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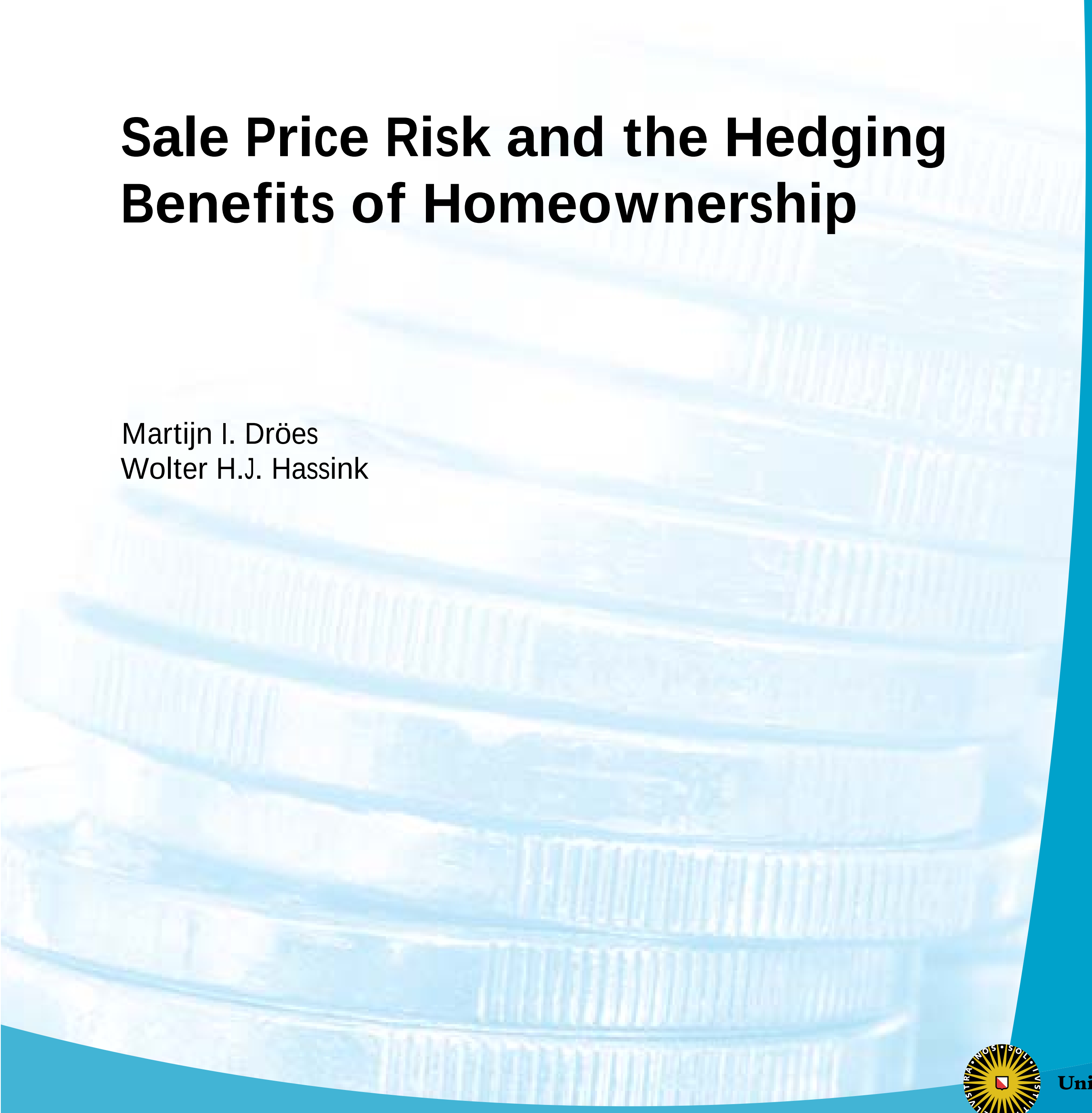

Sale Price Risk and the Hedging Benefits of Homeownership

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Sale Price Risk and the Hedging Benefits of Homeownership

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Abstract

The uncertainty with regard to the sale price of a home may be one of the most risky aspects of owning a home. This uncertainty can be measured by the volatility of house price returns. This paper investigates the extent and development of this volatility across market segments, time, and municipalities in the Netherlands. The empirical results are based on the administrative transaction prices of all existing homes sold in the Netherlands over the period 1995-2008. The results in this paper indicate that the uncertainty in house prices can be substantial. Nevertheless, types of houses that are sold frequently have the lowest return volatility. In addition, the risk per unit of return is especially high during an economic bust. Moreover, (the volatility of) returns show a clear core-periphery pattern. Finally, a homeowner who moves has a cross-location hedging opportunity against sale price risk if he buys a new home at another location. Instead, a homeowner who moves to a rental house may only have been intertemporally hedged against price changes. This paper investigates the quality of both hedging opportunities.

Keywords: sale price risk, house price risk, house price volatility, hedge

JEL classification: G01; E22

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1. Introduction

Owning a house can be quite profitable, but it is also risky. If the current economic downfall has taught us anything, it is that homeowners are not fully aware of the risk of owning a home. While the classical (institutional) investor might have the expertise and knowledge to incorporate risk in his decisions, homeowners typically have not. This problem is partly due to the lack of publically available information on the risk of owning a home (e.g. it is costly for a homeowner to acquire information on risk). In addition, it is well known that even with some information on risk, individuals have problems with choice under uncertainty and they find it difficult to assess the magnitude of risk (Kahneman and Tversky, 1979).

The uncertainty with regard to the sale price of a home may be one of the most risky aspects of owning a home. This risk is also known as sale price risk (see Sinai and Souleles, 2005). For instance, Sinai and Souleles (2009) show that house prices can be quite volatile. In particular, real house prices in the US decreased by about 31 percent between 2005 and 2008, while they increased by about 73 percent in the years before 2005. Moreover, these price changes can also be very heterogeneous across MSAs and market segments.[1] These fluctuations in price developments over time, market segments, and across locations makes owning a home risky. Nevertheless, a homeowner who moves and buys a new home may be hedged against sudden price fluctuations in the current home. In particular, a 10,000 dollar increase in the value of the current home may not lead to a net increase in wealth if a homeowner also needs to pay 10,000 dollar more for the future home (i.e. ignoring transaction costs). Hence, total asset price risk for this homeowner may be reduced due to hedging, although there is additional uncertainty with regard to the buy price of the future home (buy price risk).

If homeowners are not fully aware of sale price risk or the hedging opportunities due to a lack of knowledge or financial illiteracy (i.e. see Lusardi and Mitchell, 2007), information on the nature of this risk will be of fundamental importance, also for policy makers and mortgage lenders. In particular, if the risk does not turn out in the homeowner's favor, it will limit the amount of housing they can

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[1] For instance, according to the Federal Housing Finance Agency their purchase-only price index showed a decrease of 22 percent in the Phoenix-Mesa-Scottsdale (AZ) MSA between the third quarters of 2008 and 2009, while it increased by 3.3 percent in the Denver-Aurora-Broomfield (CO) MSA during the same time period. These results stand in stark contrast to the accumulative 94 percent increase in house price in the AZ MSA and 175.6 percent increase in the CO MSA as of 1991.

buy in the future and could ultimately affect their pension wealth, especially since a substantial amount of the wealth of households is invested in housing. For instance, households in the US hold about 34 percent of their total wealth in net home equity, but this amount can be as high as 62 percent in the UK (Banks et al. 2002).

The aim of this paper is to investigate the nature of sale price risk and the hedging benefits of homeownership. In particular, we examine (relative) price changes and the volatility of those changes in the Netherlands between 1995 and 2008. Besides some descriptive statistics on price changes (e.g. standard deviation, hedge ratio), we estimate a simple (relative) price change model and a volatility of price shocks model. We investigate price changes since we find that house prices in the Netherlands are highly persistent. The results in this paper provide evidence whether and when homeowners, but also governments, should be especially on guard against sale price risk.

The contributions of this paper are as follows. Our first contribution is to define asset price risk based on the future tenure choice of the homeowner, which results in asset price risk for two types of homeowners: a homeowner who plans to move to a rental unit and a homeowner who decides to buy a new home. In particular, a homeowner who decides to move to a rental unit is only influenced by the price fluctuations of the current home (sale price risk) and the possible rent risk of the future home at another location. Instead, the asset price risk of a homeowner who sells his current home and buys a new home is determined by the uncertainty in the house price at the current and future place of residence (i.e. sale price risk and buy price risk). In addition, the latter homeowner may be hedged against this uncertainty since the price fluctuations in the current and future home may cancel out.

The volatility of house price returns, especially with regard to house price shocks, captures the uncertainty in future house prices. Our second contribution is to measure the extent and development of this volatility across three of its most important dimensions: market segments, time, and locations. In particular, we investigate whether the return volatility may be different for an owner of a villa than for an owner of an apartment. In addition, some of the homeowners who buy a new home should take into account both risks, since they decide to trade up or down the property ladder. In addition, this paper argues that risk is not necessarily time-constant. In particular, we show empirical evidence under which economic conditions (i.e. economic boom, economic bust) house price volatility may be highest.[2] Finally, the return volatility may highly depend on the location of the home. We investigate whether this volatility is spatially related since households tend to buy a new home nearby the current place of residence.

Our third contribution is to discuss the (quality of the) hedging opportunities due to owning a home along the same three dimensions as the uncertainty in house prices. With regard to types of houses, a homeowner who moves to another type of house and stays in the owner-occupied sector may have a cross-market segment hedging opportunity due to the co-movement of house price series across market segments. In addition, the exact hedging benefit depends on the location choice of the current and future place of residence. The cross-location hedging opportunity of a homeowner who buys a new home does not imply that a homeowner who moves to a rental house in the future does not have any hedging opportunities. In particular, this type of homeowner may only be intertemporally hedged against changes in the price of the current home, since these price changes may cancel out over time. In contrast, this intertemporal hedge may be perfect for the repeated homeowner. Hence, the homeowner who moves to a rental house will simply have less hedging opportunities than the homeowner who buys a new home. We can calculate the exact hedge ratio since we will use actual transaction prices instead of a composite price index.

A structural investigation, which incorporates all of the aforementioned elements of sale price risk and the hedging opportunities, is hard to find, partly due to the quality of data necessary for an in-depth analysis. The results in this paper are based on unique dataset that consists of all administrative transaction prices of existing homes in the Netherlands over the period 1995-2008 (about 2.6 million records). An indicator for the type of house that is sold and the location (municipality) of this house are also available. The Netherlands is comparable in terms of population (about 16.5 million in 2009) to large Metropolitan Statistical Areas such as the New York MSA, but is about two and a half times as large in terms of land size (16,000 square miles). In addition, the Netherlands has about 441 municipalities, while the New York MSA consists out of 23 counties. Summarizing, the analysis in this paper could be compared to a highly disaggregated within-MSA investigation. In particular,

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[2] Sinai and Souleles (2009) provide evidence that the hedge quality is not different between a housing market boom or bust. Nevertheless, we argue that the level of sale price risk in these periods may still be relatively high.

an investigation of sale price risk on highly aggregated country or regional data could aggregate out most of the sale price risk relevant to homeowners since most households may move within their current region of residence. For instance, Sinai and Souleles (2009) report that about four-fifth of households who move within a five-year period will decide to move within their MSA. In addition, the individual-level data has an important benefit relative to aggregate regional price data. In particular, we can also use the price variation within municipalities. This level of detail is important because price shocks may be highly location specific. Moreover, we will use price information per house type in our analysis. In contrast, the commonly used composite (across market segments) price indices may lead to outcomes that are the result of composition effects.

Although sale price risk is an important phenomenon, the literature on sale price risk is scarce. In a seminal paper Sinai and Souleles (2005) discuss sale price risk relative to rent risk.[3] They argue that owner-occupied housing can act as a hedge against rent risk. Sinai and Souleles (2005) conclude that homeownership is only risky when the expected length of stay is short and housing markets have a low spatial correlation. From an empirical point of view, Sinai and Souleles (2005) provide evidence that house prices relative to rents, as well as homeownership, increase with net rent risk. However, they do not investigate sale price risk in further detail. In a recent related contribution Sinai and Souleles (2009) demonstrate that the hedge quality of home owning (i.e. the correlation between house price growth series) across MSAs might be higher than previously considered, since households have a tendency to move to correlated housing markets. As mentioned, our contribution differs since our paper is comparable to a within-MSA investigation. In addition, we discuss the volatility of house price returns and the hedging opportunities (hedge ratio) along the aforementioned three dimensions.

The previous literature also suggests that sale price risk may relate to (lead to) other types of risk. Chan (2001) for instance discusses the risk of lock-in of credit-constrained households due to the price drops after the US recession in the 1990s. In addition, the risk position of households may be aggravated, because income shocks and house price shocks are usually positively correlated. In particular, in combination

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[3] The role of sale price risk is also mentioned by Flavin and Nakagawa (2008) as a key feature in their housing market model on household consumption and portfolio allocation choice.

with lock-in households face the risk of default (i.e. foreclosure).[4] Hence, sale price risk may be only one facet of the risk of owning a home.

Finally, there is some literature on methods to mitigate sale price risk. In particular, Caplin et al. (2003) describe the implementation of home equity insurance. They argue that homeowners could pay a premium to avoid a sudden downfall in the price of the home. Alternatively, some researchers have suggested the use of housing price derivatives, such as futures and options, to hedge price risk (Case et al., 1993; Iacoviello and Ortalo-Magné, 2003). However, as mentioned by Sinai and Souleles (2009), the homeowner could be easily "unhedged" by the use of a simple derivative. A more complex combination of derivatives may be necessary, depending on the housing equity position and future plans of the homeowner. As mentioned, we only focus on the "natural" hedging opportunities of homeownership.

The remainder of this paper is organized as follows. Section 2 considers the underlying theory. Section 3 outlines the empirical strategy. Section 4 discusses the data. Section 5 reports some stylized facts on house prices levels and returns. Section 6 shows descriptive statistics on sale price risk and the hedge against this risk. Section 7 discusses sale price risk and the hedging benefits of homeownership based on regression analysis. Section 8 concludes.

[-TABLE 1 ABOUT HERE-]

2. Theory

This section defines asset price risk with regard to the total value of the home for two types of homeowners: a homeowner who will become a renter in the future and a homeowner who remains an owner-occupier after he has moved to a new home. In addition, we discuss the hedging opportunities against sale price risk. Table 1 summarizes the results. The empirical strategy and hypotheses are discussed in the next section.

A homeowner has a long position in the current home CV_t,

$$CV_t = -p_t^{A,r} + \delta^{t+s}\tilde{p}_{t+s}^{A,r} \qquad (1)$$

where the homeowner paid $-p_t^{A,r}$ when he bought the home at location *A,* time *t,* and of house type *r*. The homeowner receives $\tilde{p}_{t+s}^{A,r}$ at time $t+s$ when he sells the house.

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[4] In particular, low or negative price changes (i.e. negative net housing equity) may deter residential mobility (see Henley, 1997). However, negative equity is a necessary, but not sufficient condition of default (see Foote et al., 2008).

Hence, s is the expected length of stay at time t (where $s > t$). The term δ^{t+s} is the discount factor (where $\delta \leq 1$). The selling price of the current home $\tilde{p}_{t+s}^{A,r}$ is uncertain at time t (indicated by the tilde). Hence, this uncertainty constitutes a risk to the homeowner in terms of the housing wealth position. This sale price risk is only important to a homeowner if he considers at time t to move at time $t+s$.[5]

Although previous residence spells affect the total asset position of households, the resulting pay-offs are already realized (i.e. this may be part of the term $-p_t^{A,r}$). Hence, these previous asset positions do not attribute to sale price risk and are ignored. Consequently, the asset position in equation (1) is relevant for a homeowner who was previously a renter (starter in the owner-occupied housing sector) or homeowner before time t. In addition, we ignore the pay-offs (risk) of future residence spells after $t+s$. In particular, these pay-offs may be highly discounted, since the expected length of residence is usually quite large.[6] Moreover, transaction costs are ignored (also with regard to the hedge against price risk in the latter part of this section).[7] A further issue is that only a few homeowners may have purchased the house outright. In particular, the homeowner can take more risk than his own current wealth allows due to a mortgage loan. Nevertheless, we will not incorporate the mortgage in this analysis. In particular, we will ignore the risk of default and interest rate risk.[8] Finally, Sinai and Souleles (2005) include the costs and pay-offs of rental housing (rent risk) in their analysis. We abstract from rent risk. This assumption allows us to focus on house price variation only (i.e. sale price risk). Moreover, such an assumption may be justified, since rents are highly regulated in the Netherlands.[9] Since renting a future home is not assumed to be risky (it also does not

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[5] If households consider (at time *t)* to move at time *t*+*s*, but at time *t*+*s* they do not move, due to for instance a change in preferences or hyperbolic preferences (i.e. see Liabson, 1997), the household still incurred asset price risk from an ex ante point of view (i.e. at time *t*), although he does not have to deal with the final realization of a state of the world from an ex post perspective.

[6] In the Netherlands, about 17 percent of homeowners in 2006 wanted to move house within two years. 36 percent of those homeowners wanted to move within one year. The median length of residence in 2006 for those homeowners who wanted to move within 2 years was about 9 years (Source: WoON 2006).

[7] In particular, we assume that transaction costs are not risky. Consequently, the homeowner does not need to be hedged against this risk.

[8] In addition, we abstract from households that possess multiple houses at a particular point in time. This distinguishes the households from the institutional investor like realtors, project developers or other investors in real estate. We also ignore the portfolio choice between assets (housing, stocks, and bonds) (see for instance Englund et al. (2002) for the portfolio choice of homeowners). Furthermore, we abstract from other sources of risk (e.g. lock-in risk, rent risk, housing consumption risk).

[9] In particular, there is a maximum (percentage change in) rent. However, in recent years part of the

lead to a hedging benefit), the sale price risk as a result of equation (1) is typically faced by homeowners who consider moving from the owner-occupied housing sector to the rental housing sector in the future.

Homeownership is typically a persistent state. A homeowner tends to stay a homeowner.[10] [11] This type of homeowner buys a house in the future at location *B*, of type c (which may be the same type as the current home), at time $t+s$. The homeowner pays $\tilde{p}_{t+s}^{B,c}$. This asset position FV_t is characterized by the following payoff structure at time t,

$$FV_t = 0 - \delta^{t+s}\,\tilde{p}_{t+s}^{B,c} \tag{2}$$

Hence, not only the selling price of the current home is at risk, but also the buy price of the future home. In combination with equation (1), the total value position $Total_t$ in housing for a homeowner who plans to stay a homeowner in the future is,

$$Total_t = CV_t + FV_t = -p_t^{A,r} + \delta^{t+s}\,(\tilde{p}_{t+s}^{A,r} - \tilde{p}_{t+s}^{B,c}) \tag{3}$$

This resembles the cost of owning, as in Sinai and Souleles (2005), in simplified form.[12]

Risk is measured by the variance of the portfolio owned by the homeowner. The variance of CV_t in equation (1) is relevant for the homeowner who moves to a rental unit in the future,

$$VAR(CV_t) = \delta^{2t+s}\sigma^2_{\tilde{p}A,t+s,r} \tag{4}$$

where $-p_t^{A,r}$ is assumed to be known at time t (i.e. it is in the information set of the homeowner at time t), and $VAR(\tilde{p}_{t+s}^{A,r}) = \sigma^2_{\tilde{p}A,t+s,r}$ is a measure of sale price risk. Similarly, the variance of the portfolio $Total_t$ in equation (3) is relevant for the repeated homeowner,

$$VAR(Total_t) = \delta^{2t+s}[\sigma^2_{\tilde{p}A,t+s,r} + \sigma^2_{\tilde{p}B,t+s,c} - 2COV(\tilde{p}_{t+s}^{A,r}, \tilde{p}_{t+s}^{B,c})] \tag{5}$$

In accordance with Sinai and Souleles (2005), asset price risk for both types of

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rental market has been liberalized.

[10] In particular, the homeownership rate in the Netherlands in 2006 has been about 54 percent. About 87 percent of those homeowners prefer to buy a new home instead of renting a house if they move (Source: WoON 2006).

[11] Two reasons for the persistence in homeownership are a tax benefit as a result of owning a home or more utility out of owner-occupied housing consumption than rental housing consumption.

[12] The cost of owning as stated by Sinai and Souleles (2005) is equation (3) times minus 1. However, Sinai and Souleles incorporate the subsequent sale price of the future home at location B, but not the buy price at location C (or further residence spells). As a consequence, an additional risk is introduced in their equation that is not hedged. We ignore this additional risk. Moreover, we incorporate the type of house.

homeowners is lower the longer homeowners expect to stay in the current home if the effect of the discount factor is larger than the possible increase in uncertainty due to the longer expected time horizon. If this result holds, asset price risk also converges to zero for those homeowners who never plan to move.

Empirically, we will focus on the three dimensions of risk: location, house type, and time. In particular, equation (4) (i.e. $\sigma^2_{\tilde{p}A,t+s,r}$) suggests that a homeowner who lives at location *A* may face a different level of sale price risk than the homeowner at location *B*. Moreover, this risk may be different if a homeowner owns a house of type r instead of a house of type $r+1$. In addition, risk may depend on the time t the homeowner bought the home.

The homeowner who plans to stay a homeowner after he has moved to a new home (i.e. equation (5)) faces the risk reported in equation (4), but there is also an additional risk since the buy price of the future home is uncertain (i.e. buy price risk, $\sigma^2_{\tilde{p}B,t+s,c}$). Hence, this type of homeowner should add up the risk at location *A* and *B*. The uncertainty surrounding the house price at location *B* again depends on the aforementioned three dimensions. However, sale price risk for this type of homeowner may be reduced due to the co-movement (covariance) in house prices between location *A* and location *B*. In particular, the current house acts as a hedge against the uncertainty in the price of the future house (or vice versa). In contrast to standard investors, (repeated) homeowners benefit from a positive covariance between house price series across locations. The hedging benefits of home owning may contribute to the persistence in homeownership and it may result in households who do not move randomly between locations (i.e. due to hedging demand, see Cocco, 2000; Sinai and Souleles, 2009).

The most important characteristic of the hedging opportunity in equation (5) is that it is a cross-location hedge against differences in house price developments across locations. [13] Hence, this hedging opportunity depends on the current and future place of residence. In addition, the homeowner who trades up or down ($r \neq c$) should also take into account that house price changes across market segments may not be similar. Moreover, if the time trends in $\tilde{p}^{A,r}_{t+s}$ and $\tilde{p}^{B,c}_{t+s}$ are not the same (i.e. in the empirical

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[13] This type of homeowner owns a cross hedge, since one asset (defined by location, time and type of house) is hedged with another asset. Furthermore, we assume that the homeowner can sell the current home and buy the future home simultaneously (at time $t+s$). In particular, we ignore the additional risk related to time on the market (i.e. a delta hedge).

part we assume a common time trend conditional on the type of house and location) the timing of the hedge against price risk may also be important. Finally, the correlation coefficient (or hedge ratio for that matter) may capture all the elements in equation (5), but it does not identify the separate elements of risk. In particular, it does not provide us with evidence what the uncertainty with regard to house prices (i.e. $\sigma^2_{\tilde{p}A,t+s,r}$ or $\sigma^2_{\tilde{p}B,t+s,c}$) may be. However, a high correlation does indicate whether risk has a tendency to cancel out against the hedge $COV(\tilde{p}^{A,r}_{t+s}, \tilde{p}^{B,c}_{t+s})$ and, as such, it may trace out the hedge quality.

Households that move to a rental home do not possess the aforementioned hedging opportunity. In particular, equation (5) has led to the common believe that a homeowner who becomes a renter in the future is not hedged against price changes, but he may only be hedged against rent risk. In contrast, we argue that this type of homeowner may be hedged against price changes due to the nature of the price process. To illustrate the main idea, assume that the price process at location *A*, the current place of residence, is,

$$p^{A,r}_t = \mu^{A,r}_t + \varphi_{A,t-1,r} p^{A,r}_{t-1} + \eta^{A,r}_t \qquad (6)$$

where $\mu^{A,r}_t$ is a parameter that determines the average price change for house type *r* at location *A* and time t, the parameter $\varphi_{A,t-1,r}$ captures the persistence in house prices, and $\eta^{A,r}_t$ are house price shocks, which have a zero mean and variance of $\sigma^2(\eta^{A,r}_t)$. [14] The same equation holds for location *B*. The exact structure of the asset price risk in equation (4) depends on the price process in equation (6). Without loss of generality we assume $s = 2$. Under this assumption we can still investigate the intertemporal structure of sale price risk. In addition, we assume that, house price shocks have a fully persistent effect on house prices, $\varphi_{A,t-1,r} = 1$ (i.e. we ignore the effect of the persistence parameter). These assumptions lead to the following two-period ahead price at location *A* (the price at location *B* has a similar form),

$$p^{A,r}_{t+2} = p^{A,r}_t + \mu^{A,r}_{t+1} + \mu^{A,r}_{t+2} + \eta^{A,r}_{t+1} + \eta^{A,r}_{t+2} \qquad (7)$$

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[14] We do not discuss (or restrict) the sources of house price shocks. In particular, these shocks may be pure local shocks, common shock, or a combination of the two. In addition, shocks may be supply driven or demand driven. In contrast, Sinai and Souleles (2005) assume that supply is fixed (inelastic) such that there is perfect pass trough of demand into the house price. Moreover, house price changes are the result of rent shocks.

The parameters $\mu_{t+1}^{A,r}$, $\mu_{t+2}^{A,r}$ capture the average (expected) growth in prices at period $t+1$ and $t+2$, respectively. To highlight the most important interrelationships (covariance terms) between the elements of the price process, we assume that average price changes are fully independent from price shocks. In particular, the parameters $\mu_{t+1}^{A,r}$, $\mu_{t+2}^{A,r}$ are independent from $\eta_{t+1}^{A,r}$, $\eta_{t+2}^{A,r}$, (i.e. with respect to equation (5) also at location *B* or across locations regardless of the type of house). Finally, we also impose the restriction that the discount factor is equal to one, $\delta = 1$ (i.e. we ignore the effect of the discount factor). This assumption implies that expected mobility does not play a role in the determination of risk.

Based on equation (7) and the aforementioned assumptions, the sale price risk in equation (4) becomes,

$$VAR(CV_t) = \boldsymbol{\sigma}^2(\mathbf{X_A}) \bullet \mathbf{1} + 2\boldsymbol{COV}(\mathbf{X_A}) \bullet \mathbf{1} \tag{8}$$

where $\boldsymbol{\sigma}^2(\mathbf{X_A}) = \left\{ \sigma^2(\mu_{t+1}^{A,r})\ \sigma^2(\mu_{t+2}^{A,r})\ \sigma^2(\eta_{t+1}^{A,r})\ \sigma^2(\eta_{t+2}^{A,r}) \right\}$ is a 1x4 vector, which contains the main sources of uncertainty that contribute to sale price risk. There are two sources of uncertainty: average price changes and price shocks. $\boldsymbol{COV}(\mathbf{X_A}) = \left\{ COV(\mu_{t+1}^{A,r}, \mu_{t+2}^{A,r})\ COV(\eta_{t+1}^{A,r}, \eta_{t+2}^{A,r}) \right\}$ is a 1x2 vector of covariance terms.

Of particular interest are the hedging opportunities captured by the two covariance terms in equation (8). These covariance terms suggest that the homeowner who moves to a rental house in the future may be intertemporally hedged against average price changes and price shocks. In particular, negative covariance terms may result in a reduction of the risk $VAR(CV_t)$. The covariance terms may be negative if average price changes or price shocks have a tendency to cancel out across time. In particular, total sale price risk is zero if $\mu_{t+1}^{A,r} = -\mu_{t+2}^{A,r}$ and $\eta_{t+1}^{A,r} = -\eta_{t+2}^{A,r}$. In contrast, price changes/shocks may be amplified by previous price changes/shocks, which could be an additional source of risk in equation (8). We will empirically investigate these two hedging opportunities, which are the only hedging opportunities available for the homeowner who want to move to a rental unit.

The only additional conclusion for the homeowner who buys new house after he has moved out of the current home (i.e. equation (5)) is that, besides the intertemporal hedging opportunity at location *A*, he may also have been intertemporally hedged (i.e. $\boldsymbol{COV}(\mathbf{X_B})$) against price risk $\boldsymbol{\sigma}^2(\mathbf{X_B})$ at location *B*.

However, this conclusion may only hold if time developments of price change or price shocks are also location-specific and house type-specific (i.e. which we will ignore in the empirical part). In particular, the cross-location covariance terms $\boldsymbol{COV}(\mathbf{X_A};\mathbf{X_B})$ (eight covariance terms) with respect to average price changes $\boldsymbol{COV\mu}(\mathbf{X_A};\mathbf{X_B})$ (similarly for price shocks $\boldsymbol{COV\eta}(\mathbf{X_A};\mathbf{X_B})$) are,

$$\begin{aligned}\boldsymbol{COV\mu}(\mathbf{X_A};\mathbf{X_B}) = \{&COV(\mu_{t+1}^{A,r},\mu_{t+1}^{B,c})\ COV(\mu_{t+2}^{A,r},\mu_{t+2}^{B,c})\\ &COV(\mu_{t+2}^{A,r},\mu_{t+1}^{B,c})\ COV(\mu_{t+1}^{A,r},\mu_{t+2}^{B,c})\}\end{aligned} \tag{9}$$

If time developments are common across locations and the homeowner does not trade up or trade down ($r = c$), such that $\mu_{t+1}^{A,r} = \mu_{t+1}^{B,r}$ and $\eta_{t+1}^{A,r} = \eta_{t+1}^{B,r}$ (also at $t+2$), the covariance terms in $\boldsymbol{COV}(\mathbf{X_A})$ and $\boldsymbol{COV}(\mathbf{X_B})$ cancel out against the covariance terms as a result of $COV(\tilde{p}_{t+s}^{A,r},\tilde{p}_{t+s}^{B,c})$ (i.e. $\boldsymbol{COV}(\mathbf{X_A};\mathbf{X_B})$). In particular, the first two covariance terms in $\boldsymbol{COV\mu}(\mathbf{X_A};\mathbf{X_B})$ and $\boldsymbol{COV\eta}(\mathbf{X_A};\mathbf{X_B})$ would remain. In addition, the sources of risk in $\boldsymbol{\sigma}^2(\mathbf{X_A})$ and $\boldsymbol{\sigma}^2(\mathbf{X_B})$ would cancel out against the remaining cross-location hedging opportunities (i.e. the remaining four covariance terms in $\boldsymbol{COV}(\mathbf{X_A};\mathbf{X_B})$ at $t+1$ or $t+2$). Hence, the homeowner who stays in the owner-occupied sector is perfectly hedged against common price changes or shocks ceteris paribus on the type of house and location.

The welfare implications of sale price risk depend on the utility function of homeowners. Sinai and Souleles (2005) use $E_{t=0}U(W-Co)$, where W is wealth and Co is the cost of owning. In general, if households are risk averse, sale price risk is detrimental for their welfare, although some households might be risk takers in the domain of losses. In addition, if the risk does not turn out in their favor it may well limit their future housing consumption (ex post utility).

As mentioned, the evaluation horizon is of crucial importance since sale price risk is in the future. Sinai and Souleles (2005) argue that the time horizon is the expected length of stay. However, as is discussed by Bernartzi and Thaler (1995) in relation to the equity premium puzzle, it might be that an asset is kept for a prolonged period of time, but is evaluated over a shorter time horizon. For instance, a homeowner may move at the year $t+s$, but (re)evaluates his asset position on a yearly basis. This evaluation horizon would be in accordance with the tax system (i.e. yearly tax payments). The yearly-evaluation assumption would validate an investigation (estimation) of sale price risk on a yearly basis. In addition, the volatility (at year t) of the price at $t+1$ is similar to the volatility of price changes since the price at year t is known and prices are assumed to be fully persistent. Hence, we can base our investigation of sale price risk and the hedge against this risk on (yearly) price changes. In particular, the hedge provided by owning a home is based on price changes, not percentage changes.[15] Furthermore, the yearly-evaluation assumption suggests that the heterogeneity of homeowners with regard to the expected length of stay does not result in differences in sale price risk. In addition, sale price risk for a homeowner who bought a home at time t would be similar to the sale price risk at time t for the homeowner who bought a home before time t.

In this section, we interpreted housing wealth from an investment perspective. However, it is well known that a house is a consumption good as well as an investment good (e.g. see Ioannides and Rosenthal, 1994). In particular, the variation in house prices may influence the investment and consumption decision and it may be the result of both decisions. Specifically, the house price is a revenue concept since it consists of the amount of housing consumption/investment priced by the marginal price of a housing unit. Nevertheless, if housing consumption does not unexpectedly change after buying a home, house price variation can be interpreted from an investment perspective. Although the consumption perspective may be an important aspect of housing, we predominately focus on the investment properties of the house from a homeowner perspective.

A further issue is that the housing market is not the same as a financial market. The housing market is characterized by imperfect arbitrage due to high transaction costs and the indivisibility of the housing good. In addition, the homeowner has still the possibility to avoid the future pay-offs in equation (1) and equation (3), since there is no binding contract. He either postpones the sale of the current home or he moves to another future location. Nevertheless, this paper explicitly ignores the implication of sale price risk for mobility or the endogeneity of the location choice (i.e. see Sinai and Souleles, 2009 for a discussion).

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[15] Specifically, price levels are different across locations and homeowners invest a total sum of their wealth at a particular location. As a result, a comparison of percentage changes is not of interest from a homeowner's perspective.

3. Empirical strategy and hypotheses

3.1 The persistence in house prices

To estimate sale price risk we start with a simple AR(1) model of house prices,

$$p_{i,t,r} = \mu_{i,t,r} + \varphi_{i,t,r} p_{i,t-1,r} + \varepsilon_{i,t,r} \qquad (10)$$

where $p_{i,t,r}$ is the median transaction price (in euros) at municipality *i*, house type *r*, and year *t*, $\mu_{i,t,r}$ is a municipal, time and house type specific intercept, $\varphi_{t,r,i}$ is the house price persistence parameter, and $\varepsilon_{i,t,r}$ is the error term.[16] Hence, we have a panel model with three dimensions. This price process resembles the price process in the theory section, equation (6), where we focus on the municipality as the main indicator of the location of the home.[17] In addition, we do not distinguish between the (expected) sale price or buy price of a home (i.e. sale price risk or buy price risk), but use realized transaction prices instead.

The model in equation (10) is too general to identify all of the parameters. We utilize the following simplified (restricted) version of equation (10),

$$p_{i,t,r} = \alpha_i + \tau_t + \gamma_r + \varphi p_{i,t-1,r} + \varepsilon_{i,t,r} \qquad (11)$$

where α_i is a municipal-specific intercept (municipality dummies), τ_t are time shocks (time dummies), γ_r is an intercept specific to the type of house (house type dummies), and φ is a persistence parameter. Hence, we assume that the intercept (i.e. $\mu_t^{A,r}$ in the theory section) is additively separable in the aforementioned elements to emphasize the three dimensions of the (change in) house prices. Moreover, we restrict the persistence parameter, such that it is not house type, time, and location-specific. We estimate φ along the lines of Arellano-Bond (1991), since the standard strict exogeneity assumption in equation (11) is violated. A potential downside of this model is that it only allows us to directly investigate the change of price shocks. However, if house prices are persistent house price shocks have a persistent effect on

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[16] Usually the distribution of individual transaction prices is skewed. The median price is less sensitive to this skewness and mitigates the effect of outliers on a municipal level. In addition, the yearly aggregation will cancel out any seasonal fluctuation. Moreover, it allows us to analyze risk across time even if the time span available in the dataset is limited.

[17] The municipality may not be the correct indicator of the location of the home. For instance, housing markets may be defined on a higher level of aggregation than the municipality. For example, the Dutch Association of Realtors defines 76 regions, most of which comprises several municipalities. To our opinion this would aggregate out a substantial amount of the price change variation relevant to the homeowner. In addition, a lower scale of aggregation (e.g. zip code level) would lead to a substantial loss of observations (see the latter part of the data section). As a result, the coverage of municipalities in the Netherlands would be severely limited.

house prices. In addition, the current price does not contain additional information to help the homeowner with his prediction of the future price (or the price change from the current to the future price). In particular, if house prices are persistent, we can ignore price levels in our analysis and focus solely on price changes. As a result, our first hypothesis is,

Hypothesis 1: *House prices are persistent.*

Assume that shocks indeed have a fully persistent effect on the house price (i.e. $\varphi = 1$). In this case we could rewrite equation (11) to,

$$\Delta p_{i,t,r} = \alpha_i + \tau_t + \gamma_r + \varepsilon_{i,t,r} \qquad (12)$$

Hence, house price changes have a location-specific, time-specific and house type-specific component. With regard to the error term in equation (12), we assume that the standard strict exogeneity assumption holds $E(\varepsilon_{i,t,r} | \alpha_i, \boldsymbol{\tau}, \gamma_r) = 0$, where $\boldsymbol{\tau}$ captures all τ_t. In addition, the error term has a conditional variance $\text{var}(\varepsilon_{i,t,r} | \alpha_i, \boldsymbol{\tau}, \gamma_r) = \sigma^2_{i,t,r^{\varepsilon}}$, which is per definition the same as the conditional variance of $\Delta p_{i,t,r}$ $\text{var}(\Delta p_{i,t,r} | \alpha_i, \boldsymbol{\tau}, \gamma_r) = \sigma^2_{i,t,r^{\Delta p}}$.

3.2 Sale price risk and price shocks

To investigate the main sources of sale price risk house price return volatility (i.e. $\sigma^2_{i,t,r^{\Delta p}}$ or $\sigma^2_{i,t,r^{\varepsilon}}$) is of direct interest. The unconditional versions of these risk measures cannot be directly estimated (using cross-municipal price variation), since there are as many observations as parameters to estimate. Hence, we need to impose some restrictions on the dimensions of risk. In particular, we impose that risk is additive, which is in accordance with equation (12). In particular, we estimate the following model,

$$\varepsilon^2_{i,t,r} = \alpha_i + \tau_t + \gamma_r + \xi_{i,t,r} \qquad (13)$$

where $\xi_{i,t,r}$ is the error term, which is assumed to be strictly exogenous and $\varepsilon^2_{i,t,r}$ is the squared error term from equation (12). Since $E(\varepsilon^2_{i,t,r} | \alpha_i, \boldsymbol{\tau}, \gamma_r) = \text{var}(\varepsilon_{i,t,r} | \alpha_i, \boldsymbol{\tau}, \gamma_r) = \sigma^2_{i,t,r^{\varepsilon}}$ due to the strict exogeneity assumption, we can use the model in equation (13) to investigate all the aforementioned dimensions of risk.

There are two drawbacks of this approach. First, there is a crucial difference between the regression setup of sale price risk and the theoretical definition of sale price risk. The terms α_i, γ_r, and τ_t are assumed to be direct determinants of the sources of risk (i.e. we investigate the conditional variance). As a result, the conditional variance of these determinants does not contribute to the conditional variance of price changes. This argument implies that we will mainly investigate (the conditional variability of) price shocks as the main source of the volatility of house price returns (the uncertainty component in sale price risk). However, we will investigate the volatility of total price changes from a descriptive statistics point of view (based on within and across municipal variation). Second, the regression estimates of equation (13) will not capture total sale price risk, but the spread of the main source of sale price risk (i.e. ignoring the hedging opportunities) decomposed in location-specific, house type-specific, and time-specific components. Hence, market segment, time and location should not be interpreted as the direct determinants of total sale price risk, but rather as determinants of the sources of uncertainty that influence total sale price risk.

We investigate whether the spread of one of the main sources of uncertainty, house price shocks, varies across types of houses, years and municipalities. For instance, a villa may be associated with a different level of risk than an apartment, ceteris paribus on the other dimensions of the volatility of price shocks. Moreover, the spread of price innovations may differ across time, conditional on differences in volatility across market segments and location. In particular, we would expect that price changes may be the most heterogeneous during an economic boom or bust. Furthermore, location may be an important determinant of sale price risk, ceteris paribus on time and market segment effects, since housing markets may be highly localized. This relationship may be spatial (i.e. determined by distance) due to for instance spillovers across local housing markets. Summarizing, we investigate the following hypotheses,

Hypothesis 2 (market segments): *The volatility of house price returns is the same across types of houses.*

Hypothesis 3 (time): *The volatility of house price returns is constant over time.*

Hypothesis 4 (location): *Location is not a determinant of the volatility of house price returns.*

Hence, we can investigate these hypotheses in a parsimonious model (equation (13)). In essence, we employ the standard Breusch-Pagan test (significance of α_i or τ_t or γ_r), to test the null hypothesis $\sigma^2_{i,t,r}\varepsilon = \sigma^2_{i,t}\varepsilon$, $\forall r$; $\sigma^2_{i,t,r}\varepsilon = \sigma^2_{i,r}\varepsilon$, $\forall t$; and $\sigma^2_{i,t,r}\varepsilon = \sigma^2_{t,r}\varepsilon$, $\forall i$, where we replace $\varepsilon^2_{i,t,r}$ with its estimate, the squared residual from equation (12).

3.3 The hedging opportunities

The previous subsection abstracts from the hedging benefits of homeownership. If the hedge against sale price risk is perfect, relative price changes, the hedge ratio, will be equal to one. We will investigate this hedge ratio from a descriptive statistics point of view. In addition, relative price changes are also captured by equation (12). According to equation (12), price changes have several dimensions. Similar to sale price risk, the hedge against this risk has a location, house type, and time dimension. In particular, the average hedge is captured in equation (12) by the terms α_i, γ_r, and τ_t, since $\varepsilon_{i,t,r}$ has a zero mean. As a consequence, we will not investigate the covariance terms mentioned in the theory section directly, but we will focus on the dimensions of relative price changes (capital gains). The term γ_r captures discrepancies in price changes across market segments. In particular, some households may decide to trade up or down the property ladder. If there are no disparities in price changes across market segments, $\gamma_1 = \gamma_2 ... = \gamma_r$, homeowners who trade-up or trade-down are perfectly hedged, ceteris paribus on the type of house and common price changes. In this particular case, the decision to trade up or down does not lead to additional risk on average. The time-specific intercept τ_t captures the common part of house price changes across municipalities. Homeowners who stay in the owner-occupied sector after they have moved are perfectly hedged against those common price changes, ceteris paribus on the type of house and location. In contrast, homeowners who move out of the owner-occupied sector may be intertemporally hedged against common price changes. In particular, price changes may cancel out over time, $\sum_t^T \tau_t = 0$. From a short run perspective, negative serial correlation in the error term $\varepsilon_{i,t,r}$ is also an indication of an intertemporal hedge with regard to house price shocks. We will focus on the serial correlation in the AR(1) model $\varepsilon_{i,t,r} = a_0 + \rho\varepsilon_{i,t-1,r} + \chi_{i,t,r}$. If $\rho = -1$ a homeowner who moves to a rental unit is perfectly intertemporally hedged against price shocks. However, we ignore other hedge types with regard to price shocks. For instance, a location-specific effect in the error term would result in correlation between the fixed effect in the price change equation, equation (12), and the error term. Instead, we assume that the standard strict exogeneity assumption holds. The municipal-specific intercept α_i captures the heterogeneity in price changes across municipalities. If there are no differences in price changes across municipalities, $\alpha_1 = \alpha_2 ... = \alpha_i$, homeowners who stay in the owner-occupied sector after they move may be on average perfectly hedged against differences in price changes across municipalities, ceteris paribus. In addition, the location-specific effect in price changes may not be random, but spatial of nature. We investigate the hedge quality and whether the hedge against sale price risk is perfect. Summarizing, our hypotheses are,

Hypothesis 5 (market segments): *The cross-market segment hedge is perfect.*

Hypothesis 6 (time): *The intertemporal hedge against price changes or price shocks is perfect.*

Hypothesis 7 (location): *The cross-location hedge is perfect.*

Hence, we can simply run the regression based on equation (12) and test the significance (or equality) of each of the terms α_i, γ_r, τ_t, and ρ, using the standard t-tests and F-tests. Similarly to the discussion on the sources of sale price risk, we will only capture the market segment, time and location contributions to the hedge, while the total hedge against price risk may a combination of these dimensions.

4. Data

The results in this paper are based on all transaction prices of existing homes in the Netherlands between 1995-2008. The dataset contains 2,683,130 transaction prices. We are provided access to this dataset by Statistics Netherlands/Kadaster.[18] By law (Kadaster Wet) all transaction prices are recorded by a separate institute (the

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[18] In particular, the Kadaster provided the dataset to Statistics Netherlands. Statistics Netherlands granted us access to this dataset (“Bestaande Koopwoningen 200812V1”).

Kadaster). After a transaction the notary provides the relevant information to the Kadaster (e.g. date, price, location). Sales of newly build homes are not included in the dataset. We investigate the transaction prices per year. There are 6 types of houses (apartment, row/terraced house, corner house, semi-detached house, detached house, unknown) available in the dataset. Unknown house types are not analyzed in this paper (this is the largest selection, 172,432 observations). Moreover, transaction prices smaller than 10,000 euro's and larger than 5 million euros and houses that were sold more than once in a particular month were also excluded. After these selections there are 2,486,742 observations left. Finally, 174 municipal code-zip code combinations were not unique, which is indicative of coding error. After the removal of the incorrect combinations 506 additional observations are lost, 2,486,236 observations are left.

We split up the analysis using across municipal price variation and within municipal (4-digit zip code) price variation.[19] There are 441 municipalities in the Netherlands in 2009. For privacy reasons, we impose the restriction that the median transaction price per municipality and house type is at least based on 10 observations in a particular year (19,171 observations are lost). After these modifications there are 2,467,065 observations left for the analysis across municipalities. The average (across years) number of municipalities used to calculate the median price is about 260 for apartments, 418 for row houses, 391 for corner houses, 406 for semi-detached houses, and 410 for detached houses (see Appendix 1). Hence, in a large part of the Netherlands there have been a low number of sales of apartments. The associated average (across years) number of transactions is about 180 for apartments, 150 for row houses, 62 for corner houses, 51 for semi-detached, and 53 for detached. This yearly average is based on the average (across municipalities) number of transactions per year and house type. We mainly focus on price changes. Differencing may result in an additional loss (the observations in 1995 are also lost) of the number of available municipalities with price change information (see Appendix 1), although this loss of observations seems to be minor. In particular, the yearly average number of

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[19] The total number of residential moves (including the moves associated with the rental sector) between municipalities increased from 35.3 to 39.4 percent between 1988 and 2007 in the Netherlands. Hence, most residential moves are within the municipality. As a result, we will also investigate the within municipal return variation. Both moves within and between municipalities where increasingly the result of singles, with an increase of 45.5 to 51.8 percent and 56.1 to 64.8 percent between 1998 and 2007, respectively (Source: Statistics Netherlands). Hence, the exposure to sale price risk of singles has increased over time.

municipalities available in the price change dataset is about 234 for apartments, 412 for row houses, 375 for corner houses, 395 for semi-detached house, and 401 for detached houses.

The analysis using within municipal variation is based on a 4-digit zip code (neighbourhood) level. In particular, we use the aggregate (median) price per zip code, type of residence, and year. In order to obtain a dataset with enough variation within municipalities, we impose the restriction that there are at least 4 price level observations per zip code (110,091 observations are lost) and 4 zip codes per municipality (466,673 observations are lost). Hence, there should be at least 16 observations per municipality (type of residence and year), which is more restrictive than the previous restriction of a minimum of 10 observations. In particular, only 1,909,472 observations are left (in contrast to the 2,486,236 observations after the municipal code-zip code correction). The number of unique zip codes is 1,314 for apartments, 2,125 for row houses, 1,778 for corner houses, 2,079 for semi-detached houses, and 2,456 for detached houses (against a total number of unique zip codes of 3,962 after the municipal code-zip code correction). As mentioned, we are interested in price changes (per zip code within a municipality). In particular, missing (aggregate zip code price) observations in adjacent years lead to an additional loss of observations after differencing. Moreover, we impose that there should be at least 4 zip codes per municipality with a non-missing zip code price change before an aggregate measure for the municipality is calculated. There are still 3,043 unique zip codes available. The yearly average number of zip codes is around 10 for apartments, 8 for row houses, 7 for corner houses, 6 for semi-detached houses, and 6 for detached houses. This yearly average is based on the average (across municipalities) number of zip codes with a non-missing price change statistic per municipality, house type, and year (see Appendix 2). Based on the 4-digit zip code data the statistics on a municipal level are generated. The aforementioned restrictions decrease the number of available municipalities (per house type and year) that can be used in the analysis substantially (see Appendix 2). In particular, the yearly average number of municipalities available is about 89 for apartments, 172 for row houses, 131 for corner houses, 141 for semi-detached house, and 167 for detached houses. Hence, the investigation using within municipal price variation is restricted to relatively large municipalities.

5. Some stylized facts

This subsection provides some stylized facts about the level and change of house prices in the Netherlands.

[-FIGURE 1 ABOUT HERE-]

Figure 1 shows the cross sectional average $\overline{p}_{t,r}$ at year *t* and house type *r* across $N_{t,r}$ municipalities of the median transaction price $p_{i,t,r}$ (the left hand side variable in equation (11)),

$$\overline{p}_{t,r} = \frac{1}{N_{t,r}} \sum_{i=1}^{N_{t,r}} p_{i,t,r} \tag{14}$$

Figure 1 depicts two important aspects about house prices in the Netherlands. First, the average house price shows a clear trend. Detached houses increased the most in price over the past 14 years (from 141,000 euros to 423,000 euros). Apartments had the lowest price change (from 64,000 euros to 170,000 euros). These results suggest that capital gains in the Netherlands have been quite sizeable and can possibly act as buffer against price declines. Second, there is a natural ordering in the price levels across house types. This ordering is known as the property ladder. Since there is a similar ordering in capital gains, there is a positive association between price levels and accrued capital gains.[20]

[-FIGURE 2 ABOUT HERE-]

Figure 2 reports the number of transactions $Tr_{t,r}$ per time *t* and house type *r*. The average (across time) number of sales on a yearly basis has been about 47,500 for apartments, 62,600 for row homes, 24,200 for corner houses, 20,700 for semi-detached houses, and 21,900 for detached-houses. Hence, row houses are the type of house that is sold the most in the Netherlands and (semi) detached- houses have the lowest number of sales. The market value of these transactions has been steadily increasing, in accordance with the price trend reported in Figure 1. The total market value (sum of transaction prices) of all house transactions was around 13,171 million euros in 1995 and 44,138 million euros in 2008. In comparison, nominal GDP was around 305 billion euros in 1995 and 596 billion euros in 2008.[21] Hence, there is a substantial amount of wealth invested in housing.

[-FIGURE 3 ABOUT HERE-]

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[20] This relationship is not surprising, since a high house price is an indication of a high level of housing consumption. A high level of housing consumption implies a high investment in units of housing. This higher investment translates into a higher total capital gains, since capital gains equals the total number of invested units times the price difference between the current and future house per unit of housing consumption.

[21] GDP at market prices, current prices (Source: Statistics Netherlands).

Finally, Figure 3 shows the cross-sectional (municipality) average house price change $\overline{\Delta p_{t,r}}$ at year *t* and house type *r*, [22]

$$\overline{\Delta p_{t,r}} = \frac{1}{N_{t,r}} \sum_{i=1}^{N_{t,r}} (p_{i,t,r} - p_{i,t-1,r}) \tag{15}$$

where $(p_{t-1,r,i} - p_{t-1,r,i})$ is the house price change at time *t* of house type *r* at municipality *i* (i.e. $\Delta p_{i,t,r}$). This house price change is the dependent variable in the estimation of equation (12) and equation (13). The business cycle in terms of nominal GDP growth is also reported. Across time, the yearly average return is around 7,900 euros for apartments, 9,900 euros for row homes, 10,800 euros for corner houses, 14,100 euros for semi-detached homes, and 22,000 euros for detached houses. Price changes are the highest for detached houses, but also seem to be the most volatile. Price changes peaked in 1997 and 2000, but they were relatively low in 2003 and 2008. This pattern is in accordance with the business cycle and plays an important role in our discussion on the boom-bust movement of sale price risk.

6. Simple descriptive statistics

This section discusses sale price risk and the hedge against this risk based on simple descriptive statistics. The formal tests on the dimensions of sale price risk and the hedge against this risk are based on the regressions presented in the next section.

[-FIGURE 4 ABOUT HERE-]

Our main descriptive statistics measure of sale price risk is the cross-sectional standard deviation of price changes per year *t* and house type *r* depicted in Figure 4,

$$sd_{\Delta p_{t,r}} = \left[\frac{1}{N_{t,r} - 1} \sum_{i=1}^{N_{t,r}} (\Delta p_{i,t,r} - \overline{\Delta p_{t,r}})^2 \right]^{0.5} \tag{16}$$

Hence, we use the variation of price changes across municipalities to estimate the spread of price changes (assumed to be common) across municipalities at a particular point in time. Consequently, location is abstracted from as a determinant of sale price risk. In addition, this measure also captures total asset price risk for the homeowner who moves and buys a new home if we ignore the cross-location hedging opportunity of this homeowner (i.e. price changes are independent across locations). Nevertheless, a substantial spread in price changes across municipalities at a

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[22] The removal of the first and last percentile of the price change per house type and year does not alter the pattern in price changes (Figure 3), nor does it affect the pattern in the cross-sectional spread of price changes. The average of percentage (log-difference) house price changes also shows a similar pattern as in Figure 3.

particular year does indicate that the cross-location hedge against sale price risk may be of less quality in that year. In particular, we interpret a high spread of price changes across municipalities as an indication of a high degree of asset/sale price risk (a volatile market).

Figure 4 shows that on average (across time) the sale price risk measure is about 21,000 euros for apartments, 11,000 euros for row homes, 16,000 euros for corner houses, 25,000 euros for semi-detached homes, and 46,000 euros for detached houses. Hence, there seems to be a substantial difference in the volatility of price changes across market segments. These results are in favor of a rejection of hypothesis 2. In particular, Figure 4 suggests that sale price risk is highest for homeowners with a detached house. In general, sale price risk is lowest for a homeowner with a row house. Hence, it seems that those houses that are sold frequently have the lowest sale price risk, while a low number of transactions is associated with a high degree of sale price risk. A high turnover may be indicative of a high degree of arbitrage, which may result in a more homogeneous price development across municipalities. In addition, the availability of a large number of price signals in the case of row houses may further strengthen the arbitrage process. Moreover, it might be that row houses are a more homogenous good than detached houses.

Figure 4 also suggests that sale price risk is not constant over time, which is not in accordance with hypothesis 3. In particular, sale price risk seems to be higher in 2008 than in the beginning of the sample period for all house types. Figure 4 also shows evidence that sale price risk is highest in times of economic boom and bust. In particular, sale price risk shows a peak for apartments and row houses in 1997. In addition, sale price risk peaks around 1999-2001 for all house types, when the housing market was again booming. Moreover, the economic downturn in 2003 is associated with a high sale price risk for row houses and corner houses. Furthermore, across all house types sale price risk seems to have increased in 2008 relative to 2007, which might be related to the uncertainty in the housing market as a result of the mortgage crisis.[23]

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[23] The standard deviation of price changes based on an alternative dataset, publically available data of the Dutch Association of Realtors, shows a similar sale price risk pattern (see appendix 3). In addition, the spread of percentage (log-difference) changes also differs across market segments. In some cases it also peaks during an economic boom and bust. However, the spread in percentage changes seems to have decreased over time, in contrast to the spread of price changes. The spread in percentage price

[-FIGURE 5 ABOUT HERE-]

To obtain a measure of the relative size of sale price risk, Figure 5 divides two times the standard deviation of price changes reported in Figure 5 by the average price level depicted in Figure 1. The two standard deviations $2sd_{\Delta p^{t,r}}$ are supposed to capture almost all of the possible below average price changes.[24] Hence, this measure is interpreted as the maximum percentage of the investment at risk.[25] This measure may account for a different level of investment across house types and may adjust for the possible effect of a price trend on sale price risk. As mentioned, we may underestimate this maximum since we use the total investment (i.e. price level) as benchmark (not net housing equity).

Figure 5 shows that there may be a substantial maximum percentage of the investment at risk. In particular, on average (across time) the maximum percentage at risk is 35 percent for apartments, 14 percent for row homes, 19 percent for corner houses, 24 percent for semi-detached homes, and 30 percent for detached houses. Hence, row homes are still associated with a low amount at risk, while detached houses, but also apartments, are relatively risky to invest in. These findings are in line with the previous results.

Again, Figure 5 suggests that the maximum percentage at risk is also not time constant. For instance, during the economic upturn in 1997 apartments had a maximum percentage at risk of 54 percent, which is far higher than its yearly average. In 1999, the maximum percentage at risk again peaked for apartments, with 53 percent at risk, while the risk was also higher than the yearly average for semi-detached houses, with 32 percent at risk, detached houses, with 36 percent at risk, and row homes, with 17 percent at risk. The variation of the maximum percentage at risk for corner houses seems to be relatively stable over time, but showed a small peak in 2003 with 20 percent at risk. In 2008, only apartments, corner houses and semi-

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changes may difference out unobserved housing consumption/investment, if housing consumption is constant over time (i.e. pure price variation remains). In contrast, we condition on the type of house and use the price level of the home to condition on the level of housing investment. In addition, the hedge is based on relative price changes, not relative percentage price changes.

[24] Alternatively, it may capture 95% of possible price changes under the assumption of normally distributed returns.

[25] This measure relates to the classical measure of value at risk. This classical measure multiplies, for instance, the 5th percentile (negative) percentage return with the amount invested to give an indication of the possible minimal loss an investor incurs in 5% of the extreme cases. In contrast, the measure we use gives an indication about the maximum percentage of the investment at risk.

detached houses seem to show some increase in the percentage at risk relative to 2007, with 30 percent, 18 percent, and 25 percent at risk, respectively.

[-FIGURE 6 ABOUT HERE-]

The previous measure of risk ignores returns. Figure 6 divides the standard deviation reported in Figure 4 by the average yearly return reported in Figure 3 to create a unitarized measure of risk. This measure is known as the coefficient of variation.[26] Return adjusted risk seems to be highest for apartments and, in some cases, detached houses. Risk is again lowest for row homes. In line with previous results risk in 2008 seems to be higher than in the beginning of the sample period. The unitarized measure of risk shows clear peaks in 2003-2004 and in 2008, although there is no peak around 2000 or 1997. Hence, especially during an economic downturn the risk per unit of return is relatively high. In particular, one euro of return in 2000 was associated with between 0.6 and 1.6 euros spread in returns across types of houses. In 2003, this range was between 1.5 and 3.7 per euro return, and it was even higher in 2008 with the coefficient of variation ranging from 2.8 to 4.3. Hence, risk per unit of return may be between two or three times higher during an economic bust than during an economic boom.

[-FIGURE 7 ABOUT HERE-]

Especially negative returns may be detrimental to the homeowner. Hence, Figure 7 reports the fraction of negative municipal price changes per type of house and year to estimate the chance of a negative return. Figure 7 suggests that, even in a rising market, there always seems to be a municipality with a negative price change. The average (across time) yearly chance of a negative return is about 21.1 percent for apartments, 12.6 percent for row homes, 19.8 percent for corner houses, 20.4 percent for semi-detached homes, and 24.0 percent for detached houses. Hence, the chance of a below zero return seems to be quite substantial and is again lowest for row homes and highest for detached houses. In addition, in the year 2000 the housing market was booming, which is reflected in the low chance of negative returns of 14 percent for apartments, 4 percent for row homes, 5 percent for corner houses, and 7 percent for semi-detached and detached homes. In contrast, the chance of negative returns is highest during an economic bust. In 2003, this chance was 28 percent for apartments, 18 percent for row homes, 26 percent for corner houses, 34 percent for semi-detached

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[26] The inverse of this ratio resembles the sharpe ratio, without a correction for the risk free return.

houses, and 37 percent for detached houses. During the beginning of the economic crisis in 2008 this chance became even more substantial: 35 percent for apartments, 28 percent for row homes, 33 percent for corner houses, and 37 percent for semi-detached houses and detached houses. In general, the fraction of negative price changes seems to be inversely related to house price changes and the business cycle.

[-FIGURE 8 ABOUT HERE-]

The previous measure of sale price risk is not location-specific, while there might be a substantial heterogeneity in the volatility of price changes across municipalities. Similarly to the standard deviation across municipalities, we can calculate the standard deviation of price changes within a municipality. In particular, we use the price changes on a 4 digit zip code level. As mentioned, the number of observations on a municipal level decreases substantially. Nevertheless, Figure 8 reports the average across municipalities of the standard deviation per municipality (year and type of house).

The results in Figure 8 suggest that the spread of price changes within a municipality can be quite substantial. In particular, on average (across time) this volatility measure is about 19,000 euros for apartments, 16,000 euros for row homes, 23,000 euros for corner houses, 28,000 euros for semi-detached homes, and 50,000 euros for detached houses. This volatility is somewhat (between 2000 to 5000 euros) higher than the volatility across municipalities. Hence, the inclusion of the municipality as a determinant of price risk seems to increase the average volatility. In addition, the results suggest that those households who decide to move within a municipality are also prone to sale price risk (i.e. ignoring the hedging opportunities within a municipality and the location within the municipality as a determinant of sale price risk). In accordance with previous results, there are substantial differences across market segments. Again, row houses are on average associated with the lowest volatility of price changes, while the volatility is highest for detached houses. In addition, this volatility measure is also not time constant. Nevertheless, the variability of this measure over time seems to be somewhat less pronounced than the spread across municipalities. In particular, during the economic boom in 1997 only corner houses show a small peak in volatility. Similarly, the return volatility of corner houses and detached houses peaked in the years 2000-2001. The volatility of detached houses peaked in 2003. During the beginning of the mortgage crisis in 2007-2008 only corner houses and semi-detached houses showed a small increase in sale price risk.

The average of the price change volatility within municipalities obscures the spread of this volatility across municipalities. This spread is important since it provides some indicative evidence to which extent location (the municipality) is a determinant of the volatility of price changes (hypothesis 4). The average (across time) standard deviation of the within municipal standard deviation is about 16,000 euros for apartments (min. 8,000; max 32,000), 12,000 euros for row homes (min. 6,000; max 20,000), 17,000 euros for corner houses (min. 10,000; max 23,000), 22,000 euros for semi-detached homes (min. 10,000; max 34,000), and 29,000 euros for detached houses (min. 15,000; max 45,000). This average spread is between 58 and 84 percent of the previously reported average standard deviation. Hence, there is a substantial heterogeneity of the return volatility across municipalities. This result suggests a rejection of hypothesis 4.[27]

[-FIGURE 9 ABOUT HERE-]

For illustrative purposes, Figure 9 reports the spread of price changes for the four largest (in terms of population) municipalities in the Netherlands (Amsterdam, Rotterdam, The Hague, and Utrecht). These municipalities capture a large part of the highly urbanized Center/West of the Netherlands denoted by the name Randstad. Nevertheless, the exact spatial pattern of the return volatility in the Netherlands is discussed in further detail in the next section since many of the volatility observations on a municipal level are missing.

The previous discussion ignores the hedge against sale price risk. The average accumulated capital gains between 1995 and 2008 have been 102,000 euro for apartments, 129,000 euros for row houses, 140,000 euros for corner houses, 183,000 euros for semi-detached houses, and 285,000 for detached houses. Hence, price developments across market segments have not been similar, a first indication that hypothesis 5 can be rejected. In addition, although price changes may cancel out from a short run perspective, the average yearly return has been positive across all house types in the 13 years of the sample period. As a consequence, the homeowner who

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[27] The spread of sale price risk across locations may also have a time-specific component and house type-specific component. In particular, the spread of risk across municipalities in the Netherlands is lowest for row houses and highest for detached homes. In addition, this spread seems to vary substantially over time (i.e. see the previously reported minimum and the maximum). In particular, in the years 1999-2001 all five types of houses showed a peak in the cross-location spread of risk. Moreover, semi-detached houses where associated with an increase in the spread of risk in 2008. Nevertheless, we will not discuss the (interactive) effect of market segments and time on (the spread of) risk or the hedge in further detail.

moved to a rental unit may not have been perfectly intertemporally hedged (i.e rejection of hypothesis 6). Nevertheless, this type of homeowner may have capitalized on the substantial amount of accumulated returns, such that this homeowner may have been better off in terms of total housing wealth than the homeowner who had to buy a new home (for an increasingly higher price). In addition, the accumulated capital gains may act as a buffer against subsequent price declines for the homeowner who chooses to become a renter.

The cross-location hedge quality for those homeowners who move and buy a new home can be measured by the correlation between the median house price time series per municipalities. We condition on the type of house. The contribution of differences in price developments across market segments on the hedge is discussed in further detail in the next section. The average across all (unique) pairwise correlation coefficients (maximum of 97020 correlation coefficients per house type, excluding the correlations between the same municipality) is 0.739 for apartments (50,210 pairwise correlations), 0.957 for row houses (93,419 pairwise correlations), 0.937 for corner houses (87,709 pairwise correlations), 0.928 for semi-detached houses (91,224 pairwise correlations), and 0.903 for detached houses (90,380 pairwise correlations). Hence, the average quality of the hedge seems to be quite high. Nevertheless, it is not perfect (i.e. rejection of hypothesis 7). Again, the type of house that is sold the most in the Netherlands, the row house, provides the homeowner with the best hedge quality among house types. However, this hedge against price risk may be largely the result of a common linear trend in house prices across municipalities. In particular, the average correlation of price changes is substantially lower and about 0.096 for apartments, 0.205 for row houses, 0.127 for corner houses, 0.127 for semi-detached houses, and 0.113 for detached houses.[28]

[-FIGURE 10 ABOUT HERE-]

The correlation coefficient, which is commonly used in this type of analysis (i.e. see Sinai and Souleles 2009), provides information on the sign and size of the relationship between house price series; it does not quantify such a relationship. Hence, Figure 10 reports per house type *r* and municipality *i* the distribution (kernel density estimate) of relative capital gains based on the total price change between

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[28] These correlations are substantially lower than the correlations between house price growth series reported by Sinai and Souleles (2009). This result may be due the low scale of aggregation we use in our analysis.

1995 and 2008, the hedge ratio $\mathit{Hedge\ ratio}_{r,i}$, for Amsterdam versus all other municipalities,

$$\mathit{Hedge\ ratio}_{r,i} = \frac{\Delta p_{2008-1995}{}^{r,\,i}}{\Delta p_{2008-1995}{}^{r,\,amsterdam}} \tag{17}$$

As mentioned, the hedge ratio, like the correlation coefficient, may provide us with an indication of the total asset price risk. Since the hedge ratio is based on capital gains between 1995 and 2008 the hedge ratio is a long term estimate.[29] A hedge ratio of one indicates that the hedge is perfect. The hedge ratio for Amsterdam is one. A hedge ratio below one suggests that the price change in Amsterdam has been large relatively to the price change in another municipality. In this particular case, the value of a house in the other municipality is “underhedged”. The capital gains in Amsterdam between 1995 and 2008 have been 160,395 euros for apartments, 155,093 euros for row homes, 161,416 euros for corner houses, 260,076 euros for semi-detached homes, and 439,076 euros for detached houses.

Figure 10 suggests that most hedge ratios are below 1. Hence, a one euro increase in Amsterdam is associated with less than a one euro increase (i.e. the hedge ratio) in most parts of the Netherlands. In particular, the average (excluding Amsterdam) hedge ratio is highest for corner houses (0.876) and row houses (0.834), and it is lowest for apartments (0.629), detached houses (0.641), and semi-detached houses (0.696). Hence, the hedge may provide coverage against 63 to 88 percent of price developments in Amsterdam. Specifically, the development of the value of the house in other parts of the Netherlands has been between 12 and 27 percent lower than in Amsterdam. The results suggest that the cross-location hedge (against price developments in Amsterdam) has been far from perfect.

[-TABLE 2 ABOUT HERE-]

Table 2 reports the top 5 of highest and lowest hedge ratios (with Amsterdam as benchmark) across municipalities in the Netherlands. The municipalities with the highest (lowest) hedge ratio per definition also have the highest (lowest) capital gains over the period 1995-2008. These capital gains can be calculated based on the capital gains in Amsterdam (i.e. multiply the hedge ratio by the capital gains in Amsterdam). Some municipalities seem to be consistently in the top 5 highest hedge ratios/capital gains (i.e. Heemstede, Bloemendaal, Abcoude, Wassenaar), while other municipalities

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[29] In particular, the hedge ratio at a yearly level could be negative. In addition, this hedge ratio would be highly volatile. Moreover, in contrast to the correlation coefficient the hedge ratio is not symmetric.

have a substantial low hedge quality relative to Amsterdam (i.e. Kerkrade, De Marne, Heerlen).

[-FIGURE 11 ABOUT HERE-]

If households decide to move, they may prefer to move to a new location nearby the current place of residence.[30] If nearby housing markets are correlated, this may lead to a higher effective hedge ratio for the homeowner. As a result, we weighted the hedge ratio (per house type) by the normalized inverse distance (in kilometers) to Amsterdam (distance Amsterdam-Amsterdam is zero). The previously reported cross-market segment pattern remains intact. In particular, the average hedge ratio is highest for corner houses (1.016) and row houses (0.951), and it is lowest for detached houses (0.766) and semi-detached houses (0.836). Apartments have an average hedge ratio that lies between these values (0.689). Hence, the average hedge ratio increases such that 69 to 102 percent of price developments in Amsterdam are covered by the price development in other municipalities. Nevertheless, the hedge against sale price risk is still not perfect for all types of houses. In addition, the increase in the hedge ratio due to the weights suggests that the hedge ratios close to Amsterdam are similar or higher than the hedge ratio of Amsterdam. Hence, the capital gains have been relatively high in the neighborhood of Amsterdam (i.e. the Randstad) versus the rest of the Netherlands (the periphery). In particular, the hedge ratios for the four largest municipalities in the Netherlands are depicted in Figure 11. The results in this paper suggest that homeowners who move between the core and the periphery may have a relatively low hedge quality, while the hedge quality for the homeowners who move within the core or periphery may be higher. In addition, especially homeowners in the periphery may have been underhedged against the price developments in the Randstad. These homeowners may have a substantial finance deficit if they want to move to the core, which may impair their capacity to move to the core.

7. Regression results

This section reports the estimates of the persistence in house prices model (equation 11), the price change (hedge) model (equation 12), and the volatility of

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[30] Sinai and Souleles (2009) argue that households move to correlated market due to the hedge benefits of owning a home. Instead, we argue that households move to nearby markets, for whatever reason, and that nearby markets are likely correlated. A possible explanation for the decision to move to a location nearby the current place of residence may be an information advantage about markets nearby, a social network in the current place of residence, or a job close by the current place of residence.

price shocks model (equation 13).

[-TABLE 3 ABOUT HERE-]

Table 3 reports the estimates of the persistence parameter in the house price persistence model, equation (11). It is well known that this persistence parameter cannot be consistently estimated using standard fixed effects or first differences. Hence, we estimated equation (11) along the lines of the standard Arellano-Bond (1991) method. In particular, equation (11) is differenced. As a result, the house type-specific intercept and municipality-specific intercept are differenced out. Subsequently, the lagged differenced price is instrumented by the third and fourth lag of the median house price. We estimate the parameters of the model by means of the two-step GMM estimator. We utilize the third (and fourth lag), since there seems to be first and second order autocorrelation in the differenced error term (AR(1) in levels). The results in Table 1 suggest that the instruments are relevant and valid. In accordance with hypothesis 1, the results in Table 1 provide evidence that house prices may be highly persistent. These results suggest that house price shocks may have a persistent effect on house prices and we can continue with the restricted price change model stated in equation (12).[31]

[-TABLE 4 ABOUT HERE-]

Table 4, panel A, reports the first-stage regression estimates (column 1) of the price change model in equation (12). In addition, the squared residuals of that model are used as dependent variable (column 2) in the second stage to estimate the parameters of the volatility of price shocks model in equation (13). Panel B and Panel C show the associated tests on the parameters.

We start with a discussion of the volatility of price changes (column 2). In accordance with the previous discussion, the regression estimates in column 2 seem to suggest that there are significant differences in sale price risk across market segments (see panel C). In particular, the volatility of price shocks from apartments, the reference group, differs significantly from the other types of house, except for corner houses. In addition, the null hypothesis that the coefficients are jointly equal is rejected. The volatility of price shocks is again highest for detached houses and lowest for terraced houses. As a result, we can reject hypothesis 2.

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[31] A simple Dickey-Fuller test on the aggregate time series per house type resulted in similar conclusions. Nevertheless, with the small time dimension of our dataset such a (panel) Dickey-Fuller test does not lead to reliable results.

The test results reported in panel C also suggest that sale price risk varies over time, such that hypothesis 3 is rejected. In particular, the volatility of price shocks in all years except 2006 and 2007 is significantly different from the base year 1996. In addition, all the coefficients on the year dummies are significantly different from each other. Moreover, the volatility of price shocks is relatively high in 2000, 2003, and 2008 which is in accordance with the previous results (boom-bust hypothesis).

[-FIGURE 12 ABOUT HERE-]

Finally, the test results in panel C strongly support that location is a determinant of risk. In particular, the municipality dummies are highly significant and the equality of the municipal fixed effects is also rejected. Hence, hypothesis 4 is rejected. In contrast to the price variation within municipalities, the parameters are identified using the time variation per municipality. The municipality dummies with Amsterdam as benchmark have an average coefficient of -954, a median of -1,277, a standard deviation of 1,077, a minimum of -2,668, and maximum of 7,721. Hence, the volatility of shocks is on average (954 variance in millions) lower in other parts of the Netherlands than in Amsterdam. In particular, only in 44 out of 437 municipalities (excluding Amsterdam) the volatility of price shocks seems to be higher than in Amsterdam, ceteris paribus. In addition, 48 out of 437 municipalities have a higher volatility than the municipality of Utrecht (coefficient -46), 57 out of 437 municipalities have a higher volatility than Rotterdam (coefficient 505), and 29 out of 437 municipalities have a higher volatility than The Hague (coefficient -238). In addition, the normalized inverse distance (to Amsterdam) weighted average estimated fixed effect coefficient is -512, which is higher than the unweighted average of -954. Hence, these results suggest that a core-periphery pattern also holds with regard to sale price risk. In particular, homeowners whose current or future house is in the core (the Randstad) will have to deal with a high volatility of price shocks. In addition, especially homeowners who plan to move from the owner-occupied housing market in the core to the rental market (i.e. no cross-location hedging opportunity) might have a relatively high sale price risk. The exact spatial pattern of the location-specific fixed effects in the Netherlands is depicted in Figure 12. The five municipalities with the highest estimated price shock volatility relative to Amsterdam are Wassenaar (7721 added volatility), Bloemendaal (6113 added volatility), Blaricum (6016 added volatility), Reeuwijk (3641 added volatility), and Amstelveen (2945 added volatility). The lowest estimated volatility is in Kessel (-2668 added volatility), Dantumadiel (-

2330 added volatility), Bellingwedde (-2253 added volatility), Slochteren (-2239 added volatility), and Marum (-2232 added volatility).

To investigate and test the different dimensions of the hedging opportunities, Table 4, column 1, reports the determinants of price changes. The first dimension of the hedge against sale price risk is the type of house. In particular, the house type dummies give an indication of the co-movement of returns across market segments. This hedge is especially relevant for those homeowners who decide to trade up or to trade down the property ladder. The results suggest that row homes have a yearly return that is 3,300 euro higher than apartments, corner houses have a 4,000 euro higher return than apartments, semi-detached homes have a 7,900 euro higher return than apartments, and detached homes have a 16,000 euros higher return than apartments, ceteris paribus. These differences between market segments are highly significant (see panel B). As a consequence, hypothesis 5 is rejected. In particular, if a household decides to move between market segments the hedge will become of less quality.

The coefficients on the time dummies in Table 4 suggest a similar cyclical pattern in returns as in Figure 3. A homeowner who stays a homeowner after he moves is perfectly hedged against these common price changes. However, this hedge may be imperfect for a homeowner who moves to a rental unit in the future. The estimated yearly return from 1995 to 1996 is 8,712 euros.[32] Hence, the coefficients on the time dummies suggest that yearly price changes have been predominately positive, ceteris paribus. Based on the time dummy coefficients the estimated accumulated capital gains have been 154,232 euros. In addition, the time dummy coefficients are (jointly) significantly different from 1996 and from each other (see panel B). As a result, the intertemporal hedge against price changes has been imperfect. Nevertheless, the substantial positive capital gains during the period 1995-2008 may have been beneficial for a homeowner who became a renter, which is in accordance with previous results. The homeowner who moves to a rental unit may also be intertemporally hedged against price shocks. In particular, the serial correlation coefficient of the residuals from the regression of the model in equation 12 regressed on the lagged residual is about -0.389 (the second and third lag are insignificant at the 5 percent level). The first lag suggests that a 1 euro decrease in return due to a price

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[32] We excluded the constant and included the time dummy for 1996 to obtain this estimate.

shock in a particular year is hedged by an increase of 0.389 euros in return the next year. Hence, a homeowner who becomes a renter is to some extent intertemporally hedged against price shocks. Nevertheless, this hedge is also not perfect. Concluding, homeowners are not fully hedged against price changes or price shock. In accordance with previous results, hypothesis 6 is rejected.

[-FIGURE 13 ABOUT HERE-]

Price changes may be different across locations. The test results stated in Table 4, panel B, suggest that the municipality dummies are highly significant and are significantly different from each other. Hence, the cross-location hedge may again not be perfect. In accordance with the previous results, we can reject hypothesis 7. The municipality dummies with Amsterdam as benchmark have an average coefficient of -5.562, a median of -6.209, a standard deviation of 5.164, a minimum of -20.489, and maximum of 22.619. Hence, the yearly returns are on average (5,600 euros) lower in other parts of the Netherlands than in Amsterdam. In particular, only in 49 out of 437 municipalities (excluding Amsterdam) the yearly returns seems to be higher than in Amsterdam, ceteris paribus. In addition, 39 out of 437 municipalities have a higher return than the municipality of Utrecht (coefficient 1.170), 45 out of 437 municipalities have a higher return than Rotterdam (coefficient 0.162), and 47 out of 437 municipalities have a higher return than The Hague (coefficient 0.432). In addition, the normalized inverse distance (to Amsterdam) weighted average estimated fixed effect coefficient is -3.203, which is higher than the unweighted average of -5.562. In accordance with previous results, there exists a core-periphery pattern with respect to yearly price changes relative to Amsterdam. In particular, homeowners whose current or future house is in the core (the Randstad) will have had a relatively high return (besides a high volatility of price shocks). This result also suggests that those homeowners who move within the core or periphery and do not change tenure status might have a high cross-location hedge quality relative to the homeowners who move between the core and periphery. The exact spatial pattern of the location-specific fixed effects in the Netherlands is depicted in Figure 13. The five municipalities with the highest estimated yearly return (in thousands of euros) relative to Amsterdam are Bloemendaal (22.619 higher return), Wassenaar (16.685 higher return), Heemstede (14.773 higher return), Muiden (14.714 higher return), and Blaricum (14.261 higher return). The lowest estimated returns are in Kessel (20.489

lower return), Reiderland (17.083 lower return), Scheemda (16.257 lower return), Loppersum (15.874 lower return), and Het Bildt (14.564 lower return).

[-FIGURE 14 ABOUT HERE-]

Finally, we also report the spatial distribution of the fixed effects of the price change model (equation 12) divided by the fixed effects of the volatility of price changes model (equation 13) since the fixed effects estimates are highly correlated (i.e. correlation coefficient of 0.75). In essence, we divide the statistics reported in Figure 12 by those depicted in Figure 13. This measure resembles the previously reported coefficient of variation with Amsterdam as benchmark. Figure 14 shows a more fragmented spatial pattern. In particular, the average of the relative fixed effects is 114, while the distance weighted average is only 33. Hence, the risk per unit of return seems to be lower close to Amsterdam than further away from Amsterdam. In particular, Figure 14 suggest that close to Amsterdam there are some pockets of low coefficient of variation estimates (e.g. nearby Utrecht), while the East and South (i.e. Brabant) of the Netherlands have a relatively high risk per unit of return. In addition, the North (Noord-Holland and nearby Groningen), South East (Limburg) and South West (Zeeland) of the Netherlands still have a low volatility (per unit of return), which is in accordance with previous results. In addition, the risk per unit of return is not always relatively high in the four largest municipalities in the Netherlands. In particular, only in 402 out of 437 municipalities (excluding Amsterdam) this measure seems to be higher than in Amsterdam, ceteris paribus. In addition, 407 out of 437 municipalities have a higher volatility (per unit of return) than the municipality of Utrecht, 3 out of 437 municipalities have a higher volatility than Rotterdam, and 424 out of 437 municipalities have a higher volatility than The Hague. Finally, the five municipalities with the highest estimated relative fixed effects measure are Wageningen (10,410 higher than Amsterdam), Renswoude (6,671 higher than Amsterdam), Baarle-Nassau (5,608 higher than Amsterdam), Rotterdam (3,116 higher than Amsterdam), and Lansingerland (3,003 higher than Amsterdam). The lowest volatility per unit of return is in Amersfoort (43,395 lower than Amsterdam), Bunnik (7,661 lower than Amsterdam), Teylingen (4,954 lower than Amsterdam), Velsen (4,132 lower than Amsterdam), and Capelle aan den IJssel (2,008 lower than Amsterdam).

8. Conclusion

The uncertainty with regard to the sale price of the current home and buy price of the future home may be one of the most risky aspects of owning a home. This paper contributes to the housing market literature by examining this (sale) price risk and the potential hedge against this risk as a result of owning a home. In particular, we investigated the volatility of house price returns and relative house price returns across market segments, time, and locations based on a unique dataset consisting of all transaction prices of existing homes in the Netherlands between 1995 and 2008.

Our findings indicate that house prices are highly persistent. As a result, we analyzed price changes. Besides the descriptive statistics, we examined price changes and the volatility of those changes based on a simple two-step approach. In the first step, we utilized a simple price change model. This model incorporates the hedging opportunities due to owning a home. In the second step, we estimated a conditional variance model (i.e. heteroskedasticity model). This model takes into account that price shocks may be one of the most important sources of sale price risk.

The results in this paper show that the volatility of returns, also if these returns are based on price shocks, is lowest for frequently traded house types. In particular, this risk can be quite substantial. The maximum risk relative to the total investment in housing is between 14 percent for row homes and 35 percent for apartments (30 percent for detached homes). Furthermore, sale price risk is highest during an economic boom or bust. Especially a housing market bust (i.e. the current financial crisis) may be detrimental to homeowners due to a combination of low returns, a high chance of negative returns, and a high return volatility. In particular, the spread of returns was between 0.6 and 1.6 euro per euro return during the economic boom in 2000. This coefficient of variation was about two to three times higher during the economic bust in 2003 and 2008. In addition, the chance of a negative return on a municipal level soared during these periods. In particular, this chance ranged between 4 percent for row houses and 14 percent for apartments (7 percent for detached homes) in 2000, while it became between 18 percent for row houses and 37 percent for detached homes during the economic bust in 2003 and 2008. Finally, the results in this paper show the spatial nature of sale price risk. In particular, this risk depends on the current or future place of residence. Specifically, we found a high volatility of shocks in the highly urbanized core of the Netherlands (the Randstad) versus the periphery.

A homeowner who plans to sell his current home and buys a new home is hedged against sale price risk. This cross-location hedge quality is highest for row houses and relatively low for apartments, but also detached homes. In addition, the hedge quality may be quite high, but it is not always perfect. The empirical results indicate that the hedge provides coverage against 63 to 88 percent of price developments in Amsterdam, the capital of the Netherlands. The non-randomness in the mobility of homeowners increases the quality of the hedge such that it covers 69 to 102 percent of the price developments in Amsterdam. Hence, capital gains nearby Amsterdam (the Randstad) have been relatively high. This result suggests that especially homeowners who move from the periphery to the core may have a low hedging benefit and a substantial finance deficit.

A homeowner who decides to become a renter does not have a cross-location hedging opportunity against price changes in the current and future home. Nevertheless, in this paper we argue that this type of homeowner may have an intertemporal hedging opportunity. In particular, price changes or price shocks may cancel out over time. From a short-run perspective, the results indicate that 39 percent of price shocks in the Netherlands cancel out on a yearly basis. Nevertheless, the average realized accumulated capital gains between 1995 and 2008 turned out to be large and positive for this type of homeowner. Hence, the intertemporal hedge against price changes or price shocks has been far from perfect.

The results in this paper have several implications for the extant literature. First, the hedge against sale price risk is mostly investigated using percentage house price changes (e.g. Case et al., 1993; Englund et al., 2002; Caplin et al. 2003, Iacoviello and Ortalo-Magné, 2003; Shiller, 2008; Sinai and Souleles, 2009). There are two major problems with this approach. In particular, this paper suggests that not all price changes may be risky from a homeowner perspective. Consequently, we also analyzed the volatility of price changes based on price shocks. Moreover, the hedging benefits of homeownership are not based on the equivalence of percentage returns across locations, but whether the change in the current value of the house is sufficient to hedge (the risk of) value changes in the future house. In particular, most previous studies have been limited by the use of price indices, while this paper uses detailed transaction price data.

The current literature suggests that a homeowner who decides to rent a house in the future is not hedged against price changes, but that he may only be hedged against rent risk (i.e. see Sinai and Souleles, 2009). In this paper we argued that this type of homeowner may have an intertemporal hedging opportunity due to the nature of the price process. In addition, it has been suggested that a homeowner who does not have a cross-location hedging opportunity may be worse off than the homeowner who does have this possibility. Nevertheless, even though the cross-location hedge may result in a reduction of risk, it also reduces returns since accumulated wealth gains in the current home may cancel out against change in value of the future home. Instead, a homeowner who decides to rent a house in the future may fully benefit from the price increases in the market, while these long-run accumulated capital gains may act as a buffer against sudden price declines.

Finally, Sinai and Souleles (2009) suggest that the substantial hedging benefits of homeownership may explain why a financial market for house value (i.e. see Shiller, 2008) has failed to take off. The results in this paper indicate that, although the hedge provided by owning a home may be substantial, it is far from perfect. In particular, we find significant and economic sizeable differences in price changes across market segments, years, and municipalities in the Netherlands. Hence, homeowners may obtain substantial diversification benefits as a result of a financial market for house value. As a consequence, an alternative explanation for the absence of a financial market for house value may simply be that homeowners have little knowledge about sale price risk or the possible risk-reducing benefits of a financial market for house value.

There is a potential role for governments in increasing the awareness about sale price risk since the negative consequences of sale price risk may be severe. The mortgage crisis, which started somewhere between 2007 and 2008, provides us with a clear example that owning a home does not always lead to golden eggs. In particular, the negative impact of this crisis on (pension) wealth may be highest for those households who do not plan ahead and who are financial illiterate (i.e. see Lusardi and Mitchell, 2007). Governments may use policies to reduce this illiteracy or lack of information. In particular, the supplier of an investment product in the Netherlands is required to warn an investor about the potential risks associated with the investment. A notable example is that an advertisement about a financial investment broadcasted on the Dutch radio always ends with a risk statement and the request to read the financial brochure associated with the investment. Hence, a similar warning or a property financial brochure may be beneficial to the homeowner. In particular, information on sale price risk could increase the opportunity of homeowners to make an informed housing investment decision. Realtors could help to provide this information or financial brochure.

Further research should focus on the underlying determinants of sale price risk (price changes). In addition, an important research venue might be the incorporation of different types of risk of owning or renting (e.g. sale price risk, rent risk, default risk, interest rate risk) in a uniform framework and to investigate the interdependencies between those risks. In addition, further research with regard to the financial instruments to reduce price risk could be invaluable to homeowners. Nevertheless, the implementation and impact of a financial market on which such instruments could be traded is as yet unknown. Finally, countries with different institutional settings could be more or less prone to sales price risk. We could learn from those experiences to arrive at policies to mitigate this risk.

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Appendix 1: The number of municipalities: price level and price changes

Figure A1.1: The number of municipalities in the average of median prices

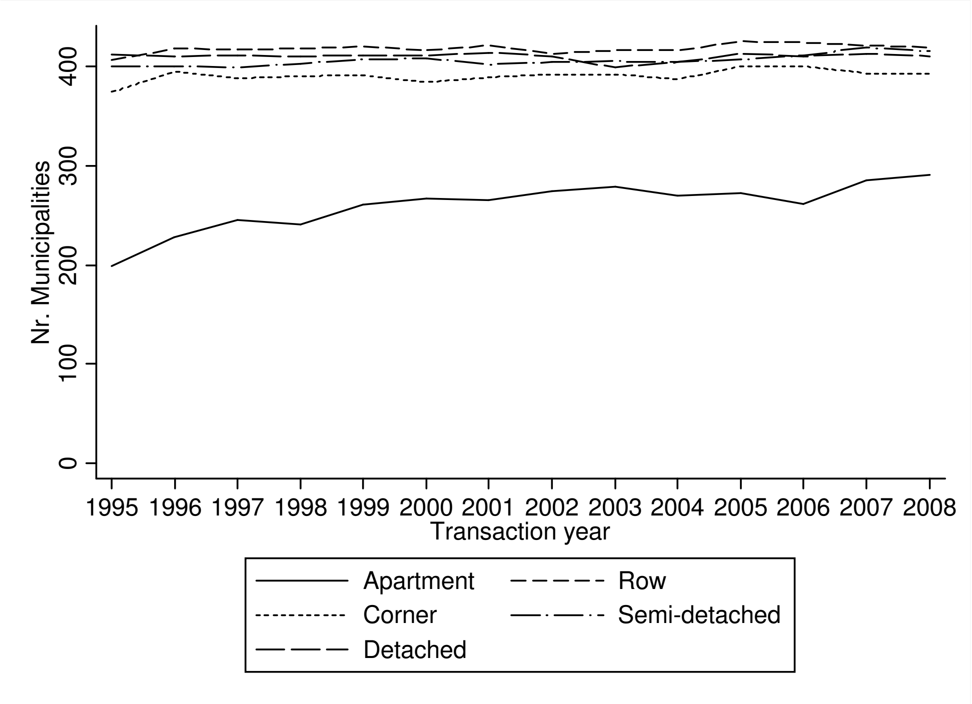
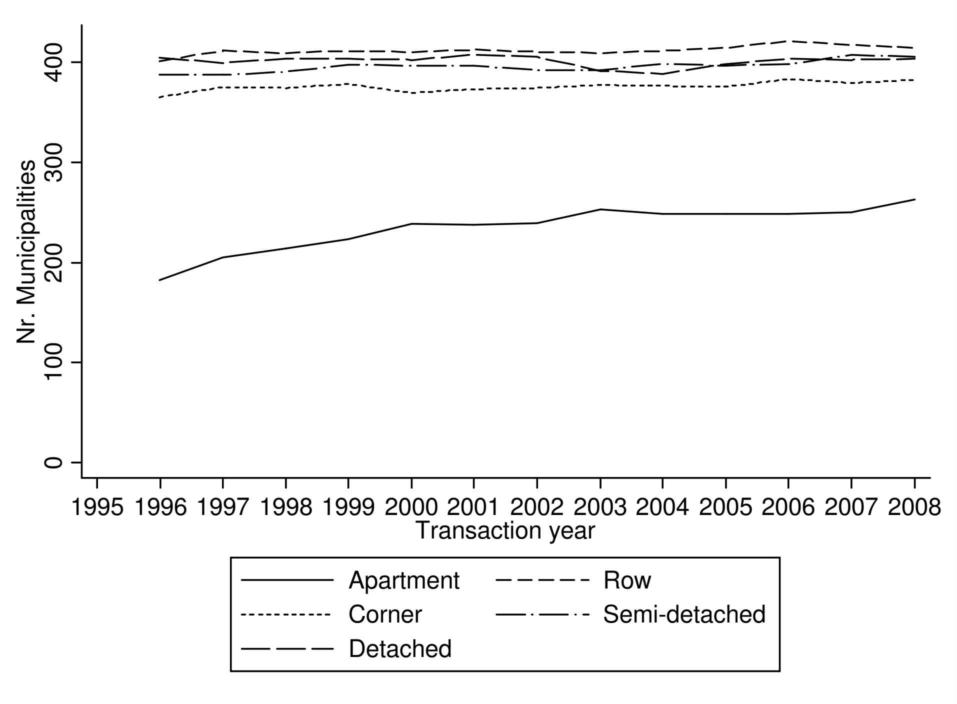


Figure A1.2: The number of municipalities in the average of median price changes



Appendix 2: The number of zip codes and municipalities: within municipal zip code variation

Figure A2.1: The average across municipalities of the number of 4 digit zip codes in the average of zip code price changes

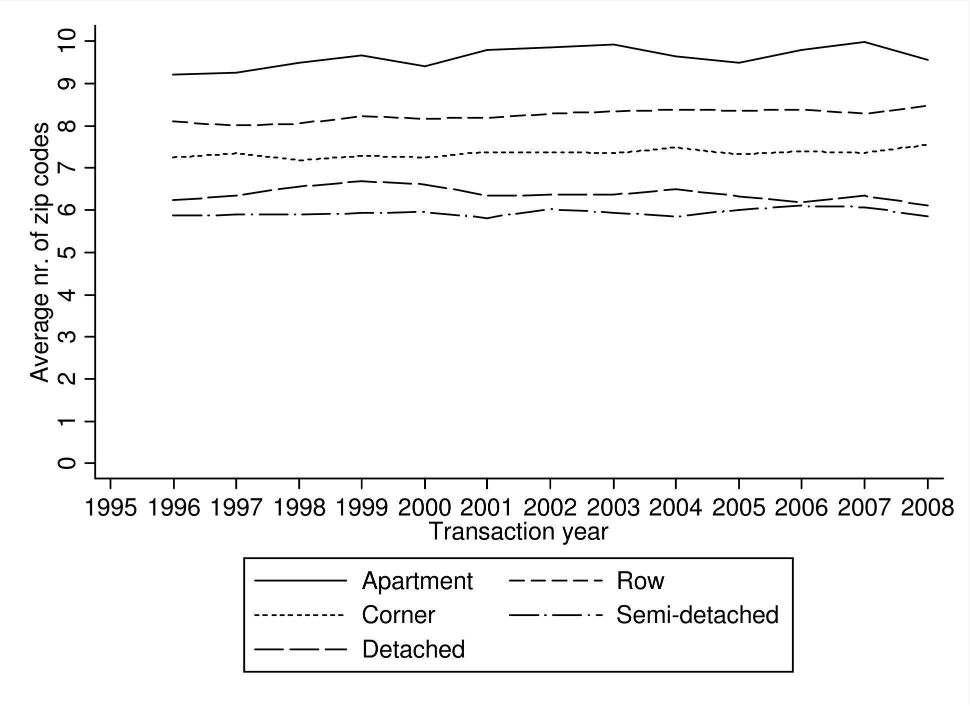
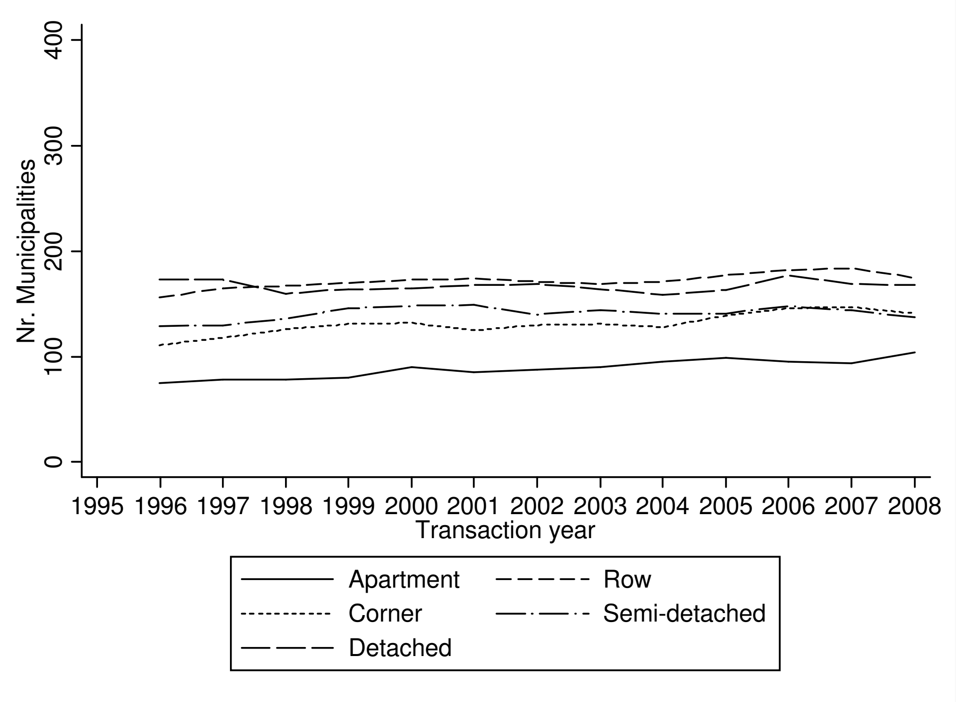
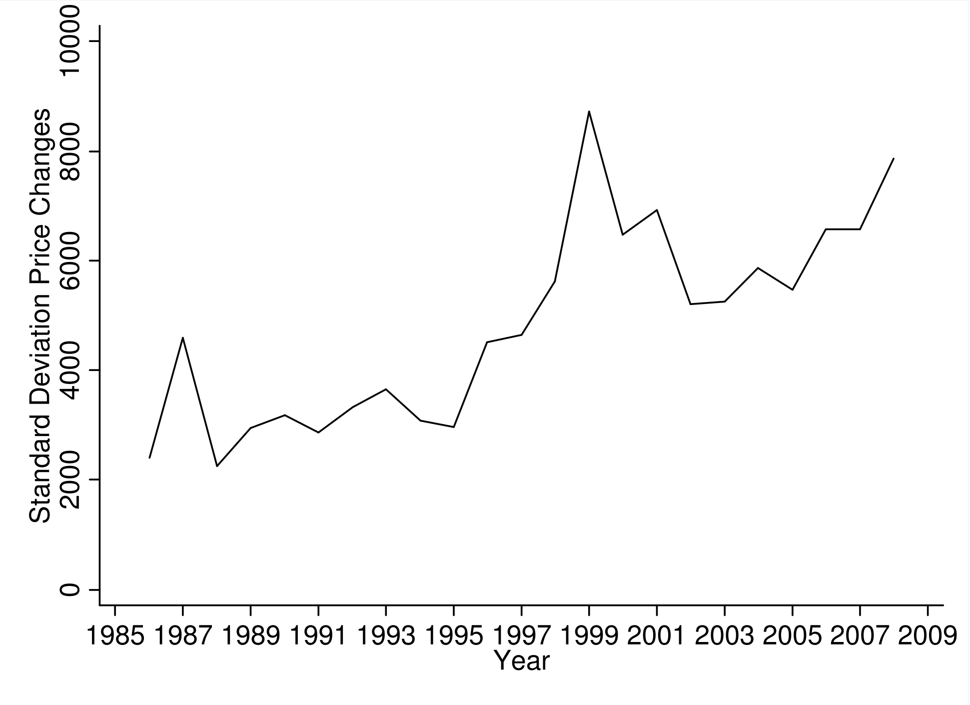


Figure A2.2: The number of municipalities across the average of zip code price changes



Appendix 3: Sale price risk based on Dutch Association of Realtors data

Figure A3.1: Standard deviation price changes (euros, in thousands)



Notes: Standard deviation across 76 regions defined by the Dutch Association of Realtors of the change in weighted (by number of transactions) average median prices on a yearly level from 1985-2008.

Table 1: Asset price risk and the hedging opportunities for two types of homeowners

	Tenure choice	
	Homeowner becomes a renter	**Homeowner stays a homeowner**
Sources of risk	Sale price of the current home (sale price risk).	Sale price of the current home (sale price risk) and buy price of the future home (buy price risk).
Dimensions of the sources of risk	-Current house type -Time -Location of the current home	-Current and future house type -Time -Location of the current and future home.
Sub-sources of risk	Average price changes and price shocks at the current place of residence.	Average price changes and price shocks at the current and future place of residence.
Hedging opportunity (intertemporal)	Intertemporal hedge against price changes and price shocks at current place of residence.	Intertemporal hedge against price changes and price shocks at current and future place of residence (perfect if price changes are common, conditional on type of house and location).
Hedging opportunity (cross-location)	-	Cross-location hedge.
Dimensions of cross-location hedge	-	-Current and future house type (if a homeowner trades up or down). -Time (perfect if price changes are common, conditional on type of house and location). -Location of the current and future home.

Table 2: Top 5 highest and lowest hedge ratios per house type

Municipality	Highest hedge ratio	Municipality	Lowest hedge ratio
Apartments			
Vianen	1.23068	Kampen	0.10606
Heiloo	1.26920	Kerkrade	0.14801
Noordenveld	1.30403	Ameland	0.19026
Wormerland	1.56367	Landgraaf	0.20574
Oirschot	1.70704	Vaals	0.21789
Row			
Abcoude	1.52468	Vaals	0.30998
Ouder-amstel	1.56445	Kerkrade	0.33423
Naarden	1.60003	Delfzijl	0.34650
Heemstede	2.11313	De Marne	0.34847
Bloemendaal	2.65906	Heerlen	0.36833
Corner			
Abcoude	1.97473	Kerkrade	0.33246
Laren (nh.)	2.04727	Heerlen	0.37011
Naarden	2.16494	Sluis	0.37509
Wassenaar	2.67553	Winterswijk	0.38905
Bloemendaal	2.97264	Winschoten	0.39987
Semi-detached			
Bloemendaal	1.73116	Onderbanken	0.20510
Naarden	1.76257	Reiderland	0.21519
Amstelveen	1.82946	Kerkrade	0.25143
Heemstede	2.02510	Delfzijl	0.26408
Wassenaar	3.06585	Menterwolde	0.26939
Detached			
Zeist	1.89699	Terneuzen	0.19335
Noordwijk	1.95560	Scheemda	0.23395
Heemstede	2.08632	De Marne	0.23937
Bloemendaal	2.56724	Reiderland	0.25238
Blaricum	2.58427	Pekela	0.26355

Notes: Multiply the hedge ratio by the capital gains (1995-2008) in Amsterdam (160,395 euros for apartments, 155,093 euros for row homes, 161,416 euros for corner houses, 260,076 euros for semi-detached homes, and 439,076 euros for detached houses) to obtain the capital gains of the municipality of interest.

Table 3: The persistence in house prices, equation (11)

	Difference in median prices (per municipality, house type, and year)
Lagged difference in median prices (per municipality, house type, and year)	0.975*** (0.068) (95% CI [0.841 - 1.108])
Centered R-squared	0.10
Tests	
Joint significance time dummies (Chi2)	834.03***
Instrumental relevance in first-stage regression (F-value)	309.94***
Instrumental validity, Hansen J statistic (Chi2)	1.167
AR(1) in residuals, rho coefficient	-0.665*** (0.011)
AR(2) in residuals, rho coefficient	0.165*** (0.025)
AR(3) in residuals, rho coefficient	-0.015 (0.028)

Notes: Robust (clustered) standard errors in parentheses. ***, **, *, 1%, 5%, 10% significance, respectively. Observations 17,315. Estimated with two-step GMM, Arellano-Bond method. The Instruments are the third and fourth lag of median prices (per municipality, house type, and year). House type and municipal fixed effects are differenced out. Only 9 time dummies are included (2000-2008) due to the differencing, the use of lagged instruments, and the inclusion of the intercept, 10452.41 (1088.373). The residual of the second stage regression is regressed on its first lag or second lag or third lag to obtain the serial correlation test (i.e. partial autocorrelation function).

Table 4: The hedge quality and the volatility of returns, equation (12) and equation (13)

Panel A: regression results	Equation (12) **Difference in median prices** (euros, in thousands, per municipality, house type, and year)		Equation (13) **Squared residual** (from difference in median prices model, in millions)	
Housetype2 (1 if row)	3.288***	(0.338)	-155**	(66)
Housetype3 (1 if corner)	3.996***	(0.360)	-38	(71)
Housetype4 (1 if semi-detached)	7.916***	(0.496)	479***	(113)
Housetype5 (1 if detached)	15.941***	(0.691)	1,980***	(236)
Timedummy3 (1 if year=1997)	3.266***	(0.637)	89***	(24)
Timedummy4 (1 if year=1998)	2.438***	(0.671)	211***	(48)
Timedummy5 (1 if year=1999)	12.520***	(0.805)	490***	(70)
Timedummy6 (1 if year=2000)	17.483***	(0.820)	670***	(97)
Timedummy7 (1 if year=2001)	9.305***	(0.888)	647***	(89)
Timedummy8 (1 if year=2002)	2.741***	(0.784)	603***	(74)
Timedummy9 (1 if year=2003)	-4.412***	(0.822)	739***	(89)
Timedummy10 (1 if year=2004)	-2.745***	(0.843)	681***	(94)
Timedummy11 (1 if year=2005)	2.040***	(0.897)	805***	(109)
Timedummy12 (1 if year=2006)	0.886	(0.877)	910***	(133)
Timedummy13 (1 if year=2007)	0.035	(0.897)	823***	(114)
Timedummy14 (1 if year=2008)	-2.581***	(0.901)	983***	(167)
AR(1) in residuals, rho coefficient	-0.389***	(0.018)	-	
R-squared	0.10		0.13	
Panel B: Tests on the hedging opportunities, equation (12) [a)]				
Significance house type dummies	172.61***		-	
Equality coefficients house type dummies	229.85***		-	
Significance time dummies	125.66***		-	
Equality coefficients time dummies	130.47***		-	
Sum of coefficient on time dummies equals zero	63.42***		-	
Significance municipality dummies	5.3x10^4***		-	
Equality coefficients municipality dummies	2.0x10^5***		-	
Panel C: Tests on the volatility of price shocks, equation (13) [a)]				
Significance house type dummies	-		60.38***	
Equality coefficients house type dummies	-		46.26***	
Significance time dummies	-		12.89***	
Equality coefficients time dummies	-		12.79***	
Significance municipality dummies	-		2.5x10^24***	
Equality coefficients municipality dummies	-		3.2x10^6***	

Notes: Robust (clustered) standard errors in parentheses. ***, **, *, 1%, 5%, 10% significance, respectively. Observations 23,627 in both specifications. Both models are estimated with OLS. A full set of 438 municipality dummies is included with Amsterdam as benchmark (437 remain since the estimates for Vlieland are missing). Apartments are the reference group for the house type effects. The year 1996 is the reference group for the year effects. a) We report the F-values of these tests.

Figure 1: Average house price (euros, in thousands)

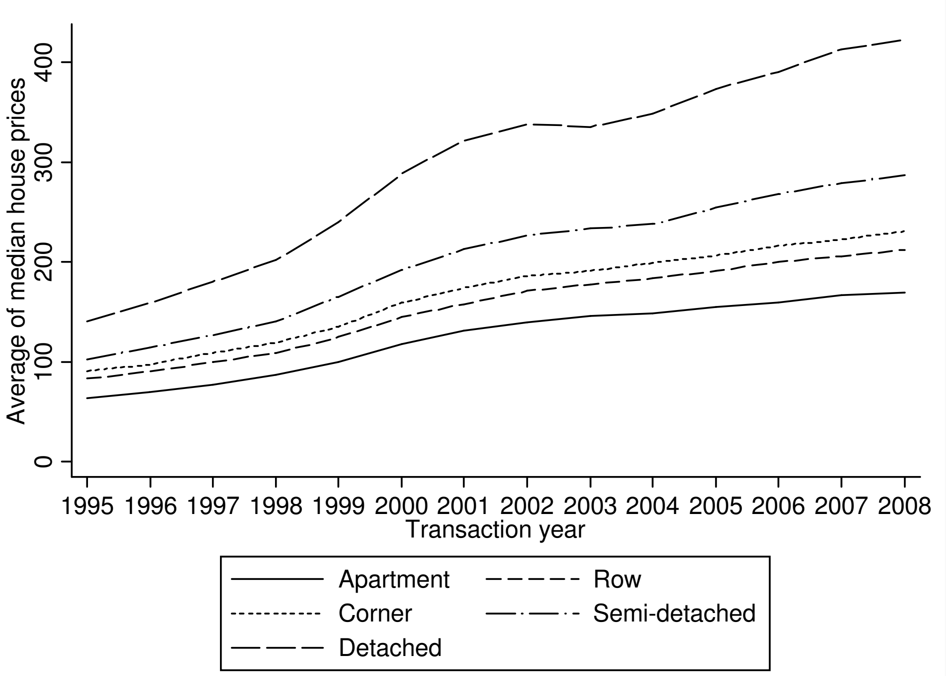


Figure 2: Number of transactions (in thousands)

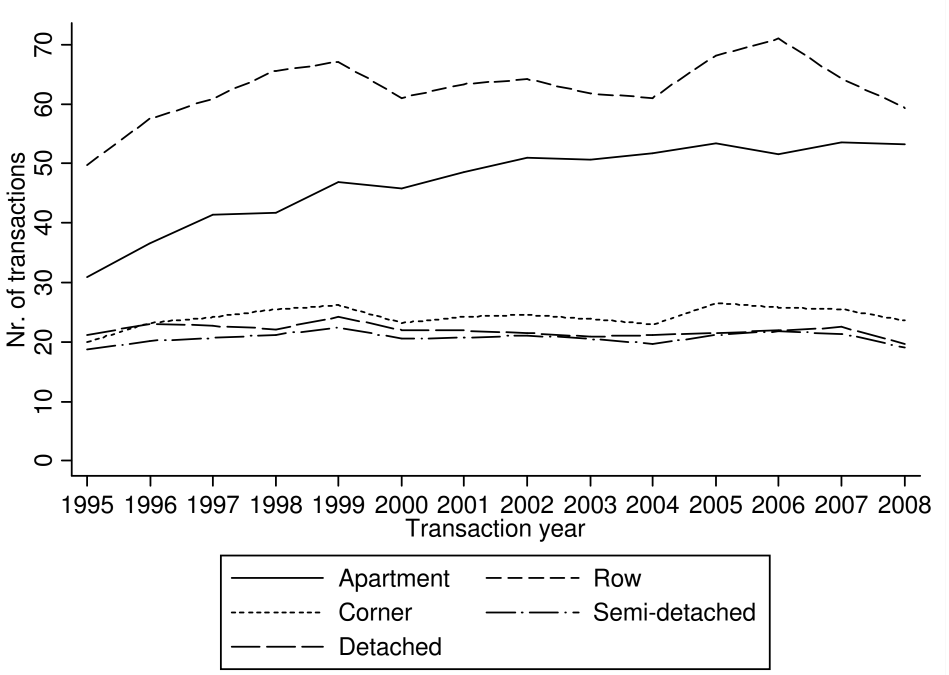
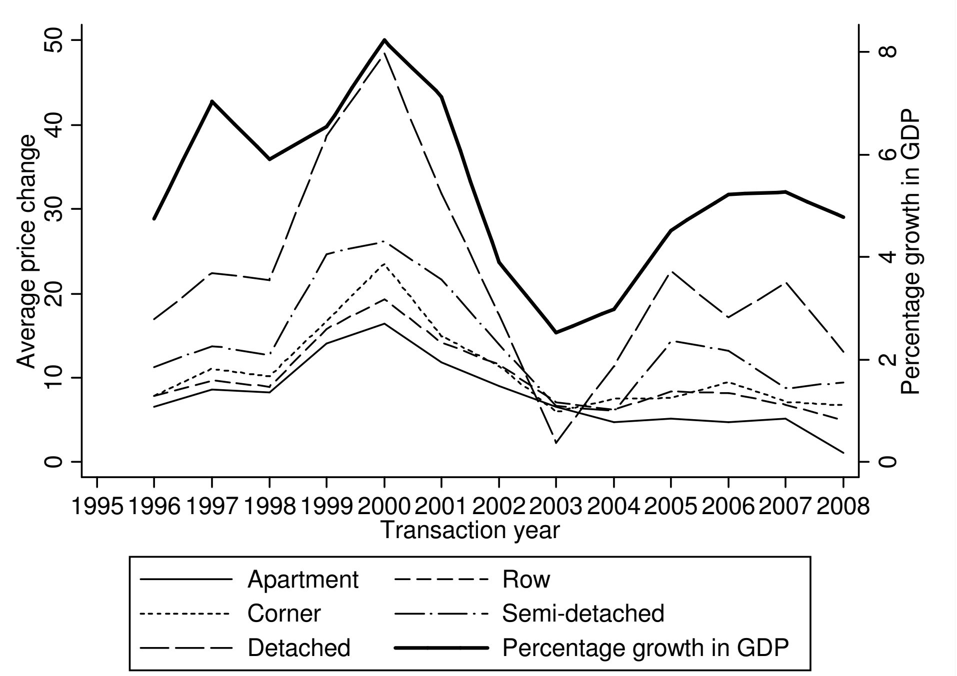


Figure 3: The business cycle and average house price changes (euros, in thousands)



Source GDP data: Statistics Netherlands. Notes: Based on GDP at market prices, current prices.

Figure 4: Sale price risk (euros, in thousands)

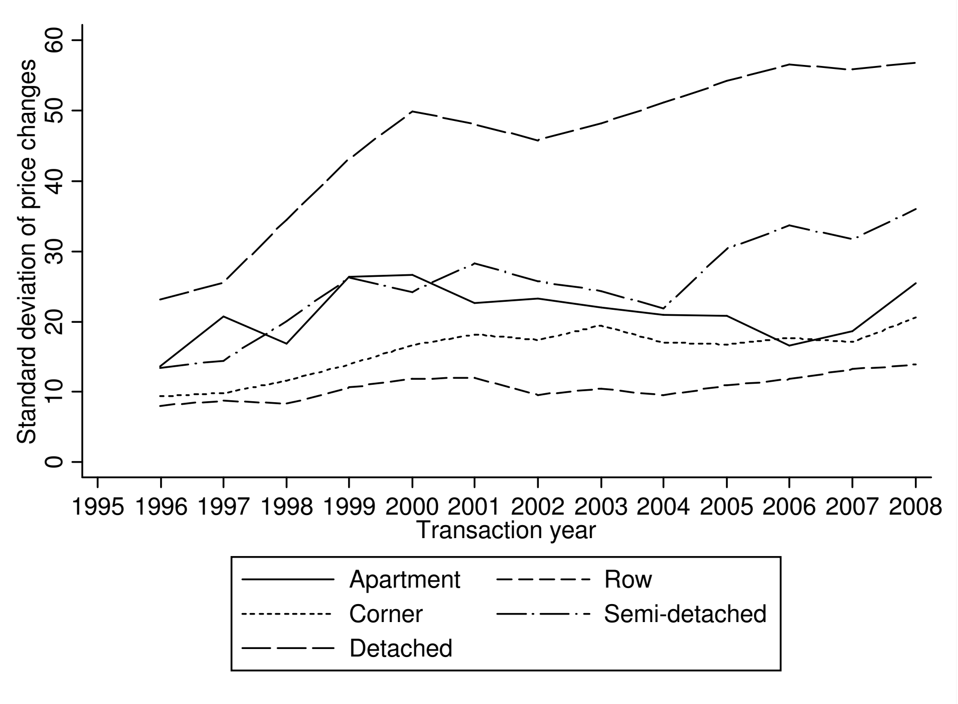


Figure 5: Maximum percentage of total investment at risk

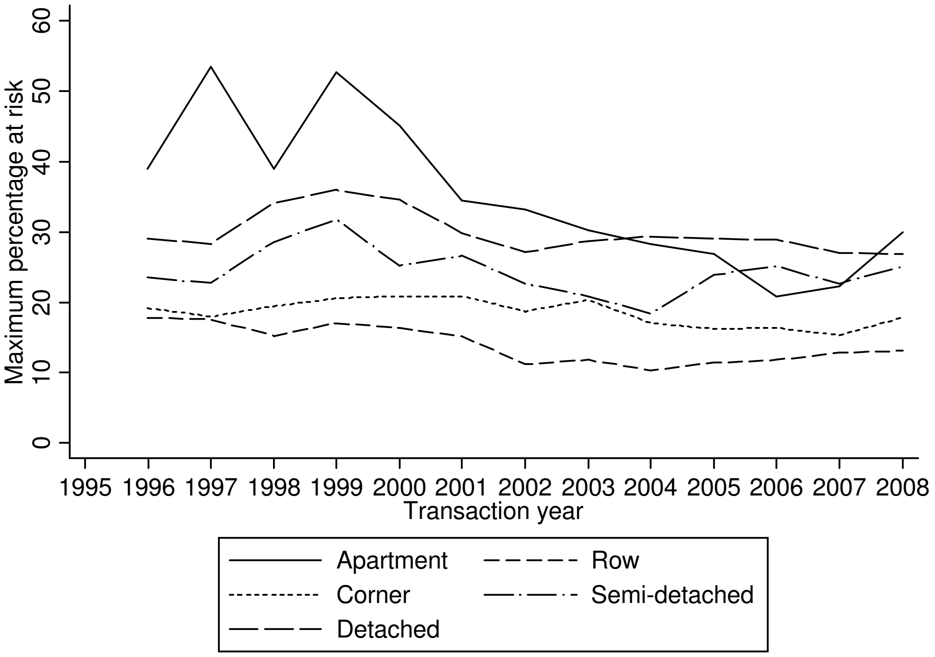
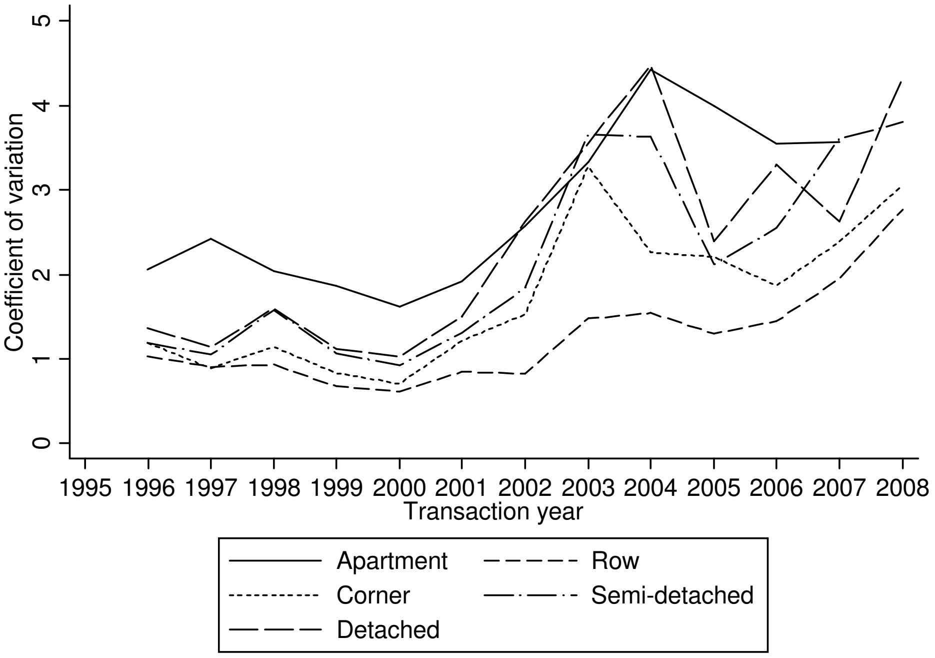


Figure 6: Sale price risk per unit of return (euros)



Notes: The coefficient of variation for detached houses in 2003 and apartments in 2008 are 20.7 and 22.6, respectively, and are excluded as outliers.

Figure 7: Chance of negative returns

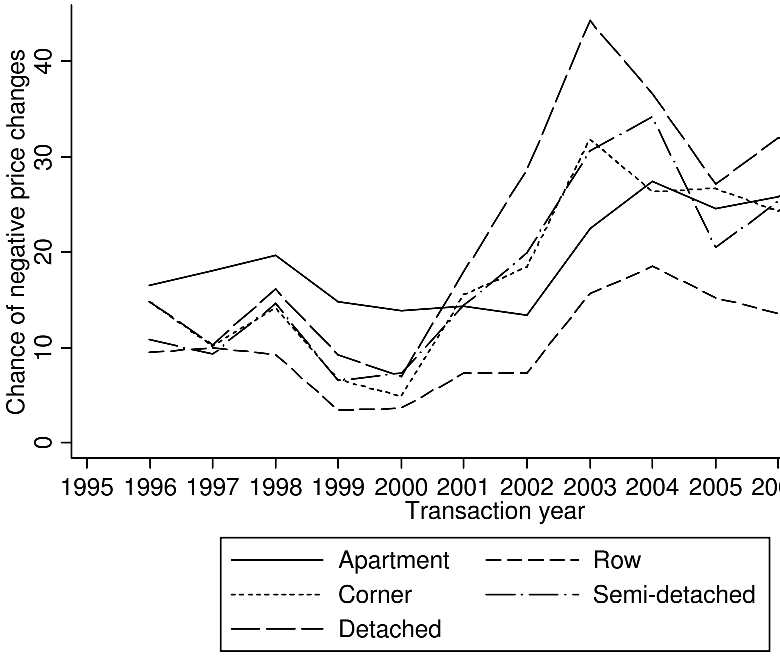
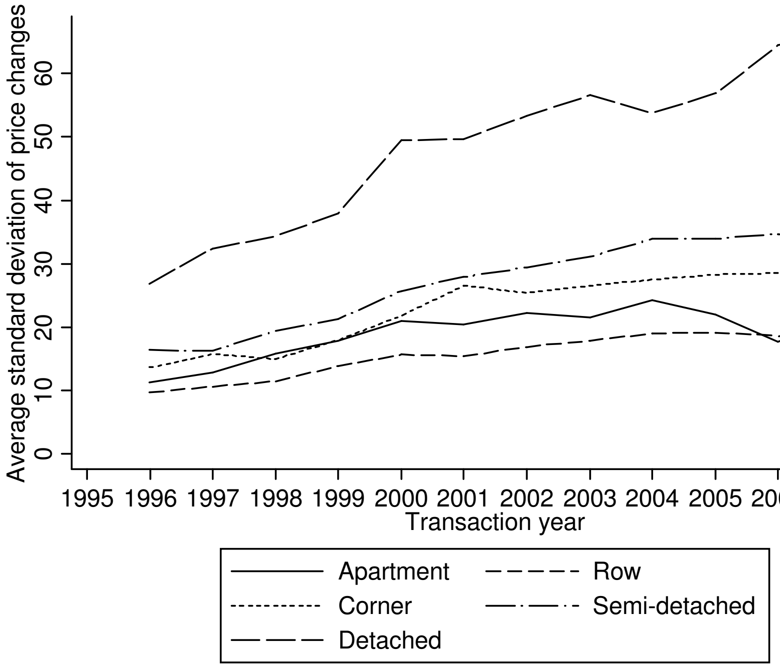
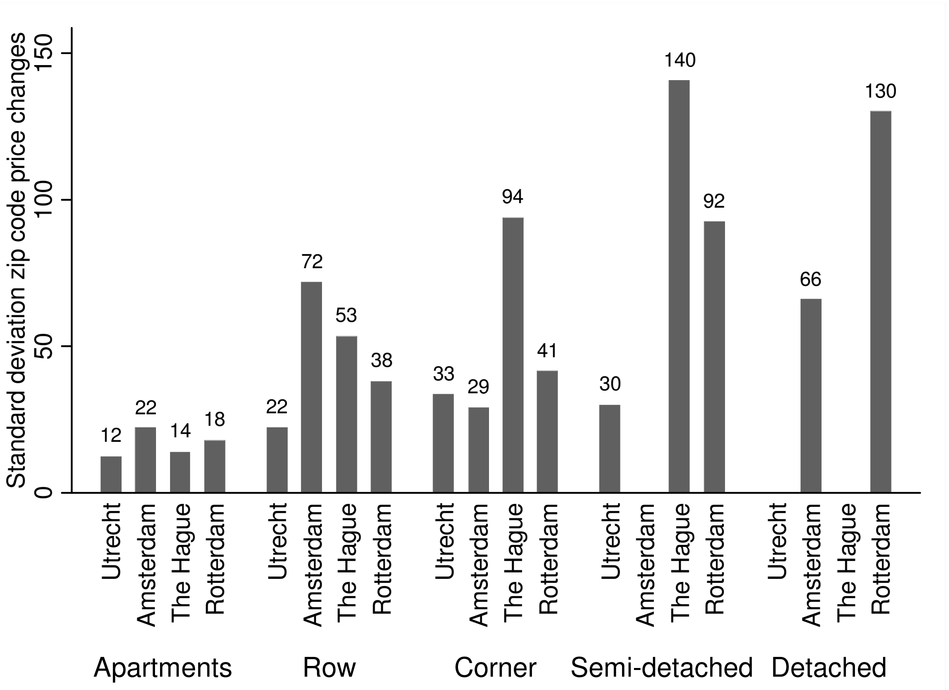


Figure 8: Location as a determinant of sale price risk (euros, in thousands)



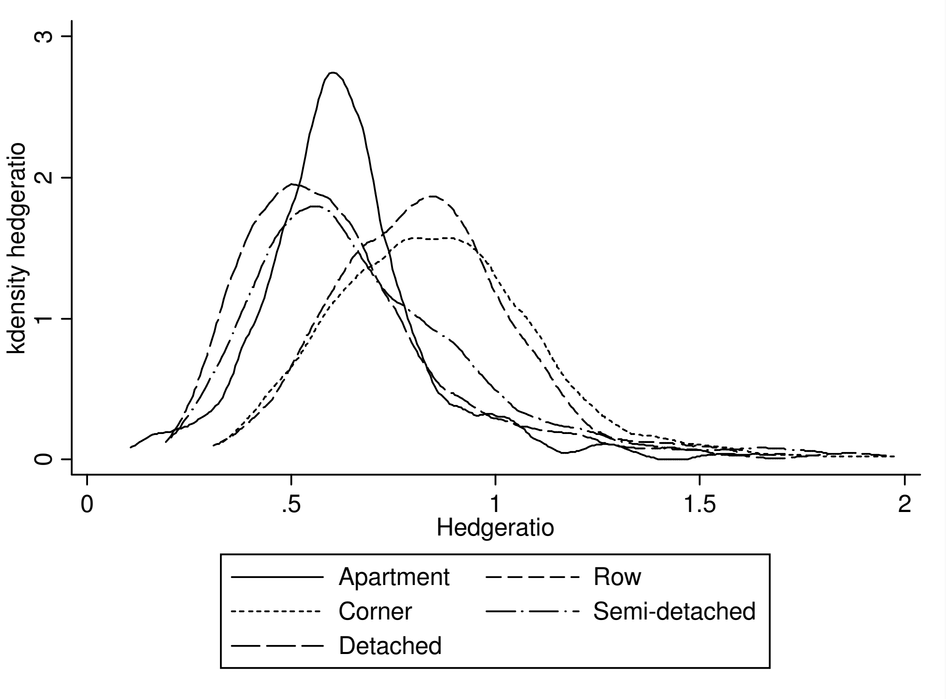
Notes: Average across municipalities based on the standard deviation of zip code price changes within each municipality (per year and type of house).

Figure 9: Sale price risk of the 4 largest municipalities (euros, in thousands)



Notes: No bar mains a missing observation. The average over 13 years is reported, except for Utrecht semi-detached houses (1 obs.); Amsterdam corner houses (12 obs.), detached houses (6 obs.); The Hague semi-detached houses (4 obs.); Rotterdam semi-detached houses (12 obs.), detached houses (7 obs.).

Figure 10: Distribution of the hedge ratio (Amsterdam as benchmark)



Notes: Hedge ratios larger than 2 are excluded in this figure. This selection leads to no loss of observations for apartments (189 obs.), and a loss of 2 observations for row houses (403 obs. remain), 4 observations for corner houses (360 obs. remain), 2 observations for semi-detached houses (391 obs. remain), and 3 observations for detached houses (402 obs. remain).

Figure 11: The hedge ratio of the 4 largest municipalities (Amsterdam as benchmark)

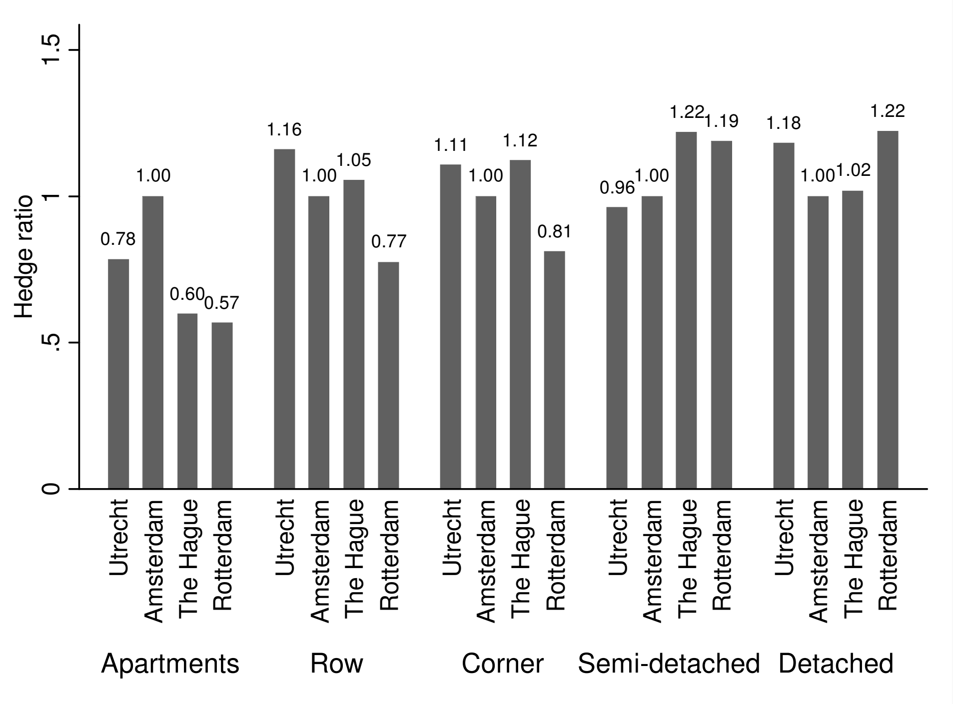
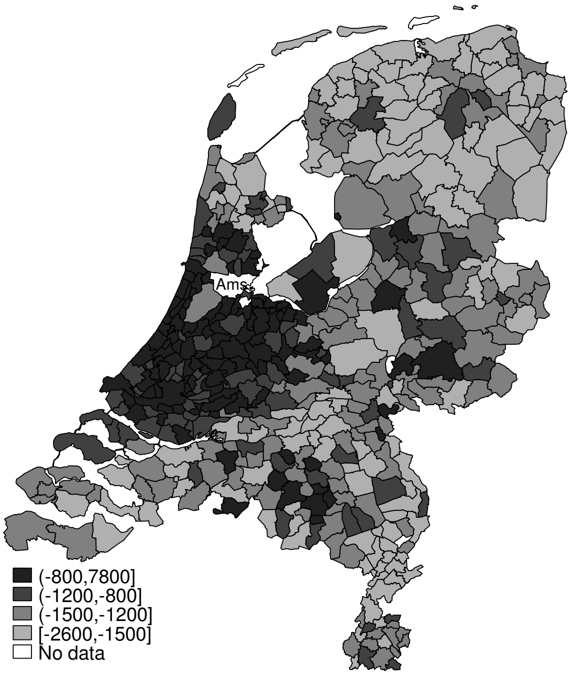
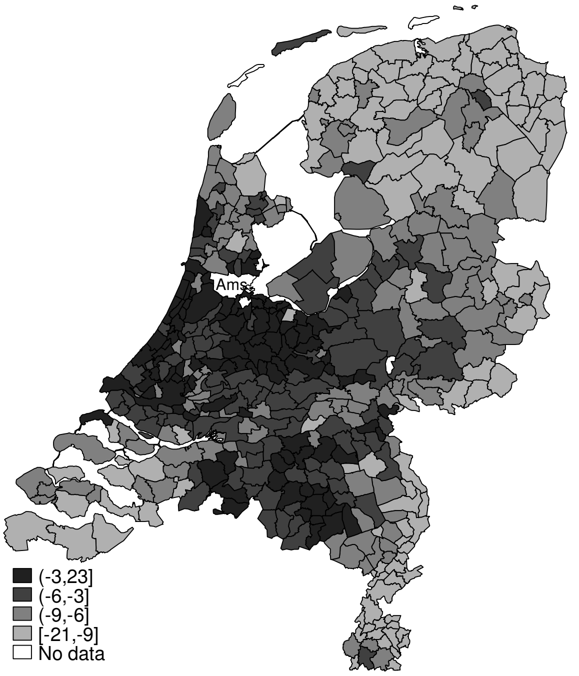


Figure 12: The spatial distribution of the volatility of price shocks across municipalities relative to Amsterdam (variance, in millions)



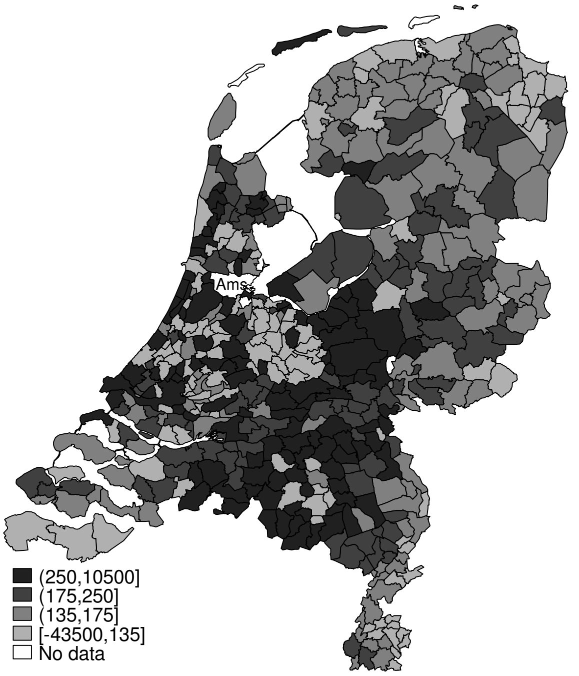
Notes: This figure plots the estimated coefficients on the municipality dummies from the volatility of price shocks model, equation 13. Amsterdam (Ams) is coded as missing since it is the reference group. Vlieland, Roozendaal, and Schiermonnikoog are also missing.

Figure 13: The spatial distribution of yearly returns across municipalities relative to Amsterdam (euros, in thousands)



Notes: This figure plots the estimated coefficients on the municipality dummies from the price change (hedge) model, equation 12. Amsterdam (Ams) is coded as missing since it is the reference group. Vlieland, Roozendaal, and Schiermonnikoog are also missing.

Figure 14: The spatial distribution of the volatility of price shocks divided by the yearly returns, relative to Amsterdam (euros, in thousands)



Notes: This figure plots the estimated coefficients on the municipality dummies from the volatility of price shocks model, equation 13, divided by the estimated coefficients on the municipality dummies from the price change (hedge) model, equation 12. Amsterdam (Ams) is coded as missing since it is the reference group. Vlieland, Roozendaal, and Schiermonnikoog are also missing.