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REAL ESTATE INVESTMENT AND UNCERTAINTY: ECONOMETRIC MODELLING USING FINNISH DATA

DECEMBER 2000
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JEL Classification: C 51, G 31, E 22, R 33

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Real Estate Investment and Uncertainty: 
Econometric Modelling using Finnish Data*

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December 28, 2000

Abstract
The purpose of this paper is to test for the effect of uncertainty in a model of real estate investment in Finland during the highly cyclical period of 1975 to 1998. We use two alternative measures of uncertainty. The first measure is the volatility of stock market returns and the second measure is the heterogeneity in the answers of the quarterly business survey of the Confederation of Finnish Industry and Employers. The econometric analysis is based on the autoregressive distributed lag (ADL) model and the paper applies a 'general-to-specific' modelling approach. We find that the measure of heterogeneity is significant in the model, but the volatility of stock market returns is not. The empirical results give some evidence of an uncertainty-induced threshold slowing down real estate investment in Finland.

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1 Introduction
Recent developments in the theory of investment under uncertainty has brought out the importance of irreversibility for the timing of investment decisions. Since

*We are grateful to Gunnar Rosenqvist, Timo Teräsvirta and participants in the NoonToNoon workshop 'Finance, Statistics and Stochastics', Helsinki, 26–27 October 2000 for useful comments and to Kajsa Fagerholm and Simo Launonen for help with the data. The authors are of course responsible for any errors.
the influential work by Dixit and Pindyck (1994), contributing by the insight that there is an option in the possibility to delay an investment decision, a number of papers have focused on the consequences for aggregate investment. However, neither the measurement problem nor the net effect of uncertainty on investment have been settled. In the basic Dixit and Pindyck analysis, the existence of an option produces a wedge between traditional net present value (NPV) analysis and the investment value including the option. Since the value of an option increases with the uncertainty about future returns, increased uncertainty will have a negative effect on irreversible investment. On the other hand and as shown earlier by Abel (1983), increased uncertainty can raise the marginal profitability of capital and therefore increase investment. In a more general model of irreversible investment proposed by Abel, Dixit, Eberly and Pindyck (1996), including both call and put options, the effect of uncertainty on investment is ambiguous.

Empirical studies of the relationship between investment and uncertainty have mainly produced evidence of a negative relationship.\(^1\) However, as noted by Carruth, Dickerson and Henley (2000), a high proportion of these studies use some derived variable measuring uncertainty. This raises concerns about the adequacy of model specification and whether the estimated relationship between investment and uncertainty is due to some omitted explanatory variable. Moreover, few studies use forward-looking measures of uncertainty.

Real estate investment is irreversible, at least in the medium to short run. Real estate markets typically exhibit patterns of prolonged cycles, with periods of underinvestment and overinvestment. Such behaviour is in line with the existence of an option-induced threshold level in investment, as pointed out in Dixit (1989 and 1992). Despite this challenging applicability of the contributions from the theory of investment under uncertainty to the field of real estate finance, there are few applications or empirical results concerning real options in this field.\(^2\) Examples of theoretical contributions include Grenadier (1995 and 1996), where the exercise of options is analysed and used to explain the persistence of real estate cycles. In Grenadier (1995), three factors are shown to influence overbuilding: construction lags, adjustment costs and uncertainty measured by the volatility of demand. The model in Grenadier (1996) predicts that property types with volatile demand would be most prone to concentrated bursts of development. Empirical tests of these predictions are, however, few and empirical models of real estate investment mainly deal with the persistency problem by including various lags.\(^3\)

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\(^1\) For a recent survey of the theory and empirical results on investment under uncertainty, see Carruth, Dickerson and Henley (2000). Recent studies of the investment-uncertainty relationship include Price (1995 and 1996) on aggregate data using conditional variance estimates from GARCH models as measure of uncertainty and Leahy and Whited (1996) on disaggregate data using the variance of stock returns as measure of uncertainty.

\(^2\) For a survey of real options in real estate finance, see e.g. Williams (1999).

\(^3\) See e.g. Kling and McCue (1987), Wheaton (1987) and Tsolacos, Keogh and McGough
The purpose of this paper is to test for the effect of uncertainty in a model of real estate investment in Finland during the highly cyclical period of 1975 to 1998. We contribute to the existing literature on the uncertainty-investment relationship using two alternative measures of uncertainty, one of which is a forward-looking variable measuring the heterogeneity of views about the future business climate. The econometric analysis is based on the autoregressive distributed lag (ADL) model and the paper applies a 'general-to-specific' modelling approach. The outline of the paper is the following. In Section 2 we briefly describe the Finnish real estate market and the data used in the paper. In Section 3 we present the statistical model and discuss the modelling strategy. Empirical results are then reported in Section 4. Some concluding comments are given in Section 5. The definitions of the variables and data sources are given in the data appendix.

2 The Real Estate Market and Data

2.1 The Finnish Real Estate Market

In the 1970s and until the middle of the 1980s the Finnish real estate market was regulated and dominated by a small number of market participants. In the beginning of the 1980s the market became more liquid and financial deregulation in the middle of the 1980s removed most of the regulations. This caused a financial boom and a rise in property prices and rents. The development was accelerated in the period 1987 to 1989, when the Finnish economy grew by 4.1, 4.9 and 5.7 per cent annually, respectively. The fast growth fuelled the demand for real estate and resulted in rising property prices. The boom induced rapid growth in the construction of commercial property. Some of the construction projects were based on expectations of rising property prices. There were some public policies in the late 1980s to restrain the real estate boom, but these policies were not very effective. In 1990 and 1991 an excess supply of real estate resulted in a sharp drop in property values, rents and construction. Real estate prices fell for four consecutive years by a total of over 50 per cent. Starting in the middle of the 1990s, the real estate market has slowly recovered.

2.2 The Data and Their Time Series Properties

This paper uses quarterly Finnish data for the time period 1975(1)–1998(4). The data set includes the following variables: real estate investment \( (i_t) \), gross domestic product \( (GDP, y_t) \), building costs \( (c_t) \), the interest rate \( (r_t) \), the volatility of stock market returns \( (v_t) \) and a measure of the heterogeneity of views about the future business climate \( (h_t) \). Lower-case letters denote logarithms, except
for the interest rate, the volatility of stock market returns and the heterogeneity measure. The data are described and data sources are given below. The figures in this section were produced using GiveWin (Doornik and Hendry, 1996).4

The real estate investment series (m 1995 FIM) includes all main types of real estate investment and is derived from the Quarterly National Accounts (QNA). Figure 1 shows real estate investment in level \((i_t)\), first difference \((\Delta i_t)\), fourth difference \((\Delta^4 i_t)\) and the real estate investment–GDP ratio \((i_t - y_t)\). The series is dominated by the strong seasonal variation. Note the negative trend in \((i_t - y_t)\).

The GDP series (m 1995 FIM) is derived from the QNA. Figure 2 shows GDP in level \((y_t)\), first difference \((\Delta y_t)\) and fourth difference \((\Delta^4 y_t)\). The trend in the level of \(y_t\) is clear, the average annual growth rate of GDP over the sample period is 2.44 per cent. Note the economic crisis in the beginning of the 1990s, when GDP declined by 12.5 per cent from 1990(1) to 1993(1).

Building costs are measured by the building cost index \((1964 = 100)\) published monthly by Statistics Finland. Prices usually behave as \(I(2)\) processes (Juselius, 1999). To avoid \(I(2)\) in the data, we use real building costs, defined as \((c_t - p_t)\), where \(c_t\) is nominal building costs and \(p_t\) is the implicit GDP deflator. The nominal-to-real transformation removes the \(I(2)\) component in the data.5 Note that \((c_t - p_t) \sim I(1)\) implies \((\Delta c_t - \Delta p_t) \sim I(0)\), so we only need to include \(\Delta c_t\) in the transformed data vector (Juselius, 1999). Figure 3 shows nominal building costs \((c_t)\), the implicit GDP deflator \((p_t)\), real building costs \(((c_t - p_t))\) and the first difference of real building costs \(((\Delta c_t - \Delta p_t))\).

We use the three month money market interest rate (Helibor) as our interest rate variable. The real interest rate is defined as \(r_t = R_t - \pi_t\), where \(R_t\) is the nominal interest rate and \(\pi_t = \Delta^4 P_t/P_{t-4}\) is the inflation rate. Figure 4 shows the nominal interest rate \((R_t)\), the real interest rate in level \((r_t)\) and first difference \((\Delta r_t)\).

We use two operational definitions of uncertainty. First we measure uncertainty by the volatility of daily stock market returns estimated from quarterly data \((v_t)\). Second we measure uncertainty by the heterogeneity of views about the future business climate \((h_t)\). This measure is derived from the quarterly business survey of the Confederation of Finnish Industry and Employers, in which firms are asked about their recent economic performance and their expectations of the near future. One of the questions (question 15) concerns business prospects in the near future. The firms give trichotomous answers and the alternatives are ‘better’, ‘the same’ and ‘worse’, respectively. The business survey is discussed

---

4The graphs in the figures are numbered from left to right and top to bottom as:

\[
\begin{array}{cc}
a & b \\
c & d \\
\end{array}
\]

5Formally, \(c_t\) and \(p_t\) must be \(CI(2, 1)\) with a coefficient of unity, i.e., \((c_t - p_t)\) must cointegrate from \(I(2)\) to \(I(1)\) (Kongsted, 2000).
in Rahiala and Teräsvirta (1993), who consider the predictive information in the answers. They find that the information is useful in predicting the next quarter’s industrial production. The heterogeneity measure is defined to be the entropy of this distribution and is computed as

\[ h_t = -\sum_{i=1}^{3} p_{it} \log_{10} p_{it}, \] (1)

where \( p_{it}, i = 1, 2, 3, \) are the relative shares of the alternative answers (Grimmett and Stirzaker, 1992, 300, Exercise 14). Figure 5 shows the volatility of stock market returns in level \( (v_t) \), first difference \( (\Delta v_t) \) and the heterogeneity measure \( (h_t) \). Stock market volatility seems to be increasing in the latter half of the sample period.

Corresponding to the two operational definitions of uncertainty, we have two information sets: \( \{i_t, y_t, (c_t - p_t), \Delta c_t, r_t, v_t\} \) and \( \{i_t, y_t, (c_t - p_t), \Delta c_t, r_t, h_t\} \). From Figures 1–5 it is clear that the series are not stationary, but the first differences look stationary. If we define \( X_t = (i_t, y_t, (c_t - p_t), \Delta c_t, r_t, v_t)' \), it seems reasonable to assume that \( X_t \sim I(1) \), i.e., integrated of order 1. The heterogeneity measure \( (h_t) \) is stationary by construction, so \( h_t \sim I(0) \). The sample period covers some major economic events that need to be modelled by dummy variables. The dummy variables used are defined in the data appendix.

### 3 The Statistical Model and Modelling Strategy

We consider a single-equation model for real estate investment \( (i_t) \). For single-equation inference to be valid and efficient there must be at most one cointegrating vector in the data and \( (y_t, (c_t - p_t), \Delta c_t, r_t, v_t, h_t) \) must be weakly exogenous for the long-run parameters defined by \( \beta \) below.\(^6\) This seems to be a reasonable assumption here. Since the data do not contain information to explain e.g. income or the interest rate, the estimated equations in a system would be descriptive equations beyond the equation for real estate investment. See Hendry (1999) for a similar approach.

We consider the autoregressive distributed lag (ADL) class of linear dynamic models given by\(^7\)

\[ \phi_0(L)y_t = \sum_{i=1}^{k} \phi_i(L)x_{it} + \epsilon_t, \quad \epsilon_t \sim NID(0, \sigma^2), \] (2)

where \( \phi_0(L) \) and \( \phi_i(L), i = 1, \ldots, k, \) are polynomials of orders \( p_0 \) and \( p_i \) in the lag operator \( L \), defined by

\[ \phi_0(L) = 1 - \phi_{01}L - \cdots - \phi_{0p_0}L^{p_0} \]

\[ \phi_i(L) = 1 - \phi_{i1}L - \cdots - \phi_{ip_i}L^{p_i} \]

\(^6\)The variable \( h_t \) is stationary, so it should not be in a cointegrating relation.

\(^7\)Note that in this section \( y_t \) is the generic notation for the dependent variable and not income. No confusion should result from this.
Figure 1: Real estate investment. Figure 1a shows real estate investment in level ($i_t$), Figure 1b the first difference ($\Delta i_t$), Figure 1c the fourth difference ($\Delta_4 i_t$) and Figure 1d the real estate investment-GDP ratio ($i_t - y_t$).
Figure 2: Gross domestic product (GDP). Figure 2a shows GDP in level ($y_t$), Figure 2b the first difference ($\Delta y_t$) and Figure 2c the fourth difference ($\Delta_4 y_t$).
Figure 3: Building costs. Figure 3a shows nominal building costs ($c_t$), Figure 3b the implicit GDP deflator ($p_t$), Figure 3c real building costs ($\left(c_t - p_t \right)$) and Figure 3d the first difference ($\left(\Delta c_t - \Delta p_t \right)$).
Figure 4: The interest rate. Figure 4a shows the nominal interest rate ($R_t$), Figure 4b the real interest rate in level ($r_t$) and Figure 4c the first difference ($\Delta r_t$).
Figure 5: The volatility of stock market returns and the heterogeneity measure. Figure 5a shows the volatility of stock market returns in level ($v_t$), Figure 5b the first difference ($\Delta v_t$) and Figure 5c the heterogeneity measure ($h_t$).
and
\[ \phi_1(L) = \phi_{i0} + \phi_{i1} L + \cdots + \phi_{ip_i} L^{p_i}. \]

There are \( k \) explanatory variables so \( X_t = (x_{1t}, \ldots, x_{kt})' \). The model can also include deterministic terms such as a constant, linear trend and dummy variables. The lag polynomial \( \phi_0(L) \) has \( p_0 \) roots and model (2) is stable if all roots of \( \phi_0(L) \) lie outside the unit circle.

We assume that \( y_t \sim I(1) \) and \( x_{it} \sim I(1), i = 1, \ldots, k \), and estimate model (2) in two stages. In the first stage we estimate the model in levels and solve for the long-run solution. The long-run solution is
\[ y_t = \sum_{i=1}^{k} \phi_{i0}^{-1}(1) \phi_i(1) x_{it}, \quad (3) \]
assuming \( \phi_{00}(1) \neq 0 \). Denote the long-run solution by \( y_t = \beta' X_t \). The long-run solution (3) is well-defined if \( (y_t - \beta' X_t) \sim I(0) \), i.e., \( y_t \) and \( X_t \) are cointegrated \( CI(1,1) \) with cointegrating vector \((1, -\beta')'\). In the second stage we reparameterize and estimate model (2) in error-correction form
\[ \psi_0(L) \Delta y_t = \sum_{i=1}^{k} \psi_i(L) \Delta x_{it} + \theta (y_{t-1} - \beta' X_{t-1}) + \epsilon_t, \quad \epsilon_t \sim NID(0, \sigma^2), \quad (4) \]
where
\[ \psi_0(L) = 1 - \psi_{01} L - \cdots - \psi_{0,p_0-1} L^{p_0-1} \]
and
\[ \psi_i(L) = \psi_{i0} + \psi_{i1} L + \cdots + \psi_{i,p_i-1} L^{p_i-1}, \]
\( \psi_0(L), \psi_i(L) \) and \( \theta \) are functions of \( \phi_0(L) \) and \( \phi_i(L) \) and \((y_{t-1} - \beta' X_{t-1})\) is the error-correction mechanism (ECM). The error-correction model (ECM) has the advantage that it combines long-run and short-run information in the data. The parameter \( \theta \) can be interpreted as measuring the adjustment to the long-run equilibrium defined by \( y_t - \beta' X_t = 0 \) and the parameters \( \psi_{ij}, i = 1, \ldots, k, j = 1, \ldots, p_i - 1 \), measure the short-run adjustment of \( y_t \) to changes in the explanatory variables \((x_{1t}, \ldots, x_{kt})\). In the second stage we use a conventional data based 'general-to-specific' modelling strategy (see e.g. Hendry, 1995).

4 Empirical Results

In the first stage the ADL model (2) with \( i_t \) as the dependent variable and the explanatory variables \( X_t = (y_t, (c_t - p_t), \Delta c_t, r_t, v_t)' \) is estimated by ordinary least squares (OLS). The variable \( h_t \) is \( I(0) \) and is not included in the ADL model for the long-run. The estimation period is 1977(1)–1998(4), so the number of observations is \( T = 88 \). The estimation and testing is done using PcGive 9.0
Table 1: Estimated coefficients for the ADL model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i$</td>
<td>-1</td>
<td>0.372</td>
<td>-0.244</td>
<td>0.221</td>
<td>0.515</td>
<td>-0.137</td>
</tr>
<tr>
<td>$se$</td>
<td>—</td>
<td>0.112</td>
<td>0.122</td>
<td>0.120</td>
<td>0.122</td>
<td>0.131</td>
</tr>
<tr>
<td>$y$</td>
<td>2.039</td>
<td>-1.271</td>
<td>0.255</td>
<td>-0.014</td>
<td>-0.443</td>
<td>0.567</td>
</tr>
<tr>
<td>$se$</td>
<td>0.358</td>
<td>0.431</td>
<td>0.467</td>
<td>0.456</td>
<td>0.472</td>
<td>0.342</td>
</tr>
<tr>
<td>$(c - p)$</td>
<td>-0.297</td>
<td>0.447</td>
<td>-0.440</td>
<td>-1.843</td>
<td>0.767</td>
<td>-1.366</td>
</tr>
<tr>
<td>$se$</td>
<td>0.705</td>
<td>0.673</td>
<td>0.711</td>
<td>0.715</td>
<td>0.683</td>
<td>0.531</td>
</tr>
<tr>
<td>$\Delta c$</td>
<td>1.548</td>
<td>0.420</td>
<td>0.177</td>
<td>1.977</td>
<td>1.747</td>
<td>5.869</td>
</tr>
<tr>
<td>$se$</td>
<td>1.213</td>
<td>1.078</td>
<td>1.019</td>
<td>0.949</td>
<td>0.875</td>
<td>2.350</td>
</tr>
<tr>
<td>$r$</td>
<td>0.252</td>
<td>0.239</td>
<td>0.069</td>
<td>0.412</td>
<td>-0.714</td>
<td>0.258</td>
</tr>
<tr>
<td>$se$</td>
<td>0.333</td>
<td>0.347</td>
<td>0.335</td>
<td>0.333</td>
<td>0.253</td>
<td>0.397</td>
</tr>
<tr>
<td>$v$</td>
<td>-0.163</td>
<td>0.032</td>
<td>-0.088</td>
<td>-0.073</td>
<td>-0.100</td>
<td>-0.392</td>
</tr>
<tr>
<td>$se$</td>
<td>0.087</td>
<td>0.087</td>
<td>0.094</td>
<td>0.098</td>
<td>0.091</td>
<td>0.184</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.160</td>
<td>2.865</td>
<td>2.865</td>
<td>2.865</td>
<td>2.865</td>
<td>2.865</td>
</tr>
<tr>
<td>Trend</td>
<td>-0.00167</td>
<td>0.00244</td>
<td>0.00244</td>
<td>0.00244</td>
<td>0.00244</td>
<td>0.00244</td>
</tr>
</tbody>
</table>

$R^2 = 0.975$ \hspace{1cm} $\hat{\sigma} = 0.047$ \hspace{1cm} $F(30, 57) = 73.617 (0.000)$

Table 2: Tests on the signiﬁcance of each variable in the ADL model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Distribution</th>
<th>Test statistic</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i$</td>
<td>$F(4, 57)$</td>
<td>18.836</td>
<td>0.000</td>
</tr>
<tr>
<td>$y$</td>
<td>$F(5, 57)$</td>
<td>10.813</td>
<td>0.000</td>
</tr>
<tr>
<td>$c - p$</td>
<td>$F(5, 57)$</td>
<td>3.230</td>
<td>0.012</td>
</tr>
<tr>
<td>$\Delta c$</td>
<td>$F(5, 57)$</td>
<td>2.258</td>
<td>0.061</td>
</tr>
<tr>
<td>$r$</td>
<td>$F(5, 57)$</td>
<td>2.690</td>
<td>0.030</td>
</tr>
<tr>
<td>$v$</td>
<td>$F(5, 57)$</td>
<td>1.217</td>
<td>0.313</td>
</tr>
</tbody>
</table>

(Hendry and Doornik, 1996). Table 1 reports the estimation results for the model with $k = 4$ lags for all variables, constant and trend. Table 2 reports tests on the significance of each variable in the model. All variables are significant in the model (at the 10 per cent level), with the exception of $v_t$. Table 3 reports tests on the significance of each lag and all lags 1–4. All lags are jointly significant (at the 5 per cent level) and only lag 2 is individually not significant. The test for common factors (Sargan, 1980 and Hendry and Doornik, 1996) suggests valid common-factor restrictions (test statistics not reported). We do not impose the common-factor restrictions since we are only interested in the long-run solution. We report some misspecification test statistics in Table 4. The diagnostic tests are all acceptable.
### Table 3: Tests on the significance of each lag and all lags in the ADL model.

<table>
<thead>
<tr>
<th>Lag</th>
<th>Distribution</th>
<th>Test Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$F(6, 57)$</td>
<td>2.772</td>
<td>0.020</td>
</tr>
<tr>
<td>2</td>
<td>$F(6, 57)$</td>
<td>1.508</td>
<td>0.192</td>
</tr>
<tr>
<td>3</td>
<td>$F(6, 57)$</td>
<td>3.402</td>
<td>0.006</td>
</tr>
<tr>
<td>4</td>
<td>$F(6, 57)$</td>
<td>5.528</td>
<td>0.000</td>
</tr>
<tr>
<td>1–4</td>
<td>$F(24, 57)$</td>
<td>15.734</td>
<td>0.000</td>
</tr>
<tr>
<td>2–4</td>
<td>$F(18, 57)$</td>
<td>17.988</td>
<td>0.000</td>
</tr>
<tr>
<td>3–4</td>
<td>$F(12, 57)$</td>
<td>8.410</td>
<td>0.000</td>
</tr>
<tr>
<td>4–4</td>
<td>$F(6, 57)$</td>
<td>5.528</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Table 4: Misspecification test statistics for the ADL model.

<table>
<thead>
<tr>
<th>Test</th>
<th>Distribution</th>
<th>Test Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM(5)</td>
<td>$F(5, 52)$</td>
<td>1.089</td>
<td>0.378</td>
</tr>
<tr>
<td>ARCH(4)</td>
<td>$F(4, 49)$</td>
<td>0.378</td>
<td>0.823</td>
</tr>
<tr>
<td>JB(2)</td>
<td>$\chi^2(2)$</td>
<td>1.961</td>
<td>0.375</td>
</tr>
<tr>
<td>RESET</td>
<td>$F(1, 56)$</td>
<td>2.073</td>
<td>0.156</td>
</tr>
</tbody>
</table>

**Notes:** LM(5) is the Lagrange multiplier (LM) test for residual autocorrelation up to order 5. ARCH(4) is the test for autoregressive conditional heteroscedastic residuals of order 4. JB(2) is the Jarque–Bera test for normality of the residuals. RESET is the regression error specification test.

The long-run solution is (standard errors in parentheses):

$$
\begin{align*}
i &= -23.081 + 4.139 y - 9.980 (c - p) + 42.866 \Delta c + 1.881 r - 2.864 v \\
&\quad - 0.01222 t.
\end{align*}
$$

(5)

The variables $c - p$, $\Delta c$, $r$ and $v$ are not significant in the long-run solution. The Wald test for the restriction that the coefficients on $c - p$, $\Delta c$, $r$ and $v$ are jointly zero is $W = 1.141$ with 4 degrees of freedom, so the restriction is accepted ($p$-value 0.888). Restrictions on the coefficients of $c - p$, $\Delta c$, $r$ and $v$ are also accepted individually (test statistics not reported). Imposing the restrictions that the coefficients on $r$ and $v$ are zero gives the restricted long-run solution (standard errors in parentheses)

$$
\begin{align*}
i &= -34.279 + 4.319 y - 3.696 (c - p) + 15.097 \Delta c - 0.02421 t.
\end{align*}
$$

(6)

Imposing further restrictions on the coefficients of $c - p$ and $\Delta c$ causes residual autocorrelation. We note that the estimated coefficients in the long-run solution have the expected signs, with the exception of the estimated coefficient on $\Delta c$. 


The estimates of the long-run elasticities of real estate investment with respect to income and real building costs are 4.319 and –3.696, respectively.

In the second stage we estimate two different ECMs in fourth differences to account for the seasonality in real estate investment. In the first model we include Δ₄vt as the measure of uncertainty, so the dependent variable is Δ₄it and the explanatory variables are Δ₄Xₜ = (Δ₄yt, (Δ₄cₜ − Δ₄pₜ), Δ₄Δcₜ, Δ₄vr, Δ₄vt)’. The ECM is estimated by OLS. The estimation period is 1978(1)–1998(4), so the number of observations is T = 84. Table 5 reports the estimation results for the model with k = 4 lags for all variables, constant and dummy variables. The dummy d792 accounts for the second oil crisis. The dummy d862 accounts for a strike in the building industry in the second quarter of 1986. The dummy d964 was added to the model after a first estimate revealed a large residual. Successive reductions of the model by deleting variables with insignificant t-values (at the 1 per cent level) yields an overall reduction test of F(27; 50) = 1.728 (p-value 0.047).

The final estimates for the first ECM are (standard errors in parentheses):

\[
\Delta_4i_t = -0.037 + 0.366 \Delta_4i_{t-1} + 1.655 \Delta_4y_t + 0.447 \Delta_4r_{t-1} - 0.077 \text{ecm}_{t-4} - 0.0942 d862 + 0.133 d964
\]

\[R^2 = 0.858 \quad F(6, 77) = 77.580 (0.000) \quad \bar{\sigma} = 0.043\]

\[\text{LM}(5) = 0.659 (0.656) \quad \text{ARCH}(4) = 0.205 (0.935)\]

\[\text{JB}(2) = 0.894 (0.640) \quad \text{RESET} = 0.321 (0.573)\]

We report some misspecification test statistics in Table 6. The diagnostic tests are all acceptable. The ECM cointegration test (Kremers, Ericsson and Dolado, 1992 and Hendry, 1995) is t_{ECM} = −3.668. The 5 per cent critical value from MacKinnon (1991) is −4.26, so formally the null hypothesis of no cointegration is not rejected. The value of the test statistic corresponds roughly to the 90 per cent quantile from Table 1 in MacKinnon (1991). Note that the test statistic t_{ECM} does not have a Dickey–Fuller (DF) distribution, so the DF critical value is only approximate (Kremers, Ericsson and Dolado, 1992). Simulation results in Kremers, Ericsson and Dolado (1992) and Ahlgren (2000) show that the distribution of t_{ECM} under the null hypothesis of no cointegration is well approximated by the DF distribution. Figure 6 shows the error-correction mechanism (ecm_t), which appears stationary. We therefore choose to maintain the hypothesis that i_t, y_t, (c_t − p_t) and Δc_t are cointegrated. Note that ecm_t is positive for most of the period 1990–1995, which explains the decline of real estate investment during the period.

Figure 7 shows the recursive parameter estimates with their approximate 95 per cent confidence intervals (±2se) and the recursive t-values. For most of the sample period the estimates are significantly different from zero and relatively
Figure 6: The error-correction mechanism ($ecm_t$).
constant. Figure 8 shows the 1-step residuals together with $\pm 2\hat{\sigma}_t$. Most of the 1-step residuals lie within their 95 per cent confidence intervals. We compute parameter constancy tests and the outcomes are summarized graphically in Figure 8. We report the 1-step Chow $F$-test, the breakpoint Chow $F$-test and the forecast Chow $F$-test (Hendry, 1995 and Hendry and Doornik, 1996). The test statistics are scaled by their 5 per cent critical values at each possible breakpoint, so values above the straight lines at unity indicate rejection of the null hypothesis of constant parameters. Most of the 1-step tests are insignificant, but there seems to be some instability around 1993. The breakpoint and forecast tests are not significant, so constancy is not rejected.

The estimated short-run elasticity of real estate investment with respect to income is 1.655 and is smaller than the long-run elasticity. The coefficient on the lagged fourth difference of the real interest rate ($\Delta_4 r_{t-1}$) has the wrong sign, possibly suggesting some simultaneity bias. The lagged fourth differences of the volatility of stock market returns ($\Delta_4 v_t$) are not significant in the ECM. The error-correction term ($ecm_{t-4}$) has a coefficient of $-0.077$. The coefficient is interpreted as follows. Approximately 7.7 per cent of the equilibrium error of

<table>
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<th>2</th>
<th>3</th>
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</table>

$R^2 = 0.927$ \quad \hat{\sigma} = 0.038 \quad F(33, 50) = 19.117 (0.000)$

Table 5: Estimated coefficients for the ECM.
Figure 7: Recursive parameter estimates with their approximate 95 per cent confidence intervals ($\pm 2se$) and the recursive $t$-values for the ECM.
Figure 8: 1-step residuals and parameter constancy tests for the ECM.
real estate investment is corrected within the next quarter. The error-correction is rather slow. Finally, the strike dummy $d_{862}$ and the dummy $d_{964}$ are significant at the 1 per cent level. Including the most significant lag of $\Delta_4 v_t$ gives the final estimates (standard errors in parentheses):

$$\begin{align*}
\Delta_4 v_t &= -0.036 + 0.373 \Delta_4 v_{t-1} + 1.629 \Delta_4 y_t + 0.448 \Delta_4 r_{t-1} \\
&\quad - 0.058 \Delta_4 v_{t-2} - 0.074 ecm_{t-4} - 0.093 d_{862} + 0.131 d_{964} \\
R^2 &= 0.860 \quad F(7, 76) = 66.966 (0.000) \quad \hat{\sigma} = 0.043 \\
LM(5) &= 0.725 (0.607) \quad ARCH(4) = 0.132 (0.970) \\
JB(2) &= 1.112 (0.574) \quad RESET = 0.237 (0.628).
\end{align*}$$

We note that $\Delta_4 v_{t-2}$ is not significant in the ECM ($t$-value $-1.151$, $p$-value 0.254).

In the second model we include $h_t$ as the measure of uncertainty, so the dependent variable is $\Delta_4 i_t$ and the explanatory variables are $\Delta_4 X_t = (\Delta_4 y_t, (\Delta_4 c_t - \Delta_4 p_t), \Delta_4 \Delta v_t, \Delta_4 r_t, h_t)^\prime$. The full estimation results are not reported.\(^8\) Successive reductions of the model by deleting variables with insignificant $t$-values (at the 1 per cent level) yields an overall reduction test of $F(25, 51) = 1.081$ ($p$-value 0.396). The final estimates for the second ECM are (standard errors in parentheses):

$$\begin{align*}
\Delta_4 i_t &= 0.050 + 0.356 \Delta_4 i_{t-1} + 1.616 \Delta_4 y_t + 0.420 \Delta_4 r_{t-1} - 0.247 h_{t-2} \\
&\quad - 0.072 ecm_{t-4} - 0.097 d_{862} + 0.143 d_{964} \\
R^2 &= 0.867 \quad F(7, 76) = 70.540 (0.000) \quad \hat{\sigma} = 0.042 \\
LM(5) &= 0.621 (0.684) \quad ARCH(4) = 0.104 (0.981) \\
JB(2) &= 1.272 (0.529) \quad RESET = 0.000 (0.991).
\end{align*}$$

\(^8\)The full estimation results (including misspecification tests and parameter constancy tests) are available from the first author on request.

Table 6: Misspecification test statistics for the ECM.
We note that $h_{t-2}$ is significant in the ECM ($t$-value $-2.208$, $p$-value $0.030$) and the other estimated coefficients do not change much. The diagnostic tests are all acceptable. The ECM cointegration test is $t_{ECM} = -3.508$, so formally the null hypothesis of no cointegration is not rejected. The recursive parameter estimates, $t$-values and the parameter constancy tests indicate some instability coming from the estimated coefficient for $h_{t-2}$, but constancy is not rejected.

5 Discussion and Conclusions

The purpose of this paper was to test for the effect of uncertainty in a model of real estate investment in Finland during a highly cyclical period. We estimate an autoregressive distributed lag (ADL) model and use a 'general-to-specific' modelling approach. The first stage estimation gives a long-run solution for real estate investment with all the estimated coefficients having the expected signs, but only income is significant. In the second stage we reparameterize and estimate the model in error-correction form and test for the significance of two measures of uncertainty. The measures of uncertainty used are stock market volatility and the heterogeneity in the answers of the quarterly business survey. Stock market volatility is insignificant in the model, but we obtain a negative and significant coefficient for the variable measuring the heterogeneity of views about the future business climate. The results in this paper therefore give some evidence of an uncertainty-induced threshold slowing down real estate investment in Finland.

References


A Data Definitions

The definitions of the variables and data sources are given below.

\[ I_t = \text{Real estate investment (m 1995 FIM). Source: Quarterly National Accounts (QNA).} \]
\[ Y_t = \text{Gross domestic product (m 1995 FIM). Source: QNA.} \]
\[ C_t = \text{Monthly building cost index (1964 = 100). Source: Statistics Finland.} \]
\[ P_t = \text{Implicit GDP deflator. Source: QNA.} \]
\[ R_t = \text{Nominal interest rate (3 month Helibor). Source: Bank of Finland.} \]
\[ v_t = \text{Volatility of stock market returns. For each quarter the volatility is computed as the standard deviation of daily stock market returns measured by the HEX stock market index. The volatility is multiplied by } \sqrt{250}, \text{ with } 250 \text{ being the approximate number of trading days per years. Source: Swedish School of Economics, Department of Finance and Statistics.} \]
$h_t = \text{Heterogeneity in the answers of the quarterly business survey of the Confederation of Finnish Industry and Employers. Question 15: Business prospects in the near future. The heterogeneity measure is computed as}
\[ h_t = - \sum_{i=1}^{3} p_{it} \log_{10} p_{it}, \]
where $p_{it}, i = 1, 2, 3$, are the relative shares of the trichotomous answers 'better', 'the same' and 'worse'. Source: Confederation of Finnish Industry and Employers.

d792 = 1 in 1979(2) and 0 otherwise.
d862 = 1 in 1986(2), d862 = -1 in 1987(2) and 0 otherwise.
d964 = 1 in 1996(4) and 0 otherwise.