6	46.83	3.74	289488.4
1984	15.8	96.1	34663.3	386011.0	47.01	2.87	301464.0
1985	15.7	93.6	37078.1	398208.7	38.90	1.35	311364.7
1986	17.5	102.1	38480.2	410732.3	37.57	3.32	330911.5
1987	17.0	100.5	46931.8	430247.1	44.10	1.25	359194.2
1988	16.2	95.4	42647.6	445590.7	59.42	-2.95	358866.6
1989	16.1	90.2	36727.5	453413.3	59.26	-0.04	359776.6
1990	14.8	83.3	38947.5	462619.2	78.96	5.53	363999.0
1991	15.8	81.5	41050.7	472572.3	77.13	0.95	364353.3
1992	15.1	80.6	34273.8	474621.0	81.03	-0.82	352326.1
1993	15.1	83.1	26795.9	468759.9	73.21	-0.39	355119.0
1994	13.3	77.9	27107.5	463607.8	83.60	3.70	369435.6
1995	14.0	79.7	29444.3	461236.9	107.55	4.54	369734.9
1996	14.3	84.4	43037.0	471212.7	171.81	4.55	389035.6
1997	14.3	92.0	50709.7	487462.5	186.64	4.67	407191.2
1998	13.4	86.4	74391.1	524860.2	167.49	3.82	430259.0
1999	13.0	97.3	70131.5	553047.1	215.87	4.76	449249.7
2000	14.3	107.6	81439.8	589445.6	197.56	-0.35	474772.2
2001	14.5	107.4	69421.6	614934.5	140.25	-0.92	487099.3
2002	13.5	104.1	49999.8	603767.1	171.75	5.12	476886.3
2003	12.0	...	61815.1	624579.5	...	...	497080.6

Table 5: Datatable.

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