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Fundamentals or trends? A long-term perspective on house prices

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Using a long-term time series covering 350 years of house prices along the Herengracht in Amsterdam, we examine whether a fundamental factor or a trend explains house prices and whether their explanatory power is time varying. We find that agents in the housing market switch in their formation of expectations about future changes in house prices between fundamental and momentum strategies. Specifically, we show that agents base their expectations more on fundamentals during economic slowdowns and more on recent trends or momentum during economic booms.

Keywords: housing markets; behavioural economics; agent-based models; historical prices

JEL Classification: G19; C22

I. Introduction

Empirical research shows that house prices persistently deviate from fundamental values and are too volatile relative to fundamental values. Fundamentals such as income, employment, construction costs, changes in the housing stock, credit availability, tax structures, demographics and interest rates provide only little explanatory power for variation in house prices (Farlow, 2004; Black *et al.*, 2006). Quigley (1999) shows that simple models for house prices based on economic fundamentals explain only between 10% and 40% of the variation in residential property prices. Farlow (2004) confirms this and argues that the most plausible explanation for the dramatic increase in house prices during recent decades cannot be found in supply and demand fundamentals.

Although house price changes cannot be explained by fundamentals alone, empirical research has shown that house prices change in a predictable way. Case and Shiller (1989) find positive serial correlation in price changes of single-family homes.[1] Cutler *et al.* (1991) share the latter conclusion after finding a strong positive autocorrelation structure, reaching out for at least 3 years, for both residential real estate and farms in the US. Positive autocorrelation in house price changes is observed outside the US as

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[1] Extended research by Case and Shiller (1990) with additional fundamental forecasting variables yields the same conclusion.

well, as Englund and Ioannides (1997) provide evidence from 15 OECD countries and Levin and Wright (1997) show that past house price changes in the UK forecast future price changes.

The above discussion suggests that variation in house prices can be explained by both fundamental factors and recent trends in house prices. Black *et al.* (2006) show that UK house prices move away from their fundamentals during some periods and move back to their fundamentals during other periods. Clayton (1998) demonstrates that a number of instruments, including lagged returns and a measure of price deviation from a fundamental value, explain house price changes for apartments in Vancouver, Canada. They suggest from their results that property may be overvalued during periods with booming markets.

The observation that house prices deviate from fundamentals in a predictably way contrasts with price behaviour in efficient markets. One explanation for this is limits of arbitrage. Black *et al.* (2006) discuss that arbitrage is limited in the housing market due to high transaction costs, illiquidity of the housing market, heterogeneity and the fact that most houses are purchased for consumption rather than investment reasons. Correction towards fundamental values is therefore not immediate, and price deviations from a fundamental (or true) value may exist for long periods of time. Fundamentals can be seen as factors from which a true value can be derived and around which actual house prices hover by moving away from it during some periods and move back to it during others. Kouwenberg and Zwinkels (2014) observe such behaviour for US house prices and find indeed that a forecasting model that combines momentum and mean reversion (prices moving to a fundamental value) with time-varying weights outperforms a range of benchmark models.

The motivation for this paper comes from Clayton's (1998) conclusion that property may be overvalued in booming markets. Knowing that trends explain house price changes raises the suspicion that trend behaviour might explain house prices better during periods of economic booms than busts. We question whether fundamentals and trends always have the same explanatory power or whether explanatory power varies over time in the sense that trend beats fundamentals during some periods and fundamentals perform better during others? And if so, does the explanatory power of fundamentals and trends coincide with the state of the economy?

The unavailability of a long high-quality time series of house prices and fundamentals makes it difficult to examine conclusively the behaviour of house prices in terms of trends and fundamentals, especially since price cycles in real estate markets tend to last relatively long. We overcome this problem by using a historical house prices covering a long period of time. We use the updated Herengracht Index, a long time series on house prices, first presented by Eichholtz (1997) and later by Ambrose *et al.* (2013). This Herengracht Index reflects the prices of houses along the Herengracht, one of the canals in Amsterdam, covering 357 years from 1649 through 2005. Over the same period of time, we have information about the general price level (consumer price index) as well. We therefore have long-term time series of both prices and a fundamental and we use this unique data to examine our research questions. We do so by applying a heterogeneous agents approach as Kouwenberg and Zwinkels (2014) apply to US property prices. Introduced by Frankel and Froot (1990), heterogeneous agents models allow for different agents in the economy to co-exist. These agents differ in the way that they form expectations about future price changes. Typical heterogeneous agents models divide the market between two types of agents: trend followers and those who believe that prices revert towards some fundamental value. This setting matches the observation from the literature we discussed before: that variation in house prices can be explained by both trends and fundamentals. Our choice to use a heterogeneous agents model for house prices is not unique. Dieci and Westerhoff (2012), Sommervoll *et al.* (2010) and Kouwenberg and Zwinkels (2014) adopt a similar approach. The latter paper empirically compares the merits of a heterogeneous agents model for house prices to other models. Using the Case/Shiller house price index, they find strong support for the heterogeneous agents model, both in- and out of sample.

In order to examine the question whether the explanatory power of fundamentals and trends changes over time, we allow the fraction of trend-following or fundamental agents in the market to change over time, as Brock and Hommes (1997) and Brock and Hommes (1998) suggest. This allows us to observe whether the fraction of agents that use either trends or fundamentals varies over time and to what extent this coincides with the state of the economy. This is what we think contributes to the literature: the long history of the Herengracht Index makes it possible to examine how trend and fundamental factors perform over time in explaining variation in house prices and whether the importance of these variables relates to the state of the economy. Our results corroborate the earlier findings of Kouwenberg and Zwinkels (2014) that the housing market is well captured by a heterogeneous agent model. We extend the literature by showing that the fraction of trend followers is positively related to the business cycle. This finding suggests that the expectation formation of agents participating in the housing market is conditional on the general economy. This is an important finding for both prospective home buyers and policymakers interested in first understanding and second preventing the dynamics of the recent housing boom.

II. Data

The Herengracht Index is a price index of houses located along one of the central canals in Amsterdam. The canal was dug in phases between 1585 and 1660, and most of the lots along it were developed by 1680 (see Eichholtz *et al.*, 2012). Until the present day, the Herengracht is one of the most prestigious locations in Amsterdam. For example, Herengracht 502, a house that was built in 1672, is the address of the major's residence.

The data span the house prices for the period from 1649 through 2005. The index is constructed by Eichholtz (2010). For each of the houses on the Herengracht, a complete record of the history of its ownership is available. The source of the Herengracht data is a book (van Eeghen *et al.*, 1976) that was published for the occasion of Amsterdam's 750th anniversary as a city in 1975. The monumental book describes the history of the development of the canal, as well as histories of each of the 614 buildings located on it. These individual histories include the names and sometimes the occupation of the owners, as well as information on the transfer of ownership. When it comes to the owners of the dwellings on the Herengracht, the primary sources are various municipal tax registers, like the register of the sufferance taxes levied by the city of Amsterdam, the real estate ownership register that was used for the land tax and the register of high-income citizens, which included most of the inhabitants of the Herengracht dwellings. On top of that van Eeghen *et al.* (1976) used burial records and, from its inception in 1851 onwards, the register of births, deaths and marriages. Regarding transaction prices they used the different property ownership transfer registers that the city of Amsterdam maintained through the centuries. Ownership transfer was through bequest or sale. In all, the data record 6109 transaction, and for 4368 of these the sales price is known. The level of detail of the transaction records increases throughout the centuries, as the share of sales without price information falls from 36% in 1650–1799 to 24% in the nineteenth century, and to 23% thereafter. Apart from this, there are no systematic effects in the availability of price information. We think that this amount of detail and that the absence of significant systematic effects makes the Herengracht Index a reliable source for understanding of house price behaviour over this long time period. Eichholtz (2010) provides more details on the index construction.

We convert the data by taking the natural logarithm of the prices. Figure 1 shows a graph of the log prices of the Herengracht Index between 1649 and 2005. Table 1 shows summary statistics of the annual returns on the Herengracht Index.[2]

An inspection of the autocorrelation pattern of log-price changes reveals the presence of a first-order moving average process in the data.[3] We will therefore include a MA (1) term in the models that we present later in this paper.

For the same time period, we use the consumer price index series for the Netherlands. This consumer price index was developed by van Zanden (2005). The price index is based on the prices of a basket of consumer goods, including rye bread, beer, butter, meat, potatoes, peas, different kinds of fish and various textiles. Important shifts in consumption patterns are incorporated in the index weights of these goods. Potato prices, for example, entered the index in 1792 since potato consumption quickly increased

[2] An augmented Dickey–Fuller test indicates that we cannot reject the presence of a unit root in the log-prices. We therefore proceed with the first differences of the log prices, which we will refer to as the annual returns.
[3] Estimation of a standard MA(1) model reveals that the coefficient on the MA(1) term equals –0.404, with SE 0.049.

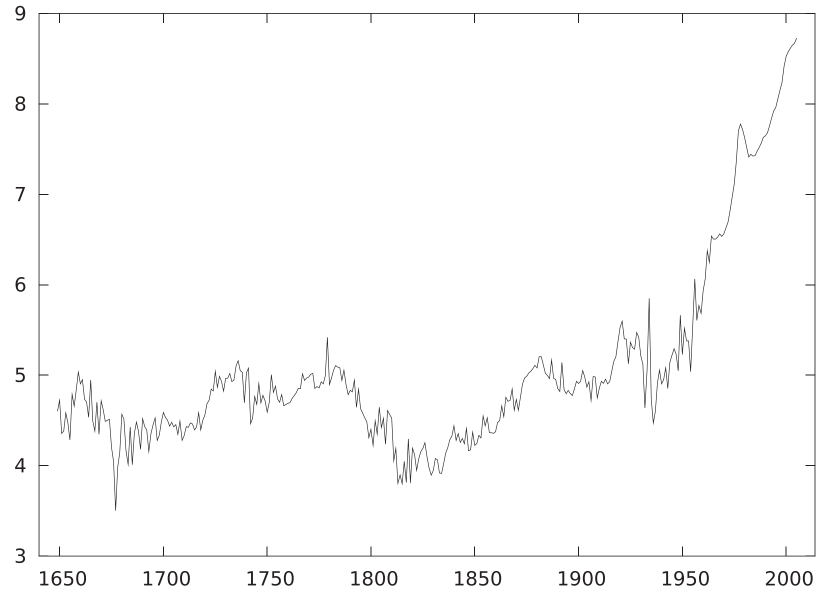

Fig. 1. Herengracht Index between 1649 and 2005
Note: Log-prices on the left axis.

Table 1. Summary statistics

Mean	0.012
Median	0.024
Minimum	−1.112
Maximum	0.789
SD	0.197
Skewness	−0.435
Excess kurtosis	3.820
n	356

after 1770.[4] For the period between 1850 and 1913, we use a series constructed by van Riel (2006), who uses a similar basket of goods and adds housing rental expenses. From 1914 onwards, we use the CPI calculated by the Dutch Central Bureau of Statistics.

III. A Heterogeneous Agents Model for Changes in House Prices

We develop the heterogeneous agents model following Frankel and Froot (1990), Brock and Hommes (1997), Brock and Hommes (1998), Dieci and Westerhoff (2012), Sommervoll *et al.* (2010) and Kouwenberg and Zwinkels (2014). We assume two groups of agents that differ in how they form expectations about future changes in house prices. In the first group, agents expect that house prices mean revert towards a fundamental value. We name the expectations strategy applied by agents in the first group the fundamental strategy. The second group of agents are trend followers and expect that recent price trends continue. We name these expectations strategy the momentum strategy.

Let us first focus on the fundamental strategy. Let $E^f_{t-1}\{\Delta p_t\}$ be the expected (log) price change Δp_t between time $t-1$ and t according to the fundamental strategy at time $t-1$. We use inflation as the fundamental variable, as discussed in the previous section, and thereby the fundamental strategy assumes that house prices changes equal inflation on average. Agents that apply the fundamental strategy expect a price decrease (increase) when house prices rose more (less) than inflation over the past years. We assume that fundamental agents form their expectations based on the n_f years moving average of the annual differences between the returns on houses Δp_t and inflation π_t, measured as the change in the log consumer price index:

[4] van Zanden (2005) provides additional information regarding the consumer price index and its composition over time.

$$E^f_{t-1}\{\Delta p_t\} = \alpha_f \frac{1}{n_f}\sum_{i=1}^{n_f}(\Delta p_{t-i} - \pi_{t-i}) \quad (1)$$

We expect that the parameter α_f is negative, being consistent with mean reversion.

The momentum strategy is that the recent trend in house price changes continues. At time $t-1$, the expected change in the house prices from $t-1$ to t under the momentum strategy, $E^m_{t-1}\{\Delta p_t\}$, is based on the n_m years moving average of house price changes:

$$E^m_{t-1}\{\Delta p_t\} = \alpha_m \frac{1}{n_m}\sum_{i=1}^{n_m}\Delta p_{t-i} \quad (2)$$

We expect that the parameter α_m is positive as that is consistent with extrapolating the trend over the recent n_m periods.

We assume that a fraction $w_{f,t}$ of all agents belongs to the group that applies the fundamental strategy at time t. A fraction $w_{m,t}$ of all agents belongs to the group that applies the momentum strategy. It holds per definition that $w_{m,t} = 1 - w_{f,t}$ as we allow for two types of agents only. The market expected change in the log price of houses, $E_{t-1}\{\Delta p_t\}$, then equals the weighted average over the expectations of all agents:

$$E_{t-1}\{\Delta p_t\} = w_{f,t-1}E^f_{t-1}\{\Delta p_t\} + w_{m,t-1}E^m_{t-1}\{\Delta p_t\} \quad (3)$$

Substituting Equations 1 and 2 into Equation 3, we can rewrite Equation 3 as

$$E_{t-1}\{\Delta p_t\} = w_{f,t-1}\frac{\alpha_f}{n_f}\sum_{i=1}^{n_f}(\Delta p_{t-i} - \pi_{t-i}) + (1 - w_{f,t-1})\frac{\alpha_m}{n_m}\sum_{i=1}^{n_m}\Delta p_{t-i} \quad (4)$$

We allow that agents have the possibility to change their expectation strategy over time. We assume, as suggested by Brock and Hommes (1997), that agents consider the recent performance or fitness of both strategies when selecting the expectation strategy that they apply. Let $u_{f,t}$ be the fitness of the fundamental strategy at time t and let $u_{m,t}$ be the fitness of the momentum strategy. The fraction of agents that apply the fundamental strategy is described by the following multinomial logit probability:

$$w_{f,t} = \frac{e^{\gamma u_{f,t}}}{e^{\gamma u_{f,t}} + e^{\gamma u_{m,t}}} \quad (5)$$

The parameter $\gamma > 0$ in Equation 5 is the intensity of choice parameter. It measures how sensitive agents are in selecting the optimal strategy. The case $\gamma = 0$ corresponds with the situation in which agents will not switch between strategies. In this case, $w_{f,t} = w_{m,t} = 1/2$ for all times t. The other extreme case $\gamma = +\infty$ corresponds with the situation in which all agents choose the optimal forecast based on the observed fitness. Brock and Hommes (1997) propose realized profits as a natural candidate for fitness and we implement this measure for fitness in this paper. We assume that an agent measure the profit of a strategy as the average annual profits over the previous n_u periods in case the agents would have adopted that specific strategy. The fitness of the fundamental strategy at time t equals

$$u_{f,t} = \frac{1}{n_u}\sum_{i=1}^{n_u}\Delta p_t sgn(E^f_{t-1}\{\Delta p_t\}) \quad (6)$$

where $sgn(x)$ is the sign of x. The fitness of the momentum strategy at time t equals

$$u_{m,t} = \frac{1}{n_u}\sum_{i=1}^{n_u}\Delta p_t sgn(E^m_{t-1}\{\Delta p_t\}) \quad (7)$$

The above equations describe the expected change in house prices as a time-varying weighted average over fundamental and momentum-based expectations. The following set of equations encompasses the model that we test empirically:

$$\begin{aligned}\Delta p_t &= c + w_{f,t-1}\frac{\alpha_f}{n_f}\sum_{i=1}^{n_f}(\Delta p_{t-i} - \pi_{t-i}) + \\ &\quad (1 - w_{f,t-1})\frac{\alpha_m}{n_m}\sum_{i=1}^{n_m}\Delta p_{t-i} + \sigma\epsilon_t + \theta\epsilon_{t-1} \\ w_{f,t} &= \frac{e^{\gamma u_{f,t}}}{e^{\gamma u_{f,t}} + e^{\gamma u_{m,t}}} \\ u_{f,t} &= \sum_{i=1}^{n_u}\Delta p_t sgn(E^f_{t-1}\{\Delta p_t\}) \\ u_{m,t} &= \sum_{i=1}^{n_u}\Delta p_t sgn(E^m_{t-1}\{\Delta p_t\})\end{aligned} \tag{8}$$

For estimation purposes, we include a constant term c in Equation 8 and the parameter σ measures the SD of the error term. The six parameters in the model (c, α_f, α_m, γ, σ and θ) are estimated using maximum likelihood assuming that the error term ϵ in Equation 8 is normally distributed. In the estimation procedure, we do not restrict the sign of any of the parameters, except for σ which is restricted to be positive.

The parameter estimates depend on the exact settings for the parameters n_f, n_m and n_u that cannot be directly estimated from the data. As can be seen from Equations 1, 2, 6 and 7, these numbers represent the number of observations included in the fundamental (n_f) and momentum (n_m) strategy to determine expectations about the change in the next period's price of houses and the number of periods over which the fitness is being calculated (n_u). We assume that each of these parameters can obtain the integer values 1 through 20 (referring to a 1-year through 20-year look-back period) and we estimate the parameters for all 8000 combinations of n_f, n_m and n_u. We use the Schwartz information criterion to select the optimal setting for n_f, n_m and n_u.[5]

IV. Results

Table 2 shows the parameter estimates for different settings. The first column in Table 1 contains the parameter estimates for those values of n_f, n_m and n_u that yield the highest Schwartz criterion. The column is headed 'switching' as these estimates are found

Table 2. Parameter estimates

Parameter	Switching	No switching	No switching	Switching
n_f	14	14	10	10
n_m	14	14	16	16
n_u	2	–	–	2
c	0.002	0.005	0.004	0.002
	(0.502)	(0.991)	(0.706)	(0.441)
σ	0.174***	0.181***	0.180***	0.177***
	(43.242)	(42.320)	(41.302)	(40.404)
α_f	−1.830***	−1.386***	−1.403***	−1.465***
	(−9.034)	(−4.501)	(−3.966)	(−5.860)
α_c	1.363***	1.446***	1.751***	1.316***
	(5.871)	(4.043)	(4.303)	(4.044)
γ	18.563	–	–	12.464
	(1.279)	–	–	(1.222)
θ	–0.600***	–0.456***	–0.4380***	–0.485***
	(−15.466)	(−11.607)	(−10.487)	(−11.164)
DW	1.9344	1.990	2.0147	2.027
LogLik	118.012	103.255	106.615	111.824
$2\Delta LogLik$	–	29.514***	–	10.418***
Akaike	−224.024	−196.509	−203.230	−211.649
Schwarz	−200.757	−177.121	−183.841	−188.383
Hannan–Quinn	−214.769	−188.798	−195.517	−202.395

Notes: Asymptotic t-values are in parenthesis.
*** denotes significance at the 1% level.

[5] Using the Hannan–Quinn criterion instead of the Schwartz criterion leads to the same optimal setting.

under the assumption that we allow agents to switch their expectation strategy. The optimal setting is $n_f = 14$, $n_m = 14$ and $n_u = 2$. Apparently, both fundamental and momentum strategy base expectations on observations over the last 14 years. These results already illustrate the importance of employing a long time series. The setting $n_u = 2$ implies that agents evaluate the fitness of both strategies over the last 2 years when choosing which strategy to apply. The parameter estimates conditional on this optimal setting show evidence for the existence of heterogeneous expectations in the housing market as the estimate for α_f is negative (−1.830) and significantly different from zero and the estimate for α_m is positive (1.363) and significantly different from zero. The negative estimate for α_f is consistent with the view that house prices revert towards a fundamental value. The positive estimate for α_m implies that the momentum strategy-based expectations extend the current price trend. Without going into details here, we also observe the same signs for the α parameters for the alternative settings listed in Table 2; the signs of the estimates are robust, indicating the existence of both strategies being applied in the housing market.

The results show that agents use fundamental and trend strategies to formulate expectations in house prices and, as a consequence, house price changes depend on both fundamental factors and trends; an observation consistent with the recent literature on house price changes we discussed before. The estimate for the intensity of choice parameter γ is positive but not significantly different from zero. Although this parameter reflects the agent's willingness to switch strategy, we cannot clearly observe whether agents do switch between the fundamentalist and chartist strategies from γ only as the fraction of agents that apply a strategy depends on a logistic transformation of fitness and γ (see Equation 5). To assess whether switching behaviour is apparent, we test whether the fit of the model with the optimal setting in which we allow for switching behaviour is better than the fit of a model with the same setting, but in which switching is not allowed. The results for the latter model are listed in the column headed 'no switching' for the optimal setting (14, 14, –). We apply a likelihood ratio test to determine which model fits the data better. Table 2 shows that the log-likelihood of the original, allowing switching, model is 118.012 and of the alternative, no switching, model it is 103.255, and the likelihood ratio test statistic, $2\Delta LogLik$ as in Table 2, equals 29.514. This difference between log-likelihoods of both models implies that the model that allows for switching fits the data significantly better. These results are consistent with the findings of Kouwenberg and Zwinkels (2014), who also find fundamentalists and momentum traders, as well as switching in the US housing market.

For now, we conclude that agents change their strategies over time based on the fitness of each strategy, but the estimates that we discussed so far are derived under the assumption of the optimal setting for n_f, n_f and n_u that was obtained under the assumption that switching is allowed. To check the robustness of our results, we also estimate the parameters under the assumption that agent cannot switch. To do so, we selected the optimal setting for the model while keeping the value of γ equal to zero. The optimal setting and the parameter estimates under this assumption can be observed from the third column in Table 2 headed 'no switching'. The optimal setting is 10 years for n_f and 16 years for n_m. The parameter n_u does not apply here as fitness of each strategy is irrelevant when switching is not allowed. To obtain whether allowing to switch strategies fits the data better, we compare the log-likelihood of this setting with the log-likelihood obtained after estimating a model in which n_f and n_m were kept at 10 and 16, respectively, but in which switching is allowed. This gave an optimal setting for n_u equal to 2, consistent with our previous results. The parameters of the latter model are listed in the fourth column of Table 2. Allowing for switching yields a higher log-likelihood and the likelihood ratio test statistic equals 10.418. Again, allowing for switching fits the data significantly better. We therefore conclude that the result that agents switch their strategy over time is robust and we treat the parameter estimates in the first column in Table 2 as the best fit.

The estimates from the first column in Table 2 show that agents switch in their expectations formation between fundamental and momentum strategies. Hence, house prices depend on fundamentals and momentum and the importance of each of these factors driving house prices varies over time as agents focus more on the fundamental strategy in some periods and on momentum in other periods. This becomes more clear from the graph in Fig. 2, which shows the fraction of agents that adopt a fundamental strategy, $w_{f,t}$, over time. The graph clearly shows that

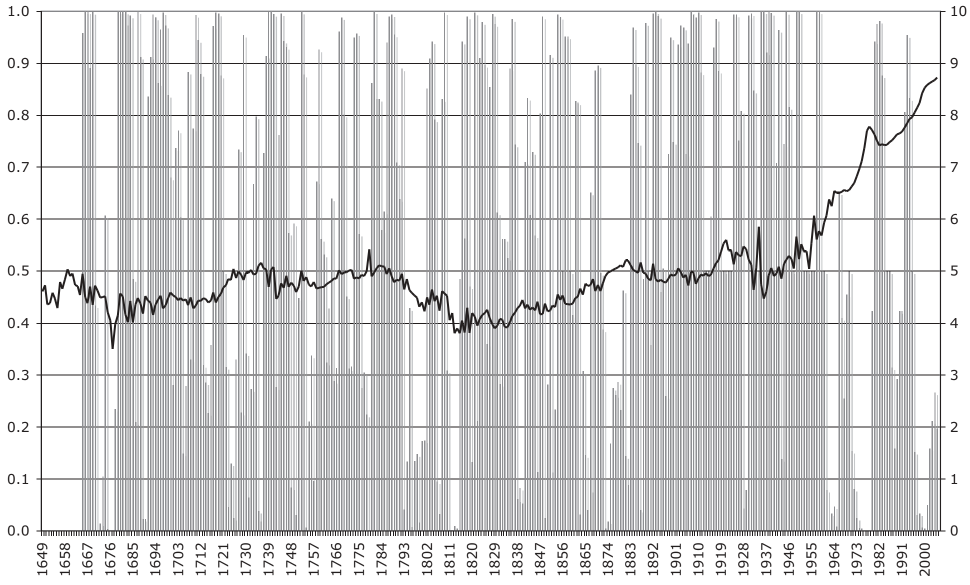

Fig. 2. Fraction of agents that apply the fundamental strategy between 1649 and 2005
Note: The grey bars are the fundamental strategy weights (left axis), and the black line represents the annual log prices of the Herengracht Index (right axis).

the fraction of agents that adopt a fundamental strategy varies strongly over time. Between approximately 1890 and 1960, more than 50% of the agents in the housing markets applied a fundamental strategy on average. In that period, house prices were driven mostly by the fundamental factors that we examine here. Since the end of the 1990s, the fraction of agents using the fundamental strategy did not exceed 30%. House prices were predominantly driven by the momentum strategy, and agent expectations appeared to be predominantly based on extending the recent price trend. This behaviour also occurred during the 1790s and between 1870 and 1890 approximately. The graph clearly shows that the latter half of the twentieth century, on which most empirical studies of the housing markets are based, was historically unique: trend chasing was more important in that period than in the years before. This illustrates the importance of a long time frame to study the dynamics of house prices.

The first part of Table 3 provides summary statistics of the fundamentalist weights $w_{f,t}$. In an average year, 55.9% of all agents apply the fundamental strategy and 44.1% of the agents adopt the momentum strategy. We therefore conclude that agents' behaviour in terms of expectation formation is more often based on fundamental information than on momentum in the long run. The SD of the fundamental strategy weights equals 35.5%.

Table 3. Summary statistics of the fraction of agents that apply the fundamental strategy

Statistic	
Mean	0.559
SD	0.355
Period	Average
Strong economy	0.517
Economic slowdown	0.580
Strong -/- slowdown	−0.063
(*p*-value)	(0.065)

So we find that agents in the housing market apply momentum and fundamental strategies to formulate expectations on future changes in house prices and that their behaviour, in terms of which strategy they use, varies over time in line with the success of each strategy. This brings us to the already mentioned conclusion of Clayton (1998) that property may be overvalued in booming markets and that recent trends explain house price changes. So trend-chasing behaviour may explain house prices better during periods of economic booms than in busts. We use our results to examine the hypothesis that trend explains house prices better during periods of economic booms. To do so, we define indicator variables to identify periods in our sample with economic booms and busts. We use the same period economic characterization as Eichholtz (2010) do for Amsterdam between 1650 and 2005. That paper divides the whole sample period in eras characterized by a strong or very strong economy (1650–1670, 1851–1913, 1946–1973, 1974–2005), by economic slowdown (1671–1720, 1721–1780, 1781–1814, 1914–1945) and by stabilization (1815–1850).

The bottom part of Table 3 shows the averages of the fraction of agents that apply the fundamental strategy during periods with a strong economy and economic slowdown. During the strong economic periods, 51.7% of the agents applied the fundamental strategy, whereas 58.0% of the agents applied the fundamental strategy during periods with economic slowdown, over 12% more. The lower fraction of agents that apply the fundamental strategy during a strong economy is in line with Clayton's (1998) claim that trends or momentum explain house prices better during economic booms. To test the significance of this result, we performed a single-sided *t*-test and we find that the difference between the average fraction of agents that use the fundamental strategy during an economic boom and bust is −0.063. The *t*-test for the hypothesis that this value is lower than zero yields a *p*-value of 6.5%. We conclude, with 93.5% confidence, that agents base expectations more on fundamentals during periods with economic slowdown and more on recent trends or momentum during periods of economic booms.

V. Concluding Remarks

We have been the first to analyse the importance of fundamental and momentum factors in explaining house price dynamics over a long period of time. This paper uses a long-term price index of houses along the Herengracht in Amsterdam, covering 357 years. We examine whether a fundamental factor or a trend (momentum) explains house prices and whether the explanatory power is constant or varies over time. We use a heterogeneous agents model for house prices to model changes in house prices in which we assume that agents base their expectations on fundamentals or trends. We allow these agents to switch between strategies over time and show that they do so based on the recent success of each strategy.

We find that agents in the housing market switch in their formation of expectations about future changes in house prices between fundamental and momentum strategies. Hence, house prices depend on fundamentals and momentum and the importance of each of these factors driving house prices varies over time, as agents focus more on the fundamental strategy in some periods and on momentum in other periods. We also show that agents base their expectations more on fundamentals during periods with economic slowdown and more on recent trends or momentum during periods of economic booms.

The implication of our results is that house prices cannot be seen to be driven by either fundamental variables or recent trends alone. Instead, both fundamentals and trends explain variation in house prices and the importance of both factors varies over time. During periods with economic booms, agents focus more on recent price trends, which potentially leads to overvalued house prices during these periods. During periods with economic slowdown, house prices correct after they have increased more than inflation recently, at least according to our model. This is an important finding for both prospective home buyers and policymakers interested in first understanding and second preventing the dynamics of the recent housing boom.

Clearly, the results are conditional on the choice of fundamental. We are bounded in our choice by data availability over a period as long as the house price index itself. The choice of inflation, however, is a natural candidate given the results of Ambrose *et al.* (2013) that real estate does not earn positive real returns in the very long run.

References

Ambrose, B., Eichholtz, P. M. A. and Lindenthal, T. (2013) House prices and fundamentals: 355 years of evidence, *Journal of Money, Credit and Banking*, **45**, 477–91. doi:10.1111/jmcb.12011

Black, A., Fraser, P. and Hoesli, M. (2006) House prices, fundamentals and bubbles, *Journal of Business Finance & Accounting*, **33**, 1535–55. doi:10.1111/j.1468-5957.2006.00638.x

Brock, W. A. and Hommes, C. H. (1997) A rational route to randomness, *Econometrica*, **65**, 1059–95. doi:10.2307/2171879

Brock, W. A. and Hommes, C. H. (1998) Heterogeneous beliefs and routes to chaos in a simple asset pricing model, *Journal of Economic Dynamics and Control*, **22**, 1235–74. doi:10.1016/S0165-1889(98)00011-6

Case, K. E. and Shiller, R. J. (1989) The efficiency of the market for single-family homes, *American Economic Review*, **79**, 125–37.

Case, K. E. and Shiller, R. J. (1990) Forecasting prices and excess returns in the housing market, *Real Estate Economics*, **18**, 253–73. doi:10.1111/1540-6229.00521

Clayton, J. (1998) Further evidence on real estate market efficiency, *The Journal of Real Estate Research*, **15**, 41–57.

Cutler, D. M., Poterba, J. M. and Summers, L. H. (1991) Speculative dynamics, *Review of Economic Studies*, **58**, 529–46. doi:10.2307/2298010

Dieci, R. and Westerhoff, F. (2012) A simple model of a speculative housing market, *Journal of Evolutionary Economics*, **22**, 303–29. doi:10.1007/s00191-011-0259-8

Eichholtz, P. M. A. (1997) A long-run house price index: the Herengracht index, 1628–1973, *Real Estate Economics*, **25**, 175–92. doi:10.1111/1540-6229.00711

Eichholtz, P. M. A. (2010) House prices and fundamentals: 355 years of evidence, Technical report, Maastricht University, Maastricht.

Eichholtz, P. M. A., Straetmans, S. and Theebe, M. (2012) The Amsterdam rent index: the housing market and the economy 1550–1850, *Journal of Housing Economics*, **21**, 269–82. doi:10.1016/j.jhe.2012.09.001

Englund, P. and Ioannides, Y. M. (1997) House price dynamics: an international empirical perspective, *Journal of Housing Economics*, **6**, 119–36. doi:10.1006/jhec.1997.0210

Farlow, A. (2004) UK house prices: a critical assessment, Report prepared for the CSFB Housing Market Conference in May 2003, Credit Suisse First Boston, London.

Frankel, J. A. and Froot, K. A. (1990) Chartists, fundamentalists and trading in the foreign exchange market, *American Economic Review*, **80**, 181–85.

Kouwenberg, R. and Zwinkels, R. C. J. (2014) Forecasting the US housing market, *International Journal of Forecasting*, **30**, 415–25. doi:10.1016/j.ijforecast.2013.12.010

Levin, E. J. and Wright, R. E. (1997) The impact of speculation on house prices in the United Kingdom, *Economic Modelling*, **14**, 567–85. doi:10.1016/S0264-9993(97)00008-4

Quigley, J. M. (1999) Real estate prices and economic cycles, *International Real Estate Review*, **2**, 1–20.

Sommervoll, D. E., Borgersen, T. A. and Wennemo, T. (2010) Endogenous housing market cycles, *Journal of Banking and Finance*, **34**, 557–67. doi:10.1016/j.jbankfin.2009.08.021

van Eeghen, I., Roosegaarde Bisschop, G. and Wijnman, H. F. (1976) *Vier eeuwen Herengracht*, Het Genootschap Amstelodanum, Stadsdrukkerij Amsterdam, Amsterdam.

van Riel, A. (2006) Prices and economic development in the Netherlands, 1800–1913; markets, institutions and policy restraints. Universiteit Utrecht, Utrecht.

van Zanden, J. L. (2005) What happened to the standard of living before the industrial revolution? New evidence from the western part of the Netherlands, in *Living Standards in the Past*, Allen, R. C., Bengtsson, T. and Dribe, M. (Eds), Oxford University Press, Oxford, pp. 173–95.