Aggregate business fixed investment*

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Abstract

Three cointegrating vectors are estimated for use in an error correction model (ECM) for aggregate business fixed investment in Iceland. The long run relations are a static first order condition (FOC) of capital and the user cost of capital, the perpetual equation of capital with assumptions of stationary depreciation and growth rate; these two are then used as a basis for a long run relation between investment, value added and the user cost. The FOC of capital for profits which is derived for a constant elasticity of substitution production function has little long run role for the user cost. Investment and capital, and investment, value added and the user cost do, however, give expected estimates of cointegrating coefficients. In the short run dynamics of the ECM, gearing, Q and profit ratios are and have a significant relation to investment. Some of the recent development in the investment literature and empirical evidence such as nonconvex adjustment costs, irreversable capital, financial constraints, qualitative factors and the effects of recent technology developments on investment are briefly considered.

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

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. The main demand side agents of investment are corporations (business), the public (invests in dwellings) and the government. In this paper the focus is on business investment. Business investment is a volatile series and its greatest volatility in Iceland for the past seven decades was in the 90s. 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 not adequate. 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 here only pursued with a general discussion.

Ellis and Price (2003) augment a traditional long run investment relation 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 and additional analysis are in appendix A.

2 Theory and data

2.1 Investment theory

Initial 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 form

$$K^* = \alpha Y \tag{1}$$

where Y is value added.

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

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

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,

$$K_t = I_t + (1-\delta_t)K_{t-1}, \quad I_t = f(K_t, \delta_t) = K_t - (1-\delta_t)K_{t-1} \tag{3}$$

assuming a declining geometric depreciation pattern. One problem with this simple stock adjustment procedure is that measured and derived capital stock and physical depreciation data are subject to considerably more uncertainty than investment data in national accounts

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

and per firm.[2][3]

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

$$C_t = \frac{p_t^I}{p_t^Y}\left(r_t + \tau_t^p + \delta_t\right)\frac{(1-A_t)}{(1-\tau_t^i)}. \tag{4}$$

where r is the interest rate available to the firm and A is the present value of tax savings investment allowances. The tax savings term is calculated with

$$\begin{aligned} A_t &= T_t\left(\delta_t + \frac{\tilde{\delta}_{t+1}}{(1+r_t)} + \frac{\tilde{\delta}_{t+2}}{(1+r_t)^2} + \cdots\right) = T_t\frac{\delta_t}{1-(1-\delta_t)/(1+r_t)} \\ &= \frac{T_t(1+r_t)}{1+r_t/\delta_t} \end{aligned} \tag{5}$$

and represents the present discounted value of depriciation tax savings on a unit of investment divided by the effective tax rate.[5] At time $t+j,\ j \geq 1,\ \tilde{\delta}_{t+j}$ represents the per unit of capital depreciation of capital invested at time t. For example when $\delta_t = 6.5\%$, then $\tilde{\delta}_{t+1} = 6.1\%$ and $\tilde{\delta}_{t+2} = 5.7\%$. The fraction $(1-A)/(1-T)$ 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.[6]

The initial capital stock models were improved with capital instalment costs (see

[2] An empirical example in the spirit of eq. (2) 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. See also discussion in the data source; the National Economic Institute has a discussion of balance sheet measurement errors in its 90s business reports.

[4] See Mayes and Young (1993), Hall and Jorgenson (1967), Jorgenson and Yun (1991), Summers (1986), King and Fullerton (1983), OECD (1991) and Ellis and Price (2003). 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 comes from net worth maximisation and is sometimes not included in C.

[5] The second step in eq. (5) is obtained with the standard result for geometric series that $\sum_{n=1}^{\infty} ab^{n-1} = a/(1-b)$ when $|b| < 1$ and defining $a = \delta_t$, $b = (1-\delta_t)/(1+r_t)$.

[6] Hall and Jorgenson (1967) empirically find that tax policy is effective in changing the level and timing of investment and can cause a shift between investment categories. The government can also influence business investment through a crowding out effect. Considerable government investment demand and financing demand can raise the real cost of capital for the private sector. These effects are not considered further here, see Barro (1989) for a discussion.

references in Hayashi (1982)) and/or steady state assumptions. The resulting models 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 constant elasticity of substution (CES) production function and constant returns to scale which yields a first order condition[7]

$$k_t = a + y_t - \sigma c_t \tag{6a}$$

where lower case variables denote log values. Put $g_t = \Delta K_t / K_{t-1}$, rearrange the perpetual capital eq. (3) to get[8]

$$k_{t-1} = i_t - log(g_t + \delta_t). \tag{6b}$$

For the long run, eqs. (6a) and (6b) can be combined to give

$$i = b + y - \sigma c \tag{6c}$$

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

Modern investment models are usually intertemporal and usually assume the maximisation of the discounted firm value. The following is an example of such a model. Firms

[7]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 $K = (\alpha / C)^{\frac{1}{1-\phi}} Y$, $log(k) = \sigma log(\alpha) + log(Y) - \sigma log(C)$ where $\sigma = 1/(1-\phi)$.

[8]From (3), $g_t K_{t-1} + \delta_t K_{t-1} = I_t$, $log(K_{t-1}) = log(I_t) - log(g_t + \delta_t)$.

managers are assumed to make investment and debt decisions *as if* they maximise

$$
\begin{aligned}
V_t &= E_t\Big\{\sum_{s=t}^{T}\beta^{s-t}R_s|z_t\Big\} && \text{(7a)}\\
\text{s.t.}\quad & R_t=(1-\tau_t^i)\pi_t+K_t(\tau_t^iA_t-(1-B_t/K_t)\tau_t^p)-p_t^II_t+b_t, && \text{(7b)}\\
& \pi_t=p_t^Y[F(K_t,N_t,\xi_t)-G^K(I_t,K_t)-G^B(b_t,B_t)]-p_t^NN_t-p_t^BB_t, && \text{(7c)}\\
& F(K_t,N_t,\xi_t)=\xi_t[\alpha K_t^{\phi}+(1-\alpha)N_t^{\phi}]^{\frac{1}{\phi}}, && \text{(7d)}\\
& G^K=(\gamma^K/2)(I_t/K_{t-t})^2K_{t-1}, && \text{(7e)}\\
& G^B=(\gamma^B/2)(b_t/B_{t-1})^2B_{t-1}, && \text{(7f)}\\
& K_t=(1-\delta_t)K_{t-1}+I_t, && \text{(7g)}\\
& B_t=B_{t-1}+b_t, && \text{(7h)}\\
& Prob(lim_{t\to T}\beta^tB_t\le 0)=1, && \text{(7i)}\\
& z_t=\{\xi_t,p_t^Y,p_t^I,p_t^N,p_t^B,\delta_t,\tau_t^i,\tau_t^p,A_t\}, && \text{(7j)}\\
\text{given}\quad & \Theta=\{T,\beta,\phi,\alpha,\gamma^K,\gamma^B\} && \text{(7k)}
\end{aligned}
$$

where $\beta\in(0,1)$ is the discount factor, R is net receipts, $\tau\in(0,1)$ is the corporate tax rate, τ^i is income tax and τ^p is property tax, A is the present value of tax depreciation allowances per unit of K, for variable ν, p^{ν} is its price, K is real valued capital stock, I is real valued fixed investment, B is stock of debt where a positive B means the firm is a borrower and a negative B means the firm is a lender, b is net borrowing, N is an additional producton factor (which can easily be generalised to a vector but is almost reduntant here because of its static role in the model) assumed to have costless adjustment, F is a CES production function with a productivity shock ξ, production factor weight $\alpha\in(0,1)$ and elasticity of production factor substitution $1/(1-\phi)$ where $\phi<1$, G^K is a capital cost adjustment function and G^B is a debt cost adjustment function, eq. (7i) is a transversality condition, z is the information state and Θ contains the parameters of the model. Note that both I_t and b_t can be positive and negative. Define the Bellman equation for the model as

$$
\begin{aligned}
V(K_{t-1},B_{t-1},z_t) \;&=\; \max_{\{I_s,b_s,K_s,B_s\}_{s=t}^{T}}\Big\{R_s+\beta E_tV(K_s,B_s,z_{s+1})\Big\} && \text{(8)}\\
\text{s.t.}\quad & \text{eqs. } (7b)-(7j).
\end{aligned}
$$

This framework is standard but usually taxes and debt are not emphasised for simplicity (see Jorgenson (1963), Hayashi (1982), Fazzari et al. (1987), Gilchrist and Himmelberg (1995)). The property tax is zero in many countries and then redundant in the model. Investment purchasing subsidies could easily be added to the model. The model in eq. (8)

could be solved using Euler equation estimation or numerical methods and then building a likelihood function or use simulation estimators.

When the model in eqs. (7) is simplified it becomes the standard Tobin's Q model of investment. This version has a closed form solution under conditions discussed by Hayashi (1982) where the investment rate is determined by the Q ratio,

$$I_t/K_t = \gamma_0 + \gamma_1 (V_t^M/P_t^I - 1). \tag{9}$$

The ratio V_t^M/P_t^I is the *marginal Q* per unit of capital where V^M is the marginal value of capital.

There are four main simplifications in the model in eqs. (7) that should be noted. First, recent investment literature has emphasised nonconvex adjustment costs for investment instead of convex costs as assumed here (Caballero (1999), Cooper et al. (1999), Cooper and Haltiwanger (2002)). But it is not clear wether this nonconvexity is also an issue at the aggregate level (Thomas (2002)). Second, capital is assumed fully reversable. One way of relaxing these two strong assumptions is to change the value function from eq. (8) to

$$V(K_{t-1}, B_{t-1}, z_t) = max\{V^b(K_{t-1}, B_{t-1}, z_t), V^s(K_{t-1}, B_{t-1}, z_t), V^i(K_{t-1}, B_{t-1}, z_t)\} \tag{10}$$

where b refers to buying, s to selling and i to inactivity (Cooper Haltiwanger 1993, Cooper and Haltiwanger (2002), Adda and Cooper (2003)). Third, there still is no standard way in the literature about how to introduce (or test for) ”financial constraints” into investment models (see examples and references in Hubbard (1998), Caggese (2003)). In the eqs. (7) framework the cost of debt is added in a simple way with convex adjustment costs. Sometimes agency costs (Cuthbertson and Gasparro (1995)), stock issues and dividends (Corres et al. (1995)) and gearing dependent interest rate (Fazzari et al. (1987)) are also added to the model. Fourth, qualitative factors are ignored which could generate significant bias into the model (Corres et al. (1995)). The importance of these four issues at the plant level and in particular at the aggregate level is still an open issue in the investment literature and not pursued further here.

Another concern is the ignorance of trending depreciation rates and investment goods prices in many investment 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. 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) at the Bank of England 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) which estimate models with the first differenced investment rate as the dependent variable and has 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 a business sector investment. Managers are assumed to make investment decisions as if they behave according to this mechanism. 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.

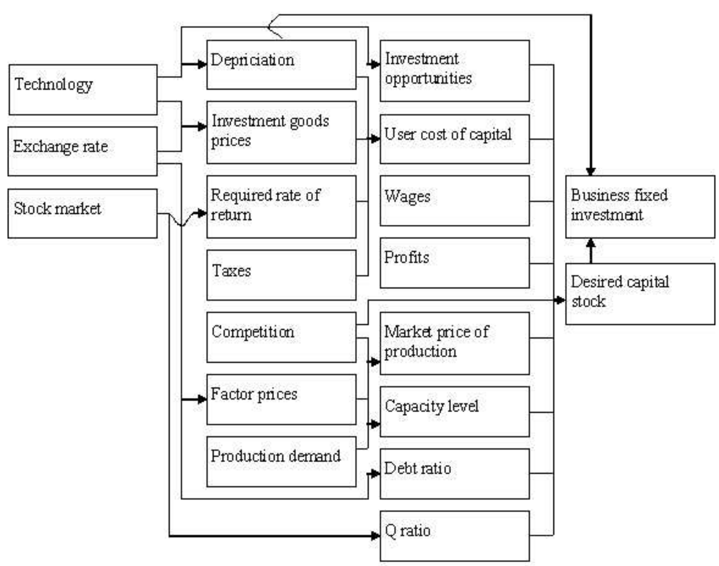

Figure 1: Business investment mechanism example.

[9]Replacement investment replaces depreciated capital stock, δK_t.

2.2 Data

This subsection contains empirical observations for the main issues from the investment theory presented in subsection 2.1. The data is annual and aggregate for Iceland. Appendix A contains data source information.

Historically, when production per unit of capital has been high (low), investment per unit of capital has overall been high (low) since 1979. Figure 2 shows the log ratios of investment and production to capital as well as the logs of capital and production. The

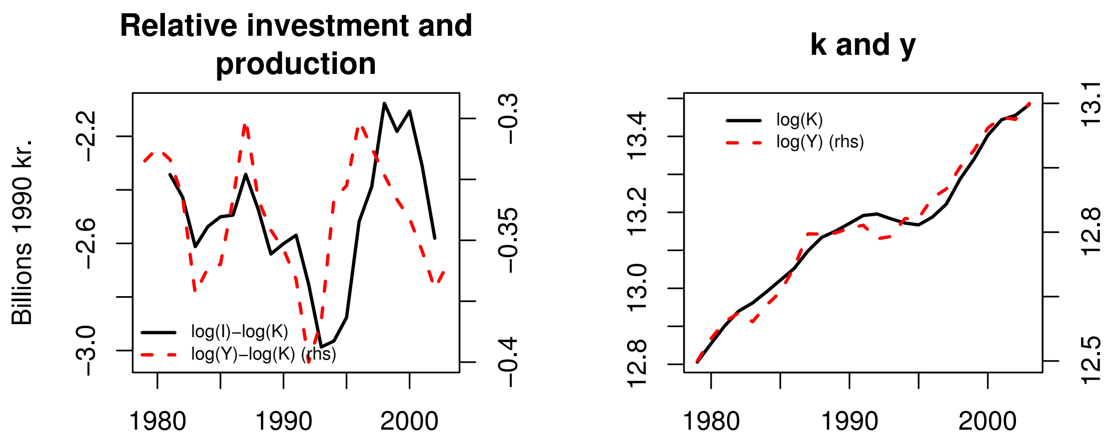

Figure 2: Investment, production and capital in log scales 1979-2003.

variability in the ratios is considerable in the sample period, in particular in the 90s. In the long run, the capital and production series seem to exhibit comovement 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 90s. 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 melting in 1992-1995 and 2002-2003 and transport in 1992-1997 and 1999. This capital fall in the 90s supports the use of the modified value function in eq. (10).

It is likely, however, that official investment figures are lacking some of the information technology (IT) investment as it had just begun and new methods needed to be applied to measure it.[10] But even though there might have been extraordinarily large measurement

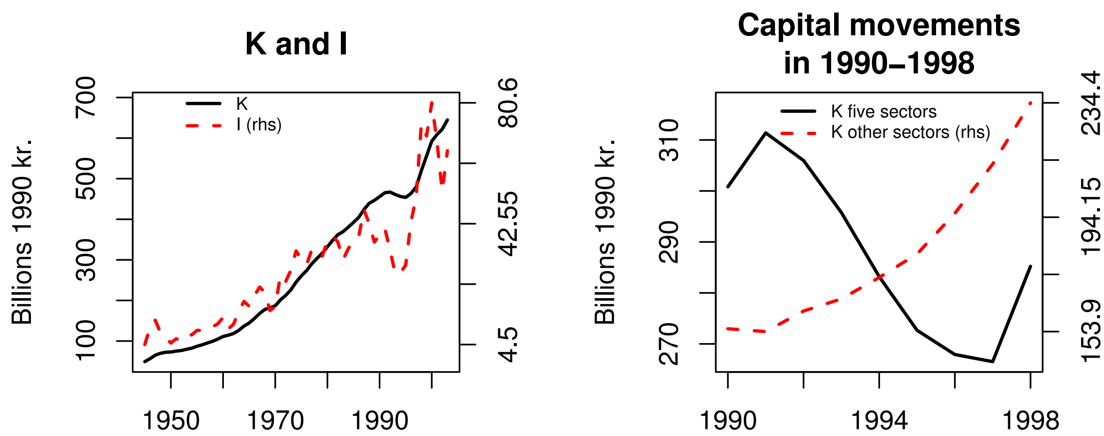

Figure 3: Left side shows business capital stock (K) and investment (I) over 1945-2002 in 1990 billions of kronas. Right side shows K over 1990-1998 split into two halves. One half is for five major business sectors' capital stock and the other half shows the rest.

errors in the beginning of the 90s, some indicators support the fall in the capital stock. Fisheries investment reached a two decade bottom,[11] interest rates were high and financial markets were not so developed that corporations could fully exploit the stock market financing route.[12]

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.[13] This trend in the ratio of investment prices and wages should cause a shift in production factors from labour to capital. The sharp fall in 1987 is due to a tax system structural change in that year.

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

[11]There was a fundamental structural change in the fisheries sector in 1983 and it is likely to have increased fisheries investment for some years.

[12]See also discussion and references in Sighvatsson et al. (2004).

[13]This observation can also be observed in terms of the *wages*/*prices* ratio positive trend.

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 of aggragate investment.[14]

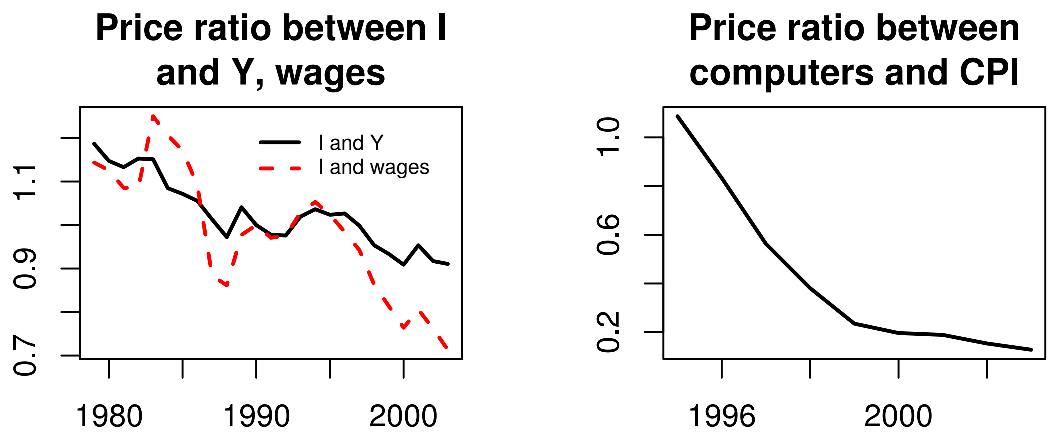

Figure 4: Relative price of business investment to gross domestic product (GDP) and wages 1979-2003 and relative price of computers to the consumer price index (CPI) 1995-2003.

Computers have been growing in importance in business activities. Currently around 60% of all employees in Iceland use computers regularly and 99% of firms have a computer with an internet connection according to a recent survey. 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 (Statistics Iceland, 2004). 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 a lack of Iceland IT investment data, 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 figures.

Figure 5 shows business investment categories 1997-2002 and also two estimates of IT's investment share in 1991-2002.[15] Computers are included in the office category (left figure) but in other investment goods are also bracketed there and some software investment might be missing. One estimate of IT's share of business investment (right

[14]Here information technology refers to computer hardware and software.

[15]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 n.e.c. (average share 3%).

figure) is conservative and the other is non-conservative. The non-conservative 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 current prices software investment 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 ICT's share of Icelandic investment in 1998 is around 28% and underestimated in official figures by around 20 percentage points.

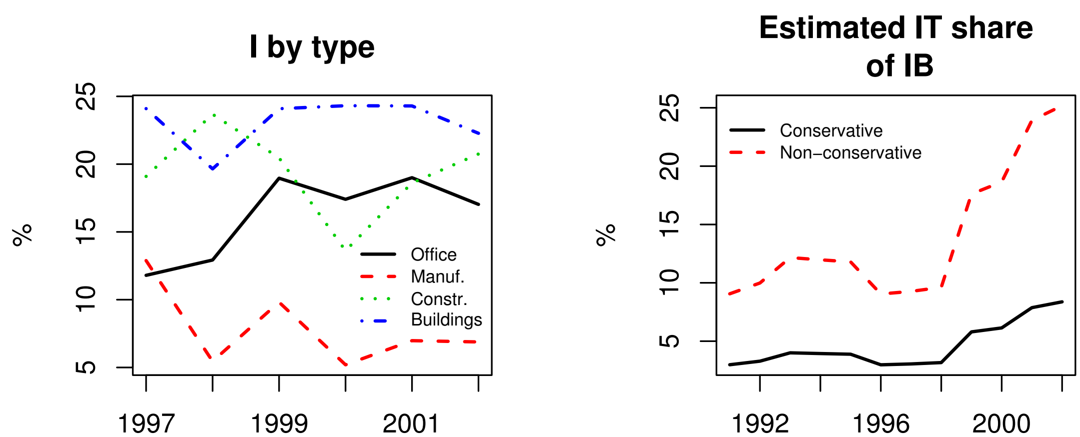

Figure 5: Four categories of business investment 1997-2002 and estimates of IT share of business investment 1991-2002. The categories of investment shown are: Office machinery and computers (Office), manufacturing machinery and equipment (Manuf.), construction other than buildings (Constr.) and buildings.

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 eq. (6a) where σ is the elasticity of production factors substitution, an x percentage point increase in C will decrease the demand for capital by $x\sigma$ percentage points. If for example $\sigma = 0.5$ then an increase in C by two per cent should decrease capital demand by one percentage point.[16] Figure 6 contains the estimated business real user cost of capital series as well as investment in log levels and

[16]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.

first differences. Figure 7 shows estimates of two policy series included in the user cost. A rise (fall) in the tax savings series should stimulate (discourage) investment. Simularly a fall (rise) in the policy series should stimulate (discourage) investment. Figure 7 shows

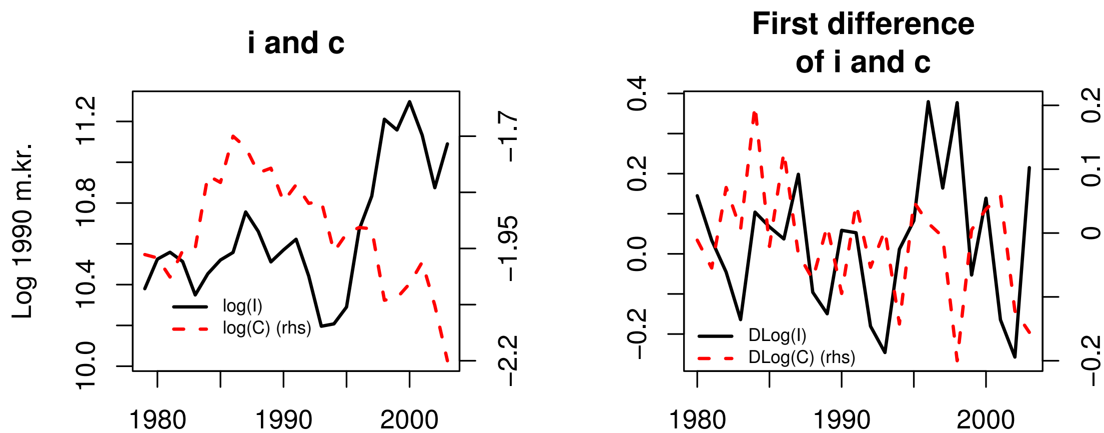

Figure 6: User cost of capital (C) in log levels and first differences 1979-2003.

estimates of $(1-A)/(1-\tau^i)$, $(1-\tau^i)$, r and τ^p.

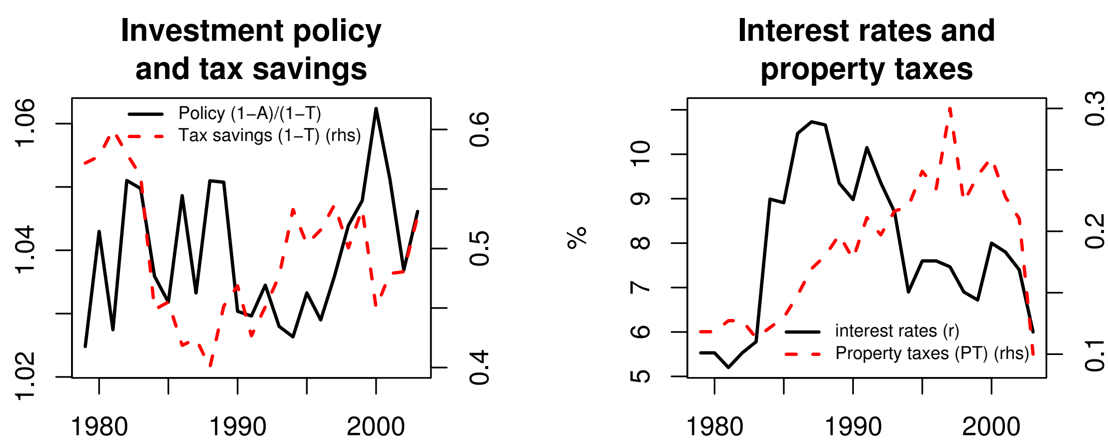

Figure 7: Investment policy and interest rates. Higher values of the policy series in the figure mean less investment incentive. The tax savings series represents present value tax savings for each investment unit.

The sample period in this paper is generally 1979-2003. The main reason for this short period is that a longer user cost series is hard to construct mainly 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

$$G_t = D_t / W_t \tag{11}$$

where D is debt and W is assets (wealth). W is defined as the capital stock at replacement cost but sometimes defined as total assets. Cuthbertson and Gasparro (1995) additionally subtract liquid assets from D. Figure 8 shows an estimate of gearing for the 1979-2002 period as well as investment in levels and first differences. From figure 8 there seems to be a comovement 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 which Hall (2001) also concludes for UK data.

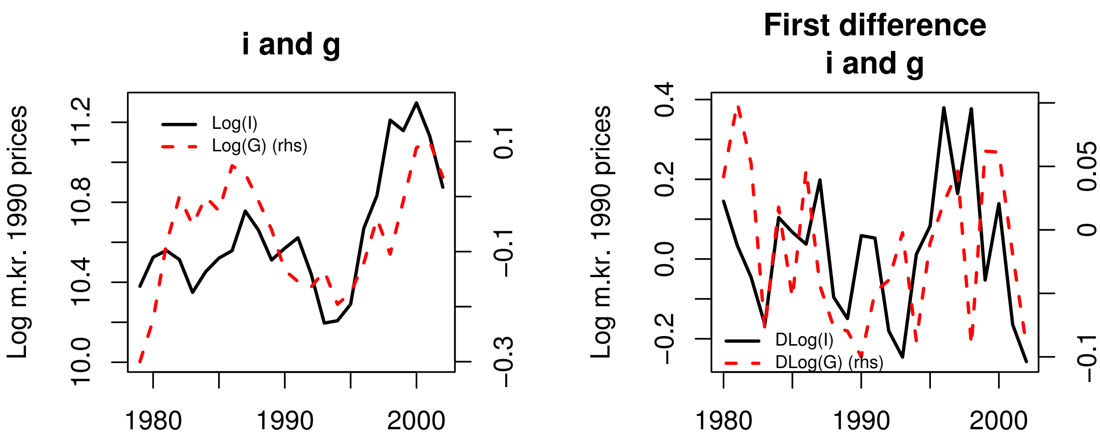

Figure 8: Investment and gearing 1979-2002 in levels and first differences.

Figure 9 shows investment and a simple estimate of the Iceland business average Q for 1981-2001. There is a comovement between the two variables according to the figure. The standard Q investment model as in equation (9) predicts a positive response of investment to the Q ratio. Figure 9 indicates that investment has a positive correlation with the Q ratio with a lag of one period or no lag. This is similar to the Blanchard et al. (1990) results for US investment.

Figure 10 shows the first difference of I and ROC with earnings before taxes (ET) in the numerator. The figure also has a comparison between ROC ratios with different

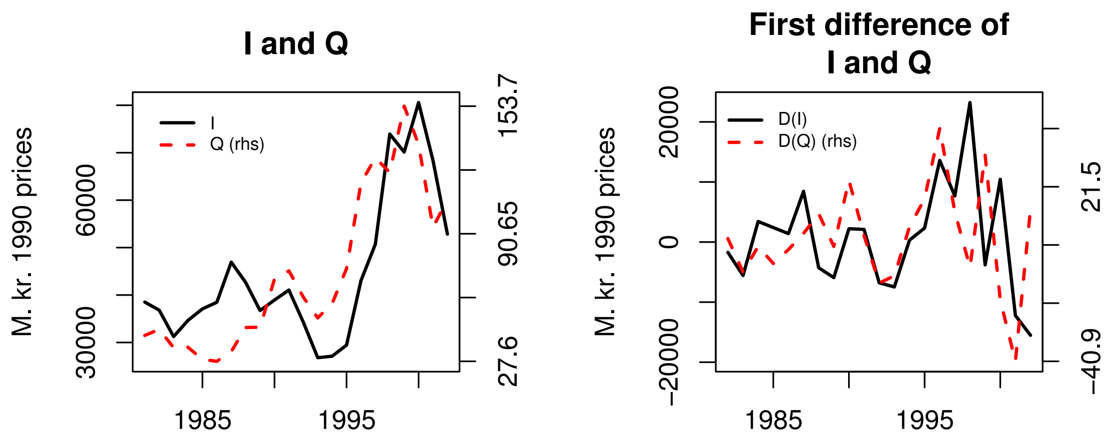

Figure 9: Investment and Tobin's Q ratio in levels and first diferences 1981-2002.

profit measures in the numerator. The timing of movements is almost identical for the profit measures over the second half of the sample period but around 1990 there are some differences. Over the sample period there is a positive response of investment to the *ROC*

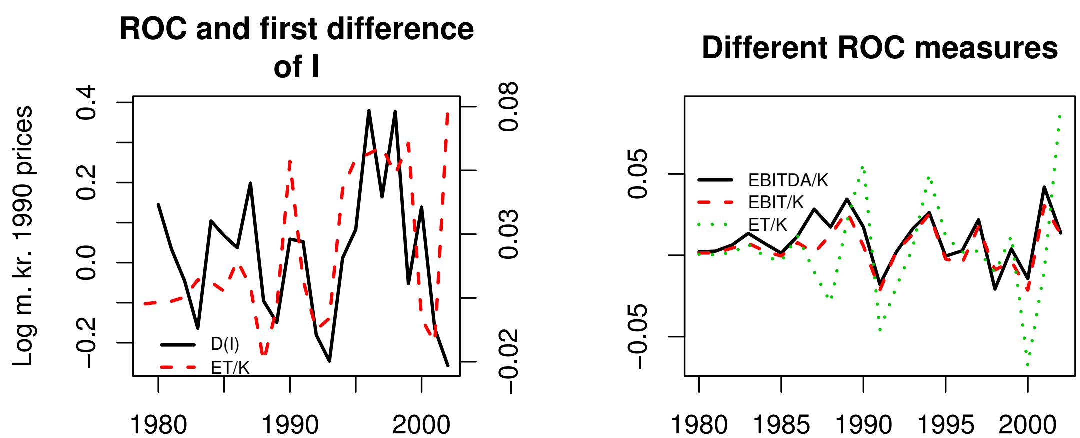

Figure 10: Left figure shows the first difference of business fixed investment 1979-2002 and level values of return on capital (*ROC*). Right figure shows first differences of nominal values of three different ROC measures.

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. Another possible link between profit and investment is that it is a special case of the accelerator model.[17] If profit is viewed as a

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

stable function of output then the role of profit for investment can be the same as the role of output.

Both the observations of comovements 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 eqs. (6a), (6b) and (6c). Note that the third cointegration space 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 are then used in a vector error correction model (VECM) and an ECM with additional short run regressors. The general VECM estimated is

$$\Delta x_t = \Phi D_t + \Gamma(L)\Delta z_t + \alpha\beta'(L)x_{t-1} + \varepsilon_t \tag{12}$$

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 matrix of "cointegration speed of adjustment coefficients" and β is a matrix of cointegration vector coefficients. Put

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

$$\Gamma(L)\Delta z_t = \sum_{i=1}^{s} \Gamma_i \Delta(i, k, y, c)'_{t-i} + \sum_{i=0}^{s} \Gamma_{i+s+1} \Delta(g, Q, E)'_{t-i} \tag{13b}$$

where D contains constants and the dummy variable $D9395$ which takes the value one in 1993-5 and zero otherwise, g is a log of a gearing ratio, Q is a Q ratio and E is a earnings

(ROC) ratio. When using the modified FOC in eq. (6c), eqs. (13) reduce to

$$\tilde{\alpha}\tilde{\beta}'\tilde{x}_{t-1} = \begin{pmatrix} \tilde{\alpha}_1 \\ \tilde{\alpha}_2 \\ \tilde{\alpha}_3 \\ \tilde{\alpha}_4 \end{pmatrix} \begin{pmatrix} \tilde{\beta}_1 & \tilde{\beta}_2 & \tilde{\beta}_3 \end{pmatrix} \begin{pmatrix} i \\ y \\ c \end{pmatrix}_{t-1}, \tag{14a}$$

$$\tilde{\Gamma}(L)\Delta\tilde{z}_t = \sum_{i=1}^{s} \tilde{\Gamma}_i \Delta(i,y,c)'_{t-i} + \sum_{i=0}^{s} \tilde{\Gamma}_{i+s+1}\Delta(g,Q,E)'_{t-i}. \tag{14b}$$

Table 1 contains the Phillips Perron (PP) test statistics for the cointegration variables. p values are in square brackets. All the variables appear to have a unit root. Figure 11

K	ΔK	Y	ΔY	C	ΔC	I	ΔI
-1,8	-2,1	-2,1	-3,8	-3,1	-6,7	-1,0	-3,7
[0,64]	[0,05]	[0,54]	[0,03]	[0,17]	[0,01]	[0,59]	[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%).

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.

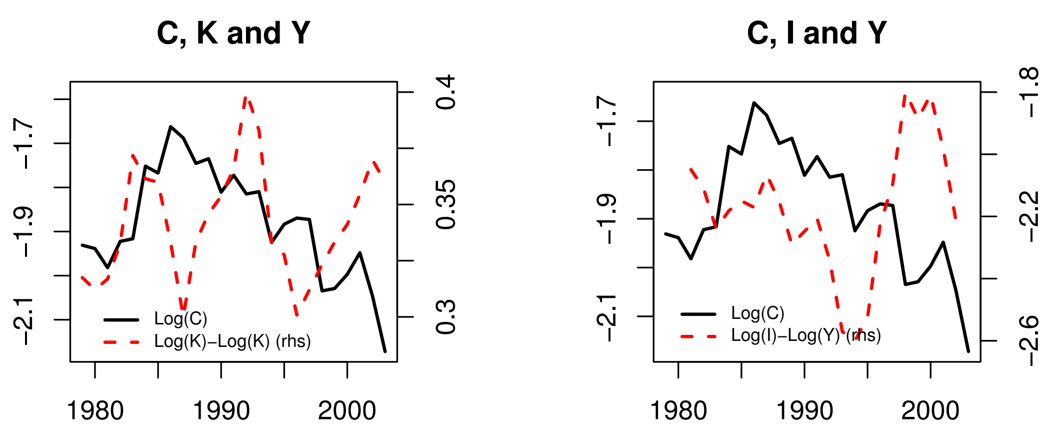

Figure 11: Cointegration variables.

Table 2 has cointegration tests for the cointegrating variables. From the table I conclude that in system (13) there are two vectors and in (14) there is one. This is as expected from the theory in section 2.1. Note, however, that a dummy variable $D9395$

with value one in 1993-5 and zero otherwise is included in the test. Without this dummy variable the results of the cointegration test change.

	Trace statistic	Max-Eigen statistic
H_0	$\{k,i,y,c\}$	
$r=0$	78.77^*	43.79^*
$r\leq 1$	34.98^*	21.87^*
$r\leq 2$	13.11	12.10
H_0	$\{i,y,c\}$	
$r=0$	$38,41^*$	26.80^*
$r\leq 1$	11.61	11.41
$r\leq 2$	0.21	0.21

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

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 are reported here.[18] 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. To choose the lag structure of the DOLS and Johansen tests, AIC (Akaike information criterion) and BIC (Bayesian information criterion) tests can be used as indicators.[19] Considering these indicators as well as the sample size, data frequency and t values, two lags (in first differences) are used for DOLS and 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 eq. (6a) does not have much role for the user cost of capital. Both the unrestricted and the restricted versions give estimates of σ with a wrong sign.[20] The capital investment cointegration vector from eq. (6b) estimate gives

[18]Full results are available on request from the author.

[19]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 $-\sigma$.

[20]However, the GE and DOLS procedures estimate 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.

unrestricted estimates of the i coefficient close to the expected value of 1. The likelihood ratio (LR) test for the restrictions of the VECM in (13) has a probability value of 0.00 and thus rejects the restrictions. The rejection of eq. (6a) and possibly eq. (6b) reduces to some extend the validity of the manipulations in eq. (6c).

Unrestricted			**Restricted**		
k	y	c	k	y	c
1	-1.44	-0.18	1	-1	-2.28
<...>	<0.07>	<0.08>	<...>	<...>	<0.67>
k	i		k	i	
1	-0.82		1	-1	
<...>	<0.07>		<...>	<...>	
i	y	c	i	y	c
1	-1.05	0.61	1	-1	0.65
<...>	<0.17>	<0.25>	<...>	<...>	<0.25>

Table 3: *Cointegration vectors* for the VECM in (12) with eqs. (13) and (14). Left side shows only normalised vectors and right side shows also vectors with coefficients restricted. Standard errors are between inequality brackets (<>). Unadjusted sample period of the estimation is 1979-2003. 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 eq. (6c) gives estimated coefficients fairly consistent with the Cobb-Douglas case of $\sigma = 1$. The user cost of capital coefficient (σ) is estimated 0.65 which is lower than implied by a Cobb-Douglas production function. The GE procedure gives similar results but DOLS has an estimate for σ of 0.80. The LR test for the restriction of the y coefficient to be 1 has probability value of 0.83 and thus does not reject the restriction. Further, restricting σ to be 1 and restricting the α coefficicents of y and c to be zero gives a probability value 0.30. This justifies Cobb-Douglas restrictions on the cointegrating vector in the model in eqs. (13) and a conditional ECM version of it as pursued in subsection 3.2.

Considering the cointegrating estimation results, the traditional FOC in eq. (6a) is not used further. Only the implied cointegrating vector $i = \text{const} + y - c$ is used in the VECM 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 constant means but not constant variances without the dummy variable.

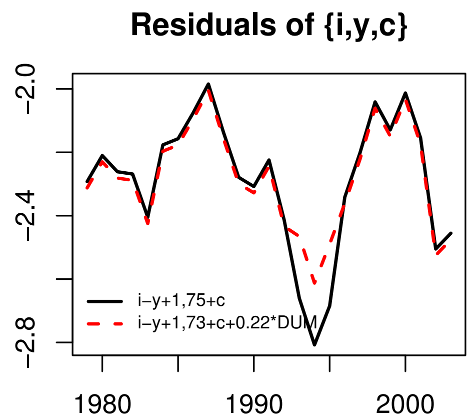

Figure 12: Cointegration residuals.

3.2 A conditional ECM for investment

The model is now reduced to a single equation ECM. Equations (12) and (14) give the general ECM. After excluding lags or variables based on t-values, expected signes of coefficients, adjusted R^2 ($\bar{R}^2$), AIC and BIC, the "simple" dynamic investment equation (15) emerges. A Breusch Godfrey LM test for serial correlation in eq. (15) with two

$$\begin{aligned}\Delta i_t &= -\underset{(-5.6)}{0.99} + \underset{(3.0)}{0.32}\Delta i_{t-1} + \underset{(1.7)}{0.18}\Delta i_{t-2} + \underset{(8.1)}{4.2}\,\Delta y_t + \underset{(1,3)}{0.36}\Delta E_{t-1} + \underset{(2.2)}{0.09}\Delta Q_{t-1} \\ &\quad - \underset{(-3.4)}{0.38}\,\Delta g_t - \underset{(-5.4)}{0.55}\,[i_{t-1} - y_{t-1} + c_{t-1}] - \underset{(-3.4)}{0.08}\,DUM9395_t. \qquad (15)\end{aligned}$$

$\bar{R}^2$	0.91
Standard error of regression	0.02
Jacque Bera	1.71 [0.42]
LM test for serial correlation	8.57 [0.01]
Unadjusted period	1979-2003

lags has probability value 0.01, thus the null of no serial correlation is rejected. The Jacque Bera test for normally distributed residuals has probability value 0.42, thus the null of normally distributed disturbances is not rejected. Cumulative sum (CUSUM) and CUSUM squared tests indicate that the residuals of the equation are stable over the whole sample period.

Table 4 contains an overview of the single equation cumulated response of investment in equation (15) to a 1% shock to the regressors. Earnings effects (E) 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 nine years. Investment response to a user cost shock steadily builds up to the long run effect with a slight oscillation.

Years	Y	E	Q	G	C
Simultaneous	4.2	0.0	0.00	-0.4	0.0
One year ahead	3.8	0.4	0.09	-0.3	-0.6
Two years ahead	2.9	0.3	0.07	-0.2	-1.0
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	...	...	...	2 years

Table 4: Cumulated shock response of investment from equation (15). Overshoots means that the short run cumulated response overshoots the long run response.

3.3 Stylised facts

Below are the main observed stylised facts for the data set for annual business fixed investment (I).

1. In the period 1993-1995 there was a first time officially measured decrease in business capital stock.

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

3. In the short run, gearing-, Q- and earning ratios have significant comovement with business investment.

4. The business required rate of return and property taxes as a fraction of capital have been falling in recent years.

4 Conclusions

As in many empirical analyses 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 here, financial markets and technology developments.

Business investment had high volatility and there was a decrease in the capital stock in the 90s. The explanations for this are probably both a structural change in the data generation 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. The other hypothised conitegration relation, between investment and capital, was statistically rejected.

The traditional first order condition did not comply well with the 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. The Q ratio and a profit ratio add explanatory power to dynamic single equation error correction models of investment.

A Data description and data

In this appendix are data descriptions and a datatable with a part of the time series used in the research. Details are not reported here or are minimal for widely available series.

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 eq. (4),

$$C_t = \frac{p_t^I}{p_t^Y}\left(r_t + \tau_t^p + \delta_t\right)\frac{(1-A_t)}{(1-\tau_t^i)}. \tag{16}$$

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 economic depriciation ratio, 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 eq. (5), r is the sum of government bond indexed 3-5 year required return and the additional private sector required return, set fixed here as 2%.[21][22]

[21]See table 5 in Mayes and Young (1993) for comparison. Caballero (1994) uses the same fixed risk premium as here.

[22]Ellis and Price (2003) and OECD (1991) represent r with a weighted real long run average business

Name: G. *Short description:* Business gearing (leverage). *Source:* National Economic Institute 1979-1997, Atvinnuvegaskyrslur. Statistics Iceland 1998-2002. *Frequency and period:* Annual 1979-2002. *Comments:* The movement of the ratio is more accurate than the level. The time series are 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. *Detailed description:* 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 official data definitions of business investment (1945-1990, 1990-1997, 1997-current). The 1997-2003 nominal values are used directly and previous 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.

Name: IIT. *Short description:* Business information technology investment. *Source:* Statistics Iceland. *Unit:* Millions of kronas current prices. *Frequency and period:* Annual 1990-2002. *Comments:* Rough approximation. *Detailed description:* Little data for business IT investment have been published in Iceland. Here figures from 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 English IT investment is estimated from the supply side. Here detailed disaggregated turnover figures are used for 2002 and backcasted using turnover in 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. 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 maintainance services and two thirds of small computers and software projects are investment. Tax regulations permit IT investment valued 130.000 kronas or less to be posted as expenses instead of investment. The ESA national accounts standard, in contrast, views IT purchases valued 500 euros or higher (around 45.000 kronas) to be investment. Because of this accounting figures would not sum up to the national account figures.

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required rate of return (real long run weighted average cost of capital).

Name: K. *Short description:* Business capital stock. *Source:* Statistics Iceland 1979-2003. *Frequency and period:* Annual 1979-2002. *Comments:* Rough approximations. *Detailed description:* For annual data there are three periods of different official data definitions of business investment (1945-1990, 1990-1997, 1997-current). The 1997-2003 nominal values are used directly and previous nominal values have the correct relative movements between years (chain linked). Quantity index figures 1979-1997 are used directly and 1998-2002 figures are chain linked.

Name: Q. *Short description:* Q ratio. *Source:* Accounting figures from the National Economic Institute 1979-1997, Atvinnuvegaskyrslur and Statistics Iceland 1998-2002. Stock price figures from the Iceland Stock Exchange and VIB before 1993. Dwelling prices are from Fasteignamat rikisins (The Land Registry of Iceland). *Unit:* Ratio, normalised to having average one. *Frequency and period:* Annual 1981-2001. *Comments:* Asset price data are considerably less reliable for the former part of the period. *Detailed description:* A simple accounting definition of Q (see Sveinbjörn Thoroddsen (1991), Wright (2004)) is

$$\begin{aligned} Q &\equiv \frac{\text{market price of equity}}{\text{book value of equity}} = \frac{\text{book amount of stocks} \times \text{stocks price}}{\text{book value of equity}} \\ &= \frac{\text{stocks price}}{\text{book value of equity} \Big/ \text{book amount of stocks}}. \end{aligned} \tag{17}$$

An general empirical implementation of the marginal Q in eq. (9) is the average Q defined as

$$Q_t \equiv V_t / \hat{K}_t \tag{18}$$

where V is the financial value of the firm and $\hat{K}$ is current value capital derived in the same way as K.[23] Blanchard et al. (1990) define the Q ratio as

$$Q \equiv \frac{\text{market value of equity} + \text{market value of debt} - \text{non interest bearing assets}}{\text{replacement cost of tangible assets}}. \tag{19}$$

Cuthbertson and Gasparro (1995) describe the Q ratio as the ratio of the market value of equity plus debt to the replacement value of trading assets. Tobin and Brainard (1977) estimate the market value with the stock (common and preferred) and debt at market prices where market prices are proxied with general indexes. Tobin and Brainard calculate the replacement cost as book value of stock (common and preferred), long term

[23] See Chirinko (1993) equation (15).

and short term debt. Jovanovic and Rousseau (2003) use e.g. similar numerator but the book value of preferred stock, long term debt and short term debt. In the denominator Jovanovic and Rousseau replace the market value of common stock with book value. 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 of e.g. (18) with only the stock price index in the numerator, normalized to having average one. End of the year smoothed stock prices are estimated as a centered average[24] of closing monthly market figures. The annual figures here 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 housing per square metre price index for the Reykjavik area.[25]

Name: E (ROC). *Short description:* Earnings over capital (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

$$ROC_t = \text{Profit}_t / \hat{K}_t. \tag{20}$$

where profit is current book value profits before income and property taxes and for data availability reasons, also excludes extraordinary income and costs. I call this profit measure profit from regular operation (earnings before direct taxes, ET). $\hat{K}$ is 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 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 amortization, EBITDA). Blanchard et al. (1990) subtract all taxes from earnings and use the net earnings measure of after tax profit for forecasing investment.

[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 a stock exchange was first founded in 1987 in Iceland. For similar reasons Thórarinn G. 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.

A.1 Data in table format

In table 5 is the main data set used in this paper.

	C ×100	G ×100	I	K	Q ×100	ROC ×100	Y
1979	14,5	70,8	32209,6	316231,5011	...	2,32	266056,6
1980	14,4	76,8	37233,9	332179,7756	...	2,40	281101,0
1981	13,7	89,0	38519,1	348128,0502	40,4	2,00	293090,0
1982	14,6	97,6	36805,4	361797,9998	43,4	2,32	299404,8
1983	14,7	92,4	31235,9	369544,3046	34,4	3,80	292964,2
1984	17,3	97,5	34663,3	380480,2643	34,5	2,92	305061,0
1985	17,1	95,0	37078,1	392327,5539	28,6	1,37	315106,2
1986	18,9	103,7	38480,2	404630,5086	27,6	3,37	334620,1
1987	18,4	102,0	46931,8	423768,4381	32,4	1,26	363402,5
1988	17,4	96,8	42647,6	439261,0476	44,3	-2,99	363182,3
1989	17,5	91,5	36727,5	446551,6874	44,5	-0,04	364190,3
1990	16,3	84,6	38947,5	455664,9872	68,3	5,62	368473,5
1991	17,0	82,8	41050,7	465233,9519	72,3	0,96	371180,7
1992	16,2	81,9	34273,8	467056,6118	59,3	-0,83	359007,7
1993	16,3	84,5	26795,9	461132,967	49,0	-0,40	361108,8
1994	14,6	79,2	27107,5	456120,6521	56,2	3,76	377238,4
1995	15,2	81,0	29444,3	453842,3272	73,4	4,61	377616,4
1996	15,4	85,8	43037,0	463411,2919	115,7	4,63	397040,4
1997	15,9	93,5	50709,7	479359,5665	128,2	4,75	405684,3
1998	13,6	87,3	73934,7	519625,7701	121,0	3,86	428172,0
1999	13,3	96,9	70131,5	556057,0971	153,7	4,75	446107,0
2000	14,2	107,4	80577,7	592488,4242	134,8	-0,35	471076,0
2001	14,3	108,7	68356,7	608786,6494	93,9	-0,93	483690,0
2002	13,1	101,4	52839,5	621729,3577	107,5	4,98	481114,0
2003	11,4	...	65516,9	644738,6169	...	...	500474,0

Table 5: Datatable.

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