Determinants and Forecasting of House Prices
ABSTRACT

This is an empirical study which goal is to determine what causes changes in housing prices. It is done by using data for Stockholm and Sydney to create a model to forecast the change of house prices in the two cities. The findings suggest that the main determinants are nominal interest, household income, and the supply of new dwellings. This is in line with previous studies. It is also investigated whether the use of financial indicators such as the development of the stock market has an impact on the house prices. The findings regarding the implication of the financial indicators are dubious. Lastly, an investigation is made to see whether the so-called “ripple effect” can be applied to an international level. The inclusion of the ripple effect seems to be positive to the forecasting models used in this paper.

Keywords: Housing, House price, Forecasting, Ripple effect
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1. INTRODUCTION

The housing market is an important indicator of how the economy of a country is performing. So, what causes changes in the aggregated price level of housing? The aim of this thesis is to gain a deeper knowledge of what causes price changes on the housing market. To do this, I will firstly present a theoretical model that describes how price formation of housing occurs in a market economy. With help from the theory I will construct a model which can, to a reasonable degree, predict the fluctuations of prices on the housing markets in two cities; Stockholm, capital of Sweden and Sydney, capital of New South Wales, Australia. The two cities will be treated independently and sometimes differently. The choice of using the two cities is mainly because they share a number of characteristics such as they are both the economic centre of a relatively small nation but still different enough for an interesting comparison.

Two forecasting models will be used, one simple and one more advanced. The optimal procedure to test the forecasting models would be to wait a few years after the calculation is made and then see how well the forecasts worked. Unfortunately this was not possible for this thesis. I have used three different techniques to determine whether the forecasts are accurate. The first is simply to apply the model to the data used to construct the forecast, from now on called technique 1 or just (1). The second way of forecasting is to leave the last two years out of the estimation, and later make a forecast for these two years (technique 2 or (2)). The third technique is to collect data for a second city in respective county\(^1\) and apply the forecasting model to the data from that city to test the accuracy of the forecasting. To avoid the biasness of different size of the second city, I will for this last technique of testing converted all variables to the percentage change of the original parameter (technique 3 or (3)).

\(^1\) I have chosen Gothenburg and Melbourne since they are second largest city in each county and therefore should share the most characteristics with the primary cities of all cities in respective country.
Estimations of the forecasting parameters will at first be made through OLS regression. To counter the problem of one-off deviations in the parameters the same estimations will later be made with an ARMA (Auto Regressive Moving Average) model to gain more consistent results. The models will be evaluated by their forecasting abilities; better forecasting ability should indicate that the model specifies the correct parameters that determine house prices. The forecasting ability is evaluated by calculating the Mean Absolute Error (MAE) of the predicted change in comparison to the actual price change. Finally, I will test whether the forecasting models can be improved by applying two new parameters to the estimations. The first of these parameters is to apply the “ripple effect” to an international level, and the second is to use financial indicators such as the development on the stock market as an indicator of house price changes. The significance level used are generally the 5 % level if not stated otherwise.

Many earlier studies have been done on this topic. On the Swedish market Hort (1998) comes to the conclusion that income, user cost, and construction cost have significant impact on house prices. Barot and Yang (2002), on the other hand put emphasis on interest rate (both nominal and real), net financial wealth (instead of income), and household debt to explain fluctuations in house prices in Sweden and the UK. In a study of data from the US, Jud and Winkler (2002) find that population growth, income, construction costs and interest rates strongly influence house prices. The ripple effect in the UK has been confirmed by Meen (1999) and (MacDonald & Taylor, 1993). The outcome of this survey is in line with earlier findings, though a bit simplified with fewer explanatory variables than most of the previous literature. This paper indicates that the main determinants of house prices are nominal interest, household income and the supply of new dwellings. The findings also suggest that the accuracy of the forecasting model can be improved by applying the ripple effect on an international level.

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2 Several earlier studies conclude that construction costs are influential to housing prices. I use the number of new dwellings instead which should be highly correlated to construction costs.
2. THE DATA

The data used in this survey is mainly collected from the respective national statistics agencies, Statistics Sweden (SCB) and the Australian Bureau of Statistics (ABS). Most of the data is collected on a yearly basis from the mid 1980s to 2006. The starting point of the data is in some instances as late as 1990. Even though this is a problem, the minimum estimation has a range of 15 years. The range covers more than a price cycle\(^3\), which makes it usable for estimation of future house prices. In addition the main focus of the paper is to determine the determinants of housing prices. This will still be possible even though the forecasts are not as accurate as they would be if the estimations were made over a longer period of time, or for example used quarterly data. The house prices are taken from SCB’s statistics of purchase price for detached houses in Stockholm County (län) (SCB, 2007a) and in the case of Australia the ABS’s House Price Index for Capital Cities (ABS, 2007a). Both are in nominal terms since the aim of the survey is to examine which factors influence the nominal house prices rather than in real values.

The variables with which this paper tries to explain the fluctuation of house prices are as follows: income, interest rate, the stock of houses in respective city, new construction of housing and wealth. The variable “income” is taken from the disposable income in nominal terms for Stockholm County (SCB, 2007b). Since data are not available for Sydney I have used data for Australia (ABS, 2007b) as a proxy for the income of Sydney residents. This might not be entirely accurate but when estimating forecasting the change of the explaining variables are more important than the actual level of the variable and the change in income of Sydney residents should be highly correlated with the change in income for residents of Australia. Both nominal and real interest is used in the survey since different models specify either. The variable for interest rate used for Stockholm is

\(^3\) The housing market tends to be cyclical with a period of high increases in property prices to be followed by lower increase and even falling prices for a couple of years. Such a cycle tends to be about 10 years from start to finish (Leung, 2004).
the Swedish Central Banks Mortgage bond\(^4\); the corresponding variable for the Sydney survey is the Australian banks standard interest rate for housing loans (RBA, 2007a).

The real interest has been calculated by subtracting consumer price index (SCB, 2007c & ABS, 2007c) from the nominal interest rate. Wealth is also used as a regressor when forecasting house prices. The concept is a bit indistinct but for both Sydney and Stockholm, the stock of assets (SCB, 2007d & ABS, 2007d) for households has been used in the respective country and divided by the country’s population (SCB, 2007e & ABS, 2007e). The stock of housing in Stockholm is taken from SCB’s calculated number of detached houses in Stockholm County (SCB, 2007f) and in Sydney from the Census of Population and Housing (ABS, 2007f & ABS, 2007g) with additions from “New South Wales in Focus” (2006) and “Yearbook Australia” (2006). Also used is the number of new dwellings in the respective city, in Stockholm the SCB’s new constructed detached houses for Stockholm County (SCB, 2007h) has been used. For Sydney no such statistics are available, instead the number of building approvals has been used to measure the increase (or decrease) of the number of houses in NSW (ABS, 2007g). Data for Gothenburg comes from the same sources as respective data for Stockholm. The same applies to the Melbourne data.

3. THEORY

The price of housing is determined on a capital market that Wheaton & DiPasquale (1996) describes with a model shown in figure 1 where the “stock” is the current stock (of square meters\(^5\)) of housing in a particular city or area. The “cost of owning” (CO) is the total annual cost associated with owning your own housing, such as interest payments. If the tenant does not own his house but is renting from a landlord the rent is the same as the cost of owning for self-owned occupants. The “price” is the actual price a

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\(^4\) A Mortgage Bond is a promissory note issued by a mortgage institution to finance its long-term home mortgage lending (Riksbanken, 2007).

\(^5\) Note that I will use the number of houses instead of m\(^2\) in the later empirical study; the same goes for the construction of new housing.
household pays to purchase a house (or apartment). Lastly “construction” is the annual new construction of housing (in square meters) in the city or area.

Cost of owning (SEK)

The upper right hand quadrant shows the demand for housing depending on the existing stock of and the annual cost of owning the house. The demand curve can shift upwards (downwards) when the number of households that demand housing at the current annual cost of owning increases (decreases). Since the stock of housing can be assumed to be fixed in the short run (Anderson, von Essen & Turner, 2004), this quadrant shows how the annual cost of owning your house is determined from the stock of housing through the demand-curve.

To acquire the price level of housing in the economy, move to the upper left-hand quadrant of figure 1. The curve “P” in this section of the model translates the annual cost of owning a house or an apartment to the price of the house using a capitalization rate (i): $P = \frac{CO}{i}$. The capitalization rate is mainly made up by the real-interest rate and an increase of the interest rate makes the P-curve rotate clockwise around the origin. Higher

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6 In the case of a tenant renting his apartment or house from a landlord the cost of owning axis is replaced by the rent specified in the lease.
interest will lower the price of a house if the annual cost of owning remains unchanged\(^7\). The capitalization rate is comprised not only by the interest rate but also, for example influenced by the government tax-code for housing.

In the bottom left-hand quadrant of the model the amount of new housing constructed is determined. The curve \(P_C\) represents the cost of replacing real estate and it points down and left because the cost of new construction is assumed to increase with higher building activity\(^8\) (C). The curve doesn’t go through origin but crosses the price-axis to the left of the construction-axis because there needs to be some value (the distance origin to where \(P_C\) crosses Price-axis) to the new property that is to be constructed. The curve is more vertical if new real estate construction can be supplied at the same cost, if however there are impediments in the development of new real estate like for example shortage of land that make new construction more expensive (inelastic supply of housing) the curve is more horizontal. The amount of new housing is generated by taking the price-level from the upper left-hand quadrant down to the cost-of-replacement-curve and then over to the construction-axis to the right of the quadrant. Lower construction would result in excess profits due to shortage of supply of housing and higher construction would lead to excess supply thus being unprofitable to the construction companies. Hence the level of new construction (C) is determined to be at the level where the price of housing (P) is equal to cost of replacement (\(P_C\)).

The remaining quadrant (the bottom right-hand one) is converting the flow of new construction to the long-run stock of housing. The curve, S, represents the depreciation of the current stock of housing, i.e. the amount of new housing needed to keep the stock constant (\(\Delta\)Housing=0). The more vertical the curve is, the higher is the depreciation rate and more new construction is needed to keep the stock of housing unchanged. This part

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\(^7\) In the case of a tenant renting his apartment from a landlord, the capitalization rate is the yield that investors (the landlord) demand to hold real estate assets. It is dependent on the same variables as the case of owner-occupied housing but also for example expected future rents and risk involved in renting.

\(^8\) This is amongst other causes because land gets more expensive and higher demand for construction workers makes building more expensive (Wheaton & DiPasquale, 1996).
of the model only shows how much new housing is needed to replace the depreciation in the economy and assumes that the stock of housing is constant over time. The market is in equilibrium when you complete a full rotation, from the level of stock, in a counter-clockwise motion back to the level of stock and end up at the same level of stock as when you started. If you don’t end up at the same level of stock as you started from, the market is not in equilibrium and cost of owning, price and construction will have to adjust.

3.1 Positive demand shock

If the demand for housing increases (for example from economic growth or changes in demographics), the demand-curve shifts up/right, since the stock of housing is fixed the CO must increase\(^9\) which makes the price level increase. Increased price level mean that more construction projects can be made profitable and therefore the level of construction increases, which in turn increases the stock of housing in the city concluding the adjustment to a new market equilibrium (see figure 2).

\[^9\] Actually the price increases which means that the CO increases. The reason for this backward impact in the model is that the model’s original form of has rent instead of CO and an increase in demand mean that the landlords can increase the rent from it’s tenants and because of this the price of real estate will increase.
3.2 Change in interest rate

If the long-term real interest rate increases, or for example new tax-regulations make it more expensive to own a house, the P-curve rotates clockwise (see figure 3). The increased interest rate lowers the price of housing since a household now can spend less on housing at the same level of CO. The lowered price makes construction of new real estate less profitable, thus lower construction reduces the stock of housing. This means that the cost of living has to increase since the same number of people has to share less housing.

![Figure 3: Increase in long-term interest rates](image)

3.3 Change in supply

The supply of new housing can be affected by changes in short-term interest rates or government regulations (Wheaton & DiPasquale, 1996). If, for example, the short-term real interest rate falls there will be a positive supply change (see figure 4) increasing production of new housing which in turn results in an increased stock of housing. Increased supply of course leads to lower cost of owning and lower prices on the housing market. When the housing prices are the same when starting and finishing the lap around the four squares of the model, equilibrium is reached.
4. VARIABLES

The price formation on the housing market seems quite simple when considering the above theory but what external factors hide behind these neat abbreviations in the theory? To start with, I assume the depreciation of the housing stock to be fixed; through this the bottom right quadrant will have no impact on house prices. In the upper left-hand quadrant, where the interest makes its impact, you can either use real interest or the nominal. Do households only consider the nominal interest while assessing their financial situation when buying a house? In an efficient market it is the real interest that should be used as explanatory variable but since the market is not efficient (Meen, 1999) and information about the rate of inflation is not as easily accessible as the interest rate, I still consider it dubious whether to use nominal or real interest. Therefore I will use both at different times in my analysis.

4.1 A simple model of forecasting

Drake (1993) uses a very simple model where he only includes disposable income, mortgage interest rate and the number of houses that started construction to set up a model to forecast UK house prices in the early 1990s. I believe that it would be more
accurate to use the number of completed houses instead of number of houses that started construction. *Equation 1* shows my version of Drake’s (1993) forecasting model, from now on called the “simple model”.

\[
\ln(P) = \beta_1 + \beta_2 \ln(Y) + \beta_3 R + \beta_4 \ln(B)
\]  

(1)

Where \(P\)= price (or indexed price), \(Y\)=disposable income, \(R\)=mortgage interest rate and \(B\)= number of new dwellings. One flaw in this estimation is due to the availability (or lack of it) of data regarding newly constructed dwellings. In the case of Stockholm I use data for completed housing, however in the case of Sydney no such data is available, I have used the statistics for building approvals in New South Wales (NSW). This is a drawback but considering Sydney make up more than half of NSW’s population I assume it can be used as a good enough proxy. Since an increase in income should increase demand for housing, the expected sign for the variable “income” is positive. The interest is according to theory expected to have a negative sign since higher interest increases the cost of owning which decreases the house prices. Also “new dwellings” are expected to be negative since increased supply should reduce house prices. The result of the estimation of the simple model is presented *table 1*.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sydney</td>
<td>Stockholm</td>
<td>Sydney</td>
<td>Stockholm</td>
<td>Sydney</td>
<td>Stockholm</td>
</tr>
<tr>
<td>Income</td>
<td>2.817 (0.00)</td>
<td>2.190 (0.000)</td>
<td>2.789 (0.000)</td>
<td>2.157 (0.000)</td>
<td>0.924 (0.399)</td>
<td>3.476 (0.000)</td>
</tr>
<tr>
<td>Interest</td>
<td>0.002 (0.885)</td>
<td>0.026 (0.146)</td>
<td>0.002 (0.881)</td>
<td>0.028 (0.094)</td>
<td>0.254 (0.717)</td>
<td>-1.688 (0.066)</td>
</tr>
<tr>
<td>New dwellings</td>
<td>0.174 (0.512)</td>
<td>0.278 (0.001)</td>
<td>0.212 (0.56)</td>
<td>0.277 (0.000)</td>
<td>0.170 (0.367)</td>
<td>-0.006 (0.971)</td>
</tr>
<tr>
<td>Constant</td>
<td>-25.516 (0.001)</td>
<td>-14.575 (0.001)</td>
<td>-25.570 (0.002)</td>
<td>-14.182 (0.001)</td>
<td>2.889 (0.705)</td>
<td>4.344 (0.544)</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.935</td>
<td>0.979</td>
<td>0.909</td>
<td>0.981</td>
<td>0.073</td>
<td>0.667</td>
</tr>
</tbody>
</table>

*Table 1: Results from regressions using simple forecasting model (p-value in parenthesis)*

As seen in *table 1*, “income” has the expected sign since an increase in income would increase the house prices according to the theory above. Strangely enough the two other variables does not have the expected sign in all but one case (the percentage regression...
for Stockholm. If this model reflects the true conditions, a one percent increase in disposable income will increase the house prices by 2.8 percent in Sydney and 2.2 percent in Stockholm. This seems to be quite a lot but since the number of regressors in the model is limited, it is close at hand to think that the variable for income reflects effects from other variables that have not been included in the model.

The remaining two variables show that if the interest rate increases by one percent, house prices are virtually unaffected in Sydney and increase by 0.26 percent in Stockholm and that a similar increase in new housing would increase the average house price by 0.17 percent in Sydney and 0.28 percent in Stockholm. These findings contradict the theory, however only the only statistically significant variable is the “New dwellings” in Stockholm. One explanation for the positive sign on “interest” could be that high house prices are usually a sign of high activity in the economy and interest is increased to cool down the economy, which could result in high house prices at a high interest rate and vice versa. In a similar manner the positive sign for “new dwellings” might come from the high prices on new dwellings. The above theory is for a long run steady state and the short-run adjustments can differ this state. For example, if lots of new houses are built, they might increase the price in the short run since new houses are more expensive than older ones. Another explanation might be that increased prices makes new construction more profitable and therefore increase construction. In the longer run however the increased supply might lower the price on the old dwellings – lowering the aggregated price level. The percentage change regression for Sydney shows a very bad fit (R² of only 7.3%), however the corresponding regression for Stockholm is the only showing expected sign for all three explanatory variables and a good fit.

When testing forecasting using the technique of only regressing variables until 2004 and then forecast the last two years in the dataset (technique 2), the outcome was not very good for Sydney with a mean error of just less than 5 percent and 8 percent for Stockholm. In spite of the bad forecasting abilities one must say that it is the latter years of the time series that show the largest differences between the calculated result and the real outcome. It is likely that this affects the second techniques forecasting abilities
negatively and the result would probably have been better if other periods were forecasted. The results from applying the secondary city (Gothenburg & Melbourne) data on the regression values of the primary city (Stockholm & Sydney) can be seen in table 2 together with result from forecasting using the other two techniques.

<table>
<thead>
<tr>
<th>Forecasting Technique 3</th>
<th>Regression City</th>
<th>Data City</th>
<th>Mean Error</th>
<th>Mean Absolute Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stockholm</td>
<td>Stockholm</td>
<td>-0.003%</td>
<td>4.24%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gothenburg</td>
<td>0.75%</td>
<td>3.83%</td>
</tr>
<tr>
<td></td>
<td>Sydney</td>
<td>Sydney</td>
<td>-0.0004%</td>
<td>6.00%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melbourne</td>
<td>0.70%</td>
<td>5.91%</td>
</tr>
</tbody>
</table>

| Forecasting Technique 2 | Stockholm | 8.51% |
| Forecasting Technique 1 | Stockholm | -0.41% |
|                        | Sydney    | -0.42% |

*Table 2: Errors when forecasting using the simple model*

When applying the percentage regression the mean error is very low for both Stockholm and Sydney, this is not surprising since the forecast is done on the same data that are used to make the forecast. More remarkable however is that the MAE is smaller for both of the alternative cities than the respective primary cities. This in combination with a small mean error for both cities suggests that this simple equation has some good (but not great) forecasting abilities, particularly when regressing the change of each variable instead of using the logarithm (which produces less favourable results).

**4.2 Life Cycle Approach**

The above model shows that you with relative simple means can make forecasts with an acceptable level of accuracy. A slightly more advanced equation to forecast house prices, and commonly used multi purpose model, is called the life-cycle model. The theory behind this approach is that households always try to maximize the (expected) utility from the consumption of housing and other goods and services under a life time budget constraint (Meen, 1999). This implies that the household is not limited by its current income when buying a new house; it takes advantage of expected future income. This would make the adjustment process from exogenous shocks as shown in the previous
chapter less direct since the household can spread the effect of the shock over its lifetime. The basics of the model are an arbitrage condition, which can be seen in equation 2.

\[
\frac{R(t)}{g(t)} + \frac{\dot{g}(t)}{g(t)} + \pi(t) - \delta(t) = (1 - \theta(t)) \cdot i(t)
\]  

(2)

\(R(t)\) = Marginal rate of substitution between housing and consumption  
\(g(t)\) = Purchase price of dwellings  
\(\theta(t)\) = Household marginal tax  
\(i(t)\) = Market interest rate  
\(\delta(t)\) = Depreciation rate on housing  
\(\pi(t)\) = General inflation rate (depreciation of financial assets)  
\((\dot{\cdot})\) = Time derivative

(Meen, 1999)

This is a versatile model that has been used to model risk and credit market constraint (Meen, 1999). It does have some flaws, it assumes that the housing market is efficient, i.e. the price of a house reflects all currently available information. This is most likely not true, several studies have rejected the assumption of efficiency on the housing market, especially in the US (Gatzlaff & Tirtiroglu, 1995) and there is no reason to believe that either the Swedish or Australian housing market should be different. This said, it is widely recognized as a good model that captures the important points of house pricing when using time series data (Meen 1999). When using equation 2 to determine house prices it can be rearranged to equation 3.

\[
g(t) = \frac{R(t)}{(1 - \theta(t)) \cdot i(t) - \pi(t) + \delta(t) - \frac{\dot{g}(t)}{g(t)}}
\]  

(3)

Since \(R(t)\) is a hypothetical value, which is hard to determine in empirical use, it is substituted by its expected determinants. Meen (1999) uses real income (RY), wealth (W) and demographic factors (H) on the demand side while using the size of the housing stock (HS) on the supply side. The model is usually presented in logarithmic form (see equation 4).
\[
\ln(g) = f(\ln(RY), \ln(W), \ln(H), \ln(HS), \ln \left( (1 - \theta) i + \delta - \frac{g}{g} \right)) \quad (4)
\]

A problem with this equation is the last term, which represents real interest. It can under
some circumstances be a negative number, which cannot be logarithmic. Usually the
method to deal with this is to express a semi logarithmic relationship between real house
prices and interest rate. In the data for this survey the real interest is not negative for any
of the countries that makes it possible to use it in the survey. The regression with which I
will test this method of forecasting is given by \textit{equation 5}, from now on called the “life
cycle model”.

\[
\ln(P) = \beta_1 + \beta_2 \ln(RY) + \beta_3 H + \beta_4 \ln(W) + \beta_5 \ln(HS) + \beta_6 RI \quad (5)
\]

As the demographic factor (H) I use, in accordance with Brown, Song & McGillivray
(1997), the percentage of population under 26 years of age. This is because this age group
is less likely to move than the other which in the above theory will shift the demand
curve down/left and ultimately lead to a decrease in house prices if the part of under 26”s
increases. The factor (RY) will affect the demand curve in an opposite fashion if the
income of the population increases. An increase in the factor HS (Stock of housing) will
cause the house prices to fall by shifting the P\textsubscript{C}-curve down/left. As shown, \textit{equation 5}
gets input from all quadrants of the theoretical model and should therefore be more
accurate in explaining house prices than the simple model. The results from estimating
the life cycle model are shown in \textit{table 3}. 
<table>
<thead>
<tr>
<th>Kind of regression</th>
<th>Logarithm regression</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Sydney</td>
<td>Stockholm</td>
</tr>
<tr>
<td>Income</td>
<td>0.899</td>
<td>8.874</td>
</tr>
<tr>
<td></td>
<td>(0.604)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Part of Under 26”s</td>
<td>0.479</td>
<td>0.676</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.116)</td>
</tr>
<tr>
<td>Wealth</td>
<td>1.075</td>
<td>-0.451</td>
</tr>
<tr>
<td></td>
<td>(0.094)</td>
<td>(0.257)</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.082)</td>
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<tr>
<td>Interest</td>
<td>-0.018</td>
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<td></td>
<td>(0.655)</td>
<td>(0.882)</td>
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<td>Constant</td>
<td>-161.285</td>
<td>166.777</td>
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<td></td>
<td>(0.023)</td>
<td>(0.122)</td>
</tr>
<tr>
<td>R²</td>
<td>0.962</td>
<td>0.960</td>
</tr>
</tbody>
</table>

Table 3: Results from regression using the life cycle model (p-value in parenthesis)

In table 3 the variables for “income” and “interest” show expected sign for most of the regressions even though only the “income”-variable in Stockholm are statistically significant. The demographic variable only showing expected sign in the percentage regressions and yet again generally not significant results. The sign of the other two regressors vary between the cities. The interpretation of the logarithmic equations is that if the average income in Sydney increases by one percent, the average house price will increase by 0.899 percent. This sounds reasonable in contrast to the corresponding value for Stockholm that predicts house prices to increase by 8.874 percent from a one percent increase in disposable income. This number seems a bit too high but it is hard to determine why the model shows these results. The Demographics variable is consistent and fairly similar in both the logarithmic regressions where it should be interpreted as a one percent increase of the ratio of under 26’s to the population as a whole, the house prices increase by 0.47 and 0.73 percent.

As with “income”, the variable “wealth” looks good for Sydney but not for Stockholm, it is hard to believe that an increase in wealth would cause a decrease in housing prices. If the general wealth of the population would increase it should cause an increase in
demand, which according to the above theory increase the house prices. The supply-
variable also shows some strange characteristics in this model. According to the theory a
bigger stock of housing should decrease the price of housing, this is the case in the
Stockholm regression but the value seems a bit high, I find it hard to believe that a one
percent increase in the stock of housing would lower the average house price by more
than a fifth. In opposite fashion the value of the average Sydney house would increase in
value by almost 10 percent when the stock of housing increases by one percent. Lastly
the variable for interest is consistent with the theory since the model predicts a price fall,
although very marginal, when the interest increases. In short the model seems to have
some inconsistencies when you compare it to the theory.

The outcome of forecasting when using equation 5 was not very satisfying; results can be
seen in table 4. The model showed many deviations from the theory and the extreme
values of the variable “stock of housing” is likely to impact the forecasting abilities
negatively. This could be because of a badly specified model but since the fact that it is
widely used in other surveys and the extreme values of some variable makes me more
inclined to think that the model would show better fit with other data sets. It was noted
that the results was much more favourable when using nominal interest instead of real
interest (see table 4) in the regressions which is why nominal interest has been used all
through the survey. This is in line with findings in Schwab (1981).

<table>
<thead>
<tr>
<th>Regression City</th>
<th>Data City</th>
<th>Mean Absolute Error</th>
<th>Real interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecasting Technique 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stockholm</td>
<td>Stockholm</td>
<td>4.66%</td>
<td>6.68%</td>
</tr>
<tr>
<td></td>
<td>Gothenburg</td>
<td>4.37%</td>
<td>6.65%</td>
</tr>
<tr>
<td>Sydney</td>
<td>Sydney</td>
<td>2.69%</td>
<td>4.11%</td>
</tr>
<tr>
<td></td>
<td>Forecasting Technique 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stockholm</td>
<td></td>
<td>11.74%</td>
<td>14.28%</td>
</tr>
<tr>
<td>Sydney</td>
<td></td>
<td>18.56%</td>
<td>20.59%</td>
</tr>
<tr>
<td></td>
<td>Forecasting Technique 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stockholm</td>
<td></td>
<td>6.42%</td>
<td>6.39%</td>
</tr>
<tr>
<td>Sydney</td>
<td></td>
<td>6.09%</td>
<td>7.54%</td>
</tr>
</tbody>
</table>

*Table 4: Results of forecasting using the life cycle model*
Since data for the stock of housing in Melbourne does not exist, the city has not been
used in this section. The errors in the logarithmic forecasts are at the same level as for the
previous equation. As in forecasting using the simple model, the MAE is smaller for the
alternative city; this is an indication that the model has good forecasting abilities, at least
for Stockholm. The main problem is still that the predictions are not accurate enough. An
Absolute Error of more than four percent is not very good. Reasons for this might be bad
dataset or a poorly specified model.

5. IMPLEMENTATION OF AN ARMA-MODEL

One problem of the above models is that the housing markets do not react instantly to the
change in the explaining variables. Big changes in exogenous variables will get too much
of an impact when using simple OLS regression. To counter the problem of inaccurate
predictions one way is to use an autoregressive moving average (ARMA) model. This
introduces two new elements to the modelling. The first being an autoregressive element,
this means that it not only uses the explanatory variable as input but also past values of
the dependent variable. In short the present change in price is being determined by the
explanatory variables and house price changes in the past. The second new element is the
usage of moving average of the variables; hence a one-off deviation in one of the
variables will not affect the outcome as much as before. These improvements should have
a positive impact since the earlier estimations show low mean average but a rather high
absolute mean average.

One important condition when using the ARMA model is that the time series must not
have a unit root (Berg, 2000). To test whether the house prices in respective city has a
unit root, the Augmented Dickey-Fuller test (ADF) was used. The result from the ADF-
test is shown in table 5.

<table>
<thead>
<tr>
<th>Type of data</th>
<th>City</th>
<th>Test Statistic</th>
<th>Critical Value (10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage change</td>
<td>Sydney</td>
<td>-4.634</td>
<td>-2.630</td>
</tr>
<tr>
<td></td>
<td>Stockholm</td>
<td>-2.990</td>
<td>-2.630</td>
</tr>
<tr>
<td>Price or indexed price</td>
<td>Sydney</td>
<td>1.247</td>
<td>-2.630</td>
</tr>
<tr>
<td></td>
<td>Stockholm</td>
<td>0.335</td>
<td>-2.630</td>
</tr>
</tbody>
</table>

Table 5: Test statistic for Augmented Dickey-Fuller test with one lag
As seen in table 5, the hypothesis of unit root could be rejected on the 10 percent level for both cities when using the percentage change, which makes it possible to use ARMA. The result also indicates that I cannot use the logarithmic estimations since the null hypothesis cannot be rejected for the price-series of either city. The result of the ARMA-estimation of the life cycle model can be seen in table 6.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Sydney</td>
<td>Stockholm</td>
</tr>
<tr>
<td>Income</td>
<td>-0.6686</td>
<td>1.731</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Part of Under 26”s</td>
<td>-0.4582</td>
<td>-35.885</td>
</tr>
<tr>
<td></td>
<td>(0.337)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Wealth</td>
<td>-1.5721</td>
<td>0.947</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Stock of Housing</td>
<td>-2.9540</td>
<td>6.709</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.360)</td>
</tr>
<tr>
<td>Interest</td>
<td>-3.6768</td>
<td>3.641</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>Constant</td>
<td>70.7470</td>
<td>1038.314</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Lags(p,q)</td>
<td>3,1</td>
<td>2,1</td>
</tr>
</tbody>
</table>

Table 6: ARMA-estimation of the life cycle model (p-value in parenthesis)

As seen in table 6, the model differs very much between the cities. While Sydney has negative sign in front of all the variables, Stockholm only has positive ones with the one exception being the demographic variable. None of the cities comply very well with the theory, both cities showing only two out of five variables with the expected sign. The models were tested as earlier; the results can be seen in table 7.

<table>
<thead>
<tr>
<th>Regression with ARMA (life cycle model) (method 3)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression City</td>
<td>Data City</td>
<td>Mean Error</td>
</tr>
<tr>
<td>Stockholm</td>
<td>Stockholm</td>
<td>0.09%</td>
</tr>
<tr>
<td></td>
<td>Gothenburg</td>
<td>22.87%</td>
</tr>
<tr>
<td>Sydney</td>
<td>Sydney</td>
<td>-0.11%</td>
</tr>
</tbody>
</table>

Short regressions with forecast of two years (2)

<table>
<thead>
<tr>
<th>Regression with ARMA (life cycle model) (method 3)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression City</td>
<td>Data City</td>
<td>Mean Error</td>
</tr>
<tr>
<td>Stockholm</td>
<td>Stockholm</td>
<td>5.48%</td>
</tr>
<tr>
<td></td>
<td>Sydney</td>
<td>15.12%</td>
</tr>
</tbody>
</table>
Table 7: Errors of forecasting using ARMA on the life cycle model.

As seen in table 7, the forecasting abilities are not very good when using ARMA. The poor performance of the ARMA model in the case of Stockholm might originate in the fact that the city’s change in house prices might be a unit root. In the ADF test above, the test statistic for Stockholm was rejected, but only on the 10 percent level and it was very close to the critical value. Also, the results from the prediction should be seen in the light of the fact that the ARMA-model naturally incurs flaws at the beginning and end of the time since it is using mean averages. Due to the poor performance another set of ARMA estimations was made, this time based on the simple model presented earlier, the results are displayed in table 8.

<table>
<thead>
<tr>
<th>Regression City</th>
<th>Data City</th>
<th>Mean Error</th>
<th>Mean Absolute Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>Stockholm</td>
<td>0.71%</td>
<td>4.63%</td>
</tr>
<tr>
<td></td>
<td>Gothenburg</td>
<td>0.23%</td>
<td>3.50%</td>
</tr>
<tr>
<td>Sydney</td>
<td>Sydney</td>
<td>-1.08%</td>
<td>4.37%</td>
</tr>
<tr>
<td></td>
<td>Melbourne</td>
<td>0.71%</td>
<td>6.10%</td>
</tr>
</tbody>
</table>

Table 8: errors of forecasting using ARMA on the simple model

This ARMA estimation seems to be more accurate than the previous, notable are the result for Gothenburg; it is much better than for Stockholm. Since the estimation for Gothenburg is made on the regression for Stockholm, the results can be interpreted as the model has good forecasting abilities. Also the MAE for the forecast of the short regression on Stockholm is only 1.59 percent. This is the best result so far, and even though it is only two observations it is an indication that the ARMA model has good forecasting abilities for Stockholm.

6. THE SPATIAL ASPECT OF HOUSE PRICES

There is not much doubt that house prices vary vastly over geographical areas; the most expensive tend to be in more densely populated areas and areas of economic significance like capital cities. As with the economy as a whole the house prices fluctuate in a cyclical pattern. In studies on the UK market, Meen (1999) found a distinct effect where a cycle of
house prices originated in the South-East of England, more specifically London, to then spread through the rest of the country over time. This is called the “ripple effect” and it has been used by for example Giussani & Hadjimateou (1991) and Munro & Tu (1996) to use house price changes in London as an exogenous variable when explaining the movements of house prices in other parts of Britain. You could interpret this in the way that the house price cycle starts in England’s Economic centre, London, and then spreads like a wave in the ocean over Britain. It seems plausible that the ripple effect occurs in any market. In the very complicated set of relationships that make up a country’s economy it seems likely that the house prices are firstly affected where the most economic activity occurs and then ripple out over the country. But is this effect limited to single economic markets or could you apply the ripple effect to an international level? Translating the ripple effect of the UK to a national level would mean that the house prices of Stockholm or Sydney could be influenced by global economic centres such as the EU, US or economically more powerful countries like England. To quickly examine this, the percentage change of house prices in Stockholm and Sydney as well as other economically strong countries (UK (Nationwide, 2007) and USA (OPHEO, 2007)) are plotted in a graph in figure 5.

Figure 5: Percentage change of house prices in different regions
From figure 5 one can see that there seems to be low correlation between the development of Stockholm’s house prices and the development of aggregated house prices in the UK and the US. Even so, there seems to be correlation between Stockholm and the house prices in London. The coefficient of correlation between the two is 0.77. During almost the entire eighties the change in house prices in London and Stockholm are almost identical. When studying the few entries from 2000 onwards the price changes differs slightly but it still seems reasonable to use the change in London house prices as a regressor for house price change in Stockholm. The problem here is the causality, is it London that leads and Stockholm that follows or vice versa or is it just a coincidence? You cannot say from this simple graph but I find it more believable that Stockholm follows London since the literature on the ripple effect specifies economic centres as the origin (MacDonald & Taylor, 1993) and smaller cities as followers and there should be no doubt that London is a bigger player on the stage of world economics than Stockholm. From the graph one could suspect that the house prices for the UK could be used as an explanatory variable for the Sydney house prices (Coefficient of correlation = 0.75). The geographical distance however makes it a bit far fetched to use this causality in a forecasting model. Due to difficulty in obtaining reliable data from Asia-pacific nations, the Sydney house prices will not be covered in this part of the survey.

To test whether there is any use to utilize the London house prices as an indicator on what will happened in Stockholm, a series of regressions was estimated. The difference to the new estimations being that the house prices in London were added as an explanatory variable. The result from the forecast using these new estimations can be seen in tables 9 and 10. Notable here is that the estimations yield a lower MAE when using London prices as an exogenous variable in all but one case. Also note that the simple model with fewer explanatory variables outperforms the life cycle model on several occasions, both with and without the extra variable of London house prices. This might be because the life cycle method catches the same effect in two of the explanatory variables giving the effect too much of an impact. For example, both “wealth” and “income” cover an increase in demand when households increases (or decreases) its economic strength.
The inclusion of the London house prices to the models seems to be beneficial to the forecasting abilities. The MAE is lower for most of the forecasts, the only exceptions being when the Stockholm estimation is applied to data for Gothenburg and when using estimation technique 2 for the simple model but the latter is only increased slightly from an exceptionally good result. The bad forecasting for the alternate city (Gothenburg) could be because Gothenburg is too small to be affected by the house price change in London or that it takes longer for the effect of London housing prices to ripple to Gothenburg that it is not covered by these models. If the latter were the case the estimations would probably be better if you a one-year lag was used for the London house prices when estimating the forecasting model for Gothenburg.

7. FINANCIAL INDICATORS

To many households, the house they live in is their biggest financial asset (Tsatsaronis & Zhu, 2004). This makes housing an interesting mix of investment and consumption; the household consumes housing services while at the same time making an investment in
the house. Looking at house prices from an investment point of view one might suspect that you could be able to use other alternatives of investment as an indicator of house price movements. The stock market is an easy option for an investigation of the financial markets implication on house prices. Earlier literature is indecisive on its implications on house prices. Chen and Patel (1998) finds that the stock market has a positive effect on house prices in Taipei and Sutton (2002) show similar results for 6 industrialized countries whilst for example Wilson, Okunev and Ta (1996) find it inconclusive to whether the Real Estate and securities, such as the stock market, affect each other. If in fact the two markets are integrated the question remains wether the markets are substitutes or complements. The correlation test between the change in Sydney house prices and the change in the ASX/200 (RBA, 2007b) of the Australian Stock Exchange show a correlation of -0.503. In figure 6 the change in stock index has been inverted for viewing purposes. Also included in figure 6 are two other financial indicators that were chosen from a number of financial indicators due to high correlation with the change in house prices\textsuperscript{10}.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6}
\caption{Percentage change in Sydney house prices and a number of financial indicators}
\end{figure}

\textsuperscript{10} These indicators are the household debt-to-asset (D-t-A) and debt-to-disposable income (D-t-I) ratios (RBA, 2007c)
Despite a relatively low correlation, the house price and stock index show a very similar pattern during the latter ten years of the time period. The reason for the difference in the early 1990’s is unknown. The sign of negative correlation between the stock market and house prices are likely to come from the fact that Real Estate is considered a safer investment than stocks. When the stock market is crumbling and uncertainty about the future rises, investors might turn to real estate to protect their assets thus increasing the demand for housing which according to the theory will increase house prices. Another financial indicator that seems to help pointing out in which direction house prices are going is the debt-to-income (D-t-I) ratio, with a coefficient of correlation of 0.68, and as seen in figure 6, this should be a good explanatory variable of house price changes. The causality should be fairly straightforward: if the ratio is high the households has greater difficulty in raising money to buy new houses, thus decreasing the demand which according to the theory affects the house prices negatively. Unfortunately data covering the debt-to-income ratio is not available for the Swedish market, which is why only Sydney will be examined in this part of the survey.

<table>
<thead>
<tr>
<th>Regression</th>
<th>Mean Absolute Error</th>
<th>Including D-t-I Ratio</th>
<th>Including Stock Market</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original model</td>
<td>Including Stock Market</td>
<td></td>
</tr>
<tr>
<td>Logarithm Full (1)</td>
<td>OLS</td>
<td>7.74%</td>
<td>5.29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.89%</td>
<td></td>
</tr>
<tr>
<td>Logarithm Short (2)</td>
<td>OLS</td>
<td>4.58%</td>
<td>5.77%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.52%</td>
<td></td>
</tr>
<tr>
<td>Percentage (3)</td>
<td>ARMA</td>
<td>6.48%</td>
<td>4.58%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.55%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OLS</td>
<td>4.24%</td>
<td>4.44%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.79%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ARMA</td>
<td>6.54%</td>
<td>5.52%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.53%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OLS</td>
<td>5.91%</td>
<td>5.48%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.56%</td>
<td></td>
</tr>
</tbody>
</table>

Table 11: Errors when forecasting using financial indicators in the simple model

<table>
<thead>
<tr>
<th>Regression</th>
<th>Mean Absolute Error</th>
<th>Including D-t-I Ratio</th>
<th>Including Stock Market</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original model</td>
<td>Including Stock Market</td>
<td></td>
</tr>
<tr>
<td>Logarithm Full (1)</td>
<td>OLS</td>
<td>6.09%</td>
<td>4.56%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.04%</td>
<td></td>
</tr>
<tr>
<td>Logarithm Short (2)</td>
<td>OLS</td>
<td>12.86%</td>
<td>7.54%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.43%</td>
<td></td>
</tr>
<tr>
<td>Percentage (3)</td>
<td>ARMA</td>
<td>2.86%</td>
<td>2.36%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.37%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OLS</td>
<td>4.37%</td>
<td>2.29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.30%</td>
<td></td>
</tr>
</tbody>
</table>

Table 12: Errors when forecasting using financial indicators in the life cycle model
There is no doubt both the debt-to-income ratio and the performance of the stock market has a positive effect on the forecasting abilities of both the models. In the life cycle model it almost makes no difference which of the two new explaining variables to use, they only differ significantly on one of the methods of estimation. In the simple model it seems like the change in stock market has more of a positive effect than using the debt-to-income ratio, performing better on all but one of the estimations. An explanation to the better performance when using the stock market as exogenous variable is that it has a more direct and visible effect on households than the D-t-I ratio. When the stock market is performing badly some investors might go straight to the real estate market while the D-t-I ratio mainly affects households which might be slower in it’s adjustments to a higher D-t-I. Another reason might be that banks lend money easier in times of good economic outlook; increasing the D-t-I ratio to higher levels than it would when house price increases are moderate or falling. This would result in a situation with both increasing house prices and increasing D-t-I ratio, which is opposite to the initial idea of the effect on house prices.

8. CONCLUDING REMARKS

The main determinants of house prices seem to be nominal interest, household income and the supply of new dwellings. These are explanatory variables in one of the models presented in this paper. Also presented was a more complicated model with more exogenous variables, however this “life cycle” model failed to create a better overall forecast despite including more explanatory variables. The simple model outperformed its more advanced counterpart on all forecasting of the Stockholm house prices. On the Sydney market the outcome was more favourable for the life cycle model but the simple model was close behind with acceptable AME’s. The addition of financial indicators to the regressions has some positive effects in this survey. Which indicator to use however cannot be determined, the two investigated indicators seem booth to have pros and cons. The choice of proffered indicator also seems to depend on which model is being used. The most interesting finding is however that the so called “ripple effect” seems to be applicable to an international level since the errors of forecasting was consistently lower
by a considerable margin when including the London house prices as an explanatory variable for the Stockholm house prices. To determine the existence of this effect further research is needed to establish the causality of this international ripple effect.
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