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How are floating houses priced in relation to comparable on-land housing? Evidence from Portland, USA

 9611 words

COLOFON

Title	How are floating houses priced in relation to comparable on-land housing? Evidence from Portland, USA
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Abstract

This study examines price differentials amongst comparable floating and nearby on-land housing in Portland, USA using properties' sales prices within 2019-2022. Finding a difference in the pricing of the two housing types can reflect how consumers perceive residing in a floating house compared to on-land housing. Considering the zoning constraints, the insufficient housing construction and the existing flooding-risk in Portland, understanding consumers' willingness to reside in a floating house can be useful for the residential real estate industry. This study may indicate whether unsinkable floating houses are a viable residential alternative to traditional housing, based on the magnitude of the price differential between on-land and floating housing. We employ a hedonic regression focusing on a binary variable that compares the impact of the floating status relative to on-land housing on sales prices. We find that floating houses are on average sold at lower prices compared to houses on land, whilst controlling for property characteristics, location and time effects. Future research may examine price differences between the two housing types in areas entailing greater housing consumption risk compared to Portland.

Keywords:
Real Estate, Floating houses, Consumption Risk, Unsinkability, Portland

9611 words

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Chapter 1: Introduction

1.1 Motivation

Floodings constitute a real threat to the built environment, especially in 'special flood hazard areas' such as Portland, Oregon (portlandoregon.gov, 2022). A fatal flood occurred in 1996 in the area surrounding the Willamette River; whilst today land surrounding most of the Columbia River in Northern Portland and the Willamette River entail at least minimal flood risk (portlandoregon.gov, 2022). The city of Portland hosts unsinkable floating houses that abate flooding risk (Endangsih & Ikaputra, 2018) at the Columbia River and the Willamette River waterfronts, as well as on-land residential communities nearby. Further, the population of Portland has increased by 74% since 1980, whilst urban zoning growth increased by only 15% (Bach, 2021), which has contributed to the current housing supply shortage (Bach, 2021). Taking into account the unsinkable nature of floating houses (Endangsih & Ikaputra, 2018) in conjunction with the declining availability of traditional residential properties in Portland (Bach, 2021), this thesis aims to assess Portland's residents' willingness to purchase a floating house rather than a comparable house on nearby land, by observing the price differences amongst the two options.

1.2 Academic relevance

Housing consumption risk & Price differentials

Established works indicate a negative relationship between housing consumption risk and sales prices (Turnbull, 1991; Turnbull et al., 2013; Bin & Polasky, 2004). Understanding how this arises can hint at potential price differentials between floating and on-land houses. Further, evidence from cited works in terms of price differentials amongst floating and on-land housing is provided. On-land houses that are located within areas that are threatened by natural hazards demonstrate approximately 2.8% lower selling prices compared to houses that are not located in high-risk zones (Turnbull et al., 2013). Precisely, Turnbull (1991) finds that the house quality uncertainty arising from flooding risk can decrease the level of demand and thus house prices. Bin & Polasky (2004) find that residential properties located within a floodplain (higher flood risk area) in North Carolina are on average sold for 5.7% lower prices than comparable properties outside floodplains. Further, Bin & Polasky (2004) observe that the size of the relative sales discount arising from consumption risk doubled after Hurricane Floyd in 1999, due to an increase in awareness for natural hazards (Bin & Polasky, 2004). Furthermore, Turnbull (1994) notes that natural hazards risk abatement is associated with a price premium in housing prices. Specifically, Turnbull (1994) notes that offsetting flooding risk yields higher housing prices along with demand surges. Penning-Roswell (2020) notes that the unsinkable nature of floating houses mitigates the risk of flooding from increasing sea levels. In addition, the more sustainable methods and materials used for the development of floating houses generate advantages in terms of safety, durability, and consumption cost in comparison to houses on land (Penning-Roswell, 2020; Endangsih & Ikaputra, 2018). These could constitute factors for attracting greater demand for floating houses by residents, compared to demand for nearby houses on land baring flood-risk, triggering a price premium. Lloyd (2021) states that the growth in prices of floating houses in Seattle, USA persistently exceeds price increases of on-land houses, which indicates that demand for floating houses is expanding to a higher rate compared to on-land houses. Additionally, Bervaes & Vreke (2004) find floating houses to be more expensive than on-land houses in the Netherlands. However, Penning-Roswell (2020) suggests that there are consumer groups who may not consider residing in a floating house as a convenient alternative, such as residents who find traditional housing more comfortable or do not deem living close to natural habitat attractive. These remarks imply that floating homes may only trigger demand by a portion of the market, which translates to relatively lower prices. Additionally, Morgan (2007) finds that on-land housing located within flood zones sell at a premium. Morgan (2007) argues that the advantage of living close to the water is more significant than the associated consumption risk, and thus the prices of these houses do not decline.

Price-determinants

After identifying arguments from established works regarding price differentials between floating and on-land houses, it is important to understand what parameters shape property prices. Following, implications from cited works in terms of the factors leading to price differentials between floating and on-land houses are analysed. Bervaes & Vreke (2004) note that the relatively higher development costs for floating houses as well as their cost linkages to on-land utilities may have been related to the price premium for floating houses compared to traditional houses on land found in their study. Similarly, Rijcken (2005) supports that the overall price differences of floating houses with traditional houses on land may arise due to development and architectural costs, whilst Miszewska-Urbanska (2016) agrees that the construction costs of floating houses are higher than the cost for developing a house on land. It is implied by these remarks that the more expensive materials used for development, as well as the level of efficiency in construction methods, may generate higher sales prices for floating compared to on-land houses. The cost of construction methods and materials should thus be accounted for when investigating the influence of the floating status on sales prices. Miszewska-Urbanska (2016) notes that floating houses may have the label of ‘resorts’. Specifically, Miszewska-Urbanska (2016) implies that this label may be aligned with modern design as well as luxury amenities and has a positive impact on sales prices. Furthermore, regarding general house price determining factors, house size (sqft), no. of bedrooms, and the provision of a garage exhibit a significant positive association with house prices (DePaul University, 2016). The use of brick as a construction material is also associated with relatively higher prices, whilst the age of a house is negatively related to property prices (DePaul University, 2016).

1.3 <u>Research problem statement, data & methodology</u>

Overall, established literature provides important remarks in terms of the negative relationship between flooding risk and house prices as well as regarding the floating houses' construction context and unsinkability advantages (Penning-Roswell, 2020; Endangsih & Ikaputra, 2018). However, implications regarding price differences between floating and on-land houses can be contradicting as indicated above. The main question this thesis aims to address regards how floating houses are priced in relation to comparable on-land housing in close proximity. Observing how flooding risk relates to house prices will generate implications connecting the unsinkability advantage of floating houses with price differences compared to on-land houses. This will be facilitated by remarks from established literature referring to the effect of consumption risk (through flooding possibility) on house prices. Precisely, this thesis aims to find the unbiased effect of the floating status on sales prices whilst controlling for location, time effects and house characteristics. This will cover a gap in existing literature. The data analysed to reach this cause have been provided by the Premier Property Group LLC, a real estate agency with seven offices in Oregon, and one specifically in Portland. Data regard sales (2019-2022) of 222 traditional houses on land and 109 floating houses, located at the Columbia River North Harbor waterfront (9721) and the Willamette River waterfront (9720-9721). A hedonic regression analysis is performed with models isolating the effect of the floating status of a house on sales prices, by controlling for the effect of property characteristics, location and time effects. The coefficient of the variable 'floating' (yes = 1) reflects the described effect, and thus allows us to assess the magnitude of the effect of the floating status on the price differential between floating and on-land housing.

An important challenge is to limit our sample to comparable floating and on-land housing. This will allow the findings of this work to provide useful insights in the real estate industry regarding consumers' perception for floating residential real estate relative to on-land housing. Using propensity-score matching as well as a logit-model, observations which do not deviate by more than 1% (caliper) from the propensity matching score range will remain in the final sample. This will allow us to assess to what extent the effect of the floating status on sales prices varies when floating and on-land housing observations of matching propensity score are regarded. This is to observe whether our prior findings are robust when relatively more, or strictly, comparable properties are regarded. Overall, we will find whether consumers are willing to pay a price premium for the purchase of a floating house due to its unsinkable feature, which mitigates flooding risk. On the other hand, if floating houses are priced lower than comparable on-land houses in close proximity, this may hint that other factors in favor of residing on land outweigh the unsinkability advantage of floating houses.

1.4 Outline & Planning

After covering the motivation, aim, and contribution of this thesis in the introductory section, the remainder of this work is formed as follows: Section 2 consists of the Literature Review, which shapes the hypothesis for the main research question. In section 3, the data used for the hedonic analysis are identified and the hedonic models used to observe the effect of the floating status on sales prices are described. We interpret regression results in section 4 and a discussion based on our findings follows. Section 5 consists of the concluding section, where findings and implications are summarised and recommendations for future research are provided.

Chapter 2: Literature review

2.1 Housing consumption risk & price differentials

Established literature provides important findings regarding the relationship of consumption risk with residential real estate sales prices, and specifically about how a change in flooding risk levels can trigger price differentials. Turnbull (199) notes that consumption risk entails purchasing a house at a price that reflects consumption for a long time-horizon, with the benefits becoming short-lived due to an event such as flooding. Turnbull (1991) indicates that properties located within high-risk areas in terms of natural hazards face relatively less demand, as consumers tend to be risk-averse. More specifically, Turnbull (1991) notes that the possibility of an unexpected event affecting a property generates uncertainty over its quality, and thus undermines its price in comparison to properties that are not within high-risk areas. Examining the effect of flooding risk on sales prices of properties in Baton Rouge, LA, Turnbull et al. (2013) find that houses located in the highest risk zone of the area are associated with a 2.8% sales discount and take more time to sell. One may note however, that Turnbull et al. (2013) only find this negative relationship of risk and selling price to be statistically significant for properties located within high-flood risk zones - not in medium or low-risk zones. Also, the described negative impact of flooding risk on house prices occurs more vividly during weaker market phases. Furthermore, Turnbull et al. (2013) observe that the negative effect of flood-risk on prices is greater, and more significant, than the positive amenity effect of living near the waterfront. It is thus clearly demonstrated that high flood risk is related to price discounts, even when the risk for natural hazards is completely covered by insurance benefits (Turnbull et al., 2013; Turnbull, 1994). In addition, Turnbull's work (1994) exhibits that mitigating the described consumption risk is associated with a price premium. Specifically, the writer (1994) suggests that in the same way that locational attributes are capitalised into the price of a house, certainty in housing consumption arising from risk abatement has a positive impact on the price of a property. More precisely, Turnbull (1994) notes that housing associated with greater consumption risk control will be priced higher than identical housing baring greater consumption risk. On the other hand, Morgan (2007) suggests that on-land housing located within flood zones sell at a premium compared to properties located further from the waterfront in non-risky zones due to the advantage of living close to the water. However, Morgan's (2007) study does not provide implications with respect to whether these properties would sell at an even greater premium if the flood-risk could be mitigated.

Moreover, relevant literature provides evidence regarding the construction context of floating houses, as well as implications in terms of price differentials with on-land houses. Fundamentally, the unsinkable nature of floating houses constitutes a line of defense against climate change and increasing sea levels (Penning-Roswell, 2020; Endangsih & Ikaputra, 2018). Precisely, Endangsih & Ikaputra's (2018) theoretical study describes how the floating houses' structure and its platform base with rotating poles incorporated underneath do not allow the house to be carried away by water offsetting the effect of dangerous winds. Also, their floating basement and the polystyrene foam filling their walls make floating houses unsinkable in the case of rising sea level (Penning-Roswell, 2020). Additionally, Endangsih & Ikaputra (2018) underline that more sustainable materials and production methods take place in the construction of floating houses compared to traditional houses. Furthermore, Penning-Roswell (2020) identifies appropriate locations for the development of floating housing such as river edges or inland lakes; land surrounding such areas may bare the risk of flooding, as in the case of Special Hazard Areas in Portland. The unsinkability advantage of floating houses may be especially important as global warming effects become increasingly influential (Penning-Roswell, 2020). One could expect residents to demonstrate a higher willingness to purchase a floating house compared to housing on land within the same area. Moreover, Bervaes & Vreke (2004) find that floating homes were 8% to 16% more expensive than houses on land in the Netherlands. However, these price differentials arise after comparing floating houses with on-land houses, which for instance do not have a view of the river or differ in proximity to greenery, which implies that the factors relevant to location are not controlled for, and thus the price differentials go beyond the influence of a house being floating compared to standing on land.

Although floating houses entail the aforementioned risk-abating advantages compared to on-land houses, one may argue that they may only facilitate the needs of a portion of the market. Penning-Roswell (2020) names specific consumer groups who may find living in a floating house more suitable, such as residents with a focus on outdoor activities, modern urbanism, and natural landscape. Furthermore, Miszewska-Urbanska (2016) suggests that floating houses may attract demand from residents who perceive them as luxury holiday resorts and may be interested in buying to rent. These insights mark that although there are consumer groups who may perceive floating houses as a preferred alternative to traditional housing, living in floating houses might not be for everyone. It is implied that consumer groups which are more accustomed to on-land housing or classic urban living may not be willing to live in a floating house (Penning-Roswell, 2020). The limited spectrum of the target market of floating houses implies that on average, the floating status could have a negative impact on the price due to restricted demand – since it may not suit the needs (or taste) of a substantial part of the population. On the other hand, relatively smaller supply of floating houses compared to traditional housing on land (McPherson, 2022) may offset the described negative impact of the floating status on prices.

2.2 *Price determinants*

To understand how price differentials between floating and traditional houses are formed, it is important to identify factors which influence housing prices. Literature suggests that variation in property characteristics, year of property purchase, and the locational context can trigger price differentials amongst houses, as analysed following. Observing the components which generate higher prices for floating houses compared to on-land housing in the Netherlands in the study of Bervaes & Vreke (2004), the development cost aspects and cost linkages to on-land utilities might be an important factor. Nevertheless, since the writers (2004) conducted their research 18 years ago, it may be important to note that improvements in construction efficiency (Penning-Roswell, 2020) may generate a relatively lower construction cost today, whilst sustainability in construction may lead to lower housing user costs. Further, Miszewska-Urbanska (2016) agrees that the construction costs of floating houses can be more expensive than the cost for developing a house on land. However, the writer (2016) notes that obtaining a lease to place the basement platform on a river/lake and develop a unit is much cheaper compared to obtaining a lease for (or purchasing) land nearby, which is a key advantage in cost-efficiency. Also, Rijcken (2005) notes that the overall price differences of floating and traditional houses vary with the cost of architecture, quality/luxury labels, mooring fees, complex installations, and the role of developers. It is inferred from the above observations that the material of construction, as well as the energy consumption source (electric/gas) of a house can influence price determination.

Differences in property characteristics constitute a crucial factor in generating price differentials amongst properties. A paper provided by The Institute for housing studies (DePaul University, 2016) identifies the effect of different variables on house prices within a small geographical area in northwest Chicago. Specifically, findings demonstrate a statistically significant (at 1%) positive effect on prices by an increase in house size (sq. ft.), no. of bedrooms, and the provision of a garage. Also, the use of brick as a construction material is associated with an increase in sales price, whilst an increase in the age of a house has a negative impact on prices. Since these factors exhibit a significant influence towards sales prices, they will be useful components in our analysis for the determination of price differentials between floating and on-land houses. Moreover, Miszewska-Urbanska (2016) sheds light to the significance of societal perception regarding floating houses and how this may influence their price. Namely, floating houses in the USA are mostly considered as resorts or relaxing holiday destinations. Therefore, the writer implies that the target audience of floating houses are typically better-off US citizens or foreign investors, whilst floating houses may be listed as Airbnb rentals (income-stream from floating houses can influence prices). One may thus argue that the floating houses' luxury label appeal can stimulate more expensive prices as their target market may entail a relatively higher purchasing power.

2.3 Theoretical Predictions

Overall, evidence from established literature suggests that properties that are threatened by high-flood risk may be related to lower prices compared to properties whose lifetime entails less consumption risk (Turnbull, 1991; Turnbull et al., 2013). Cited works furthermore imply that mitigating flooding risk may be associated with a price premium (Turnbull, 1994). One may thus expect that the unsinkable nature and sustainable development of floating houses (Penning-Roswell, 2020; Endangsih & Ikaputra, 2018) may generate a price premium on sales prices relative to nearby comparable houses on land baring flooding risk. Pulling all these together, the main hypothesis of this thesis is that floating houses will be associated with higher prices in relation to comparable on-land houses in close proximity. Finally, one may also expect that floating houses of a contemporary housing style will on average be associated with higher house prices compared to more traditional floating house styles. This is supported by Miszewska-Urbanska's (2016) noted remarks with respect to societal perception and the 'resort' label of floating houses.

Chapter 3: Data & Methodology

3.1 Study Area

Portland city, Oregon offers an interesting case study to examine whether price differences exist between floating homes and comparable houses on land that are prone to flooding risk. This is because the city hosts floating houses communities which are in close proximity to houses on land around the Columbia River in Northern Portland - zip code 9721 (Figure 1a) and the Willamette River - zip codes 9720-9721 (Figure 1b), which constitute 'Special Flood Hazard areas' (portlandoregon.gov, 2022). A fatal flooding occurred in 1996 in the areas surrounding the two aforementioned river waterfronts, which make up our case study. More specifically, the areas examined are the Columbia River North Harbor and the Willamette River waterfront, which are situated approximately 15km and 7km respectively from Portland's central business district (Figure 2). Portland is the most populated city of Oregon with 652,503 citizens whilst the state of Oregon is home to 4,236,256 residents (2020 census). The population of Portland city has experienced a 11.7% increase from 2010 to 2020 (Census) whilst Oregon and the wider US exhibited an increase of 10.6% and 7.4%, respectively. Although Portland's population growth has been exceeding the national rate, urban zoning growth has expanded to a relatively smaller extent (Bach, 2021), leading to a housing supply shortage. This may offer another reason to examine whether floating houses constitute a viable alternative for the residents. In total, there are 1,400 floating and 150,000 traditional houses in the city of Portland (McPherson, 2022).

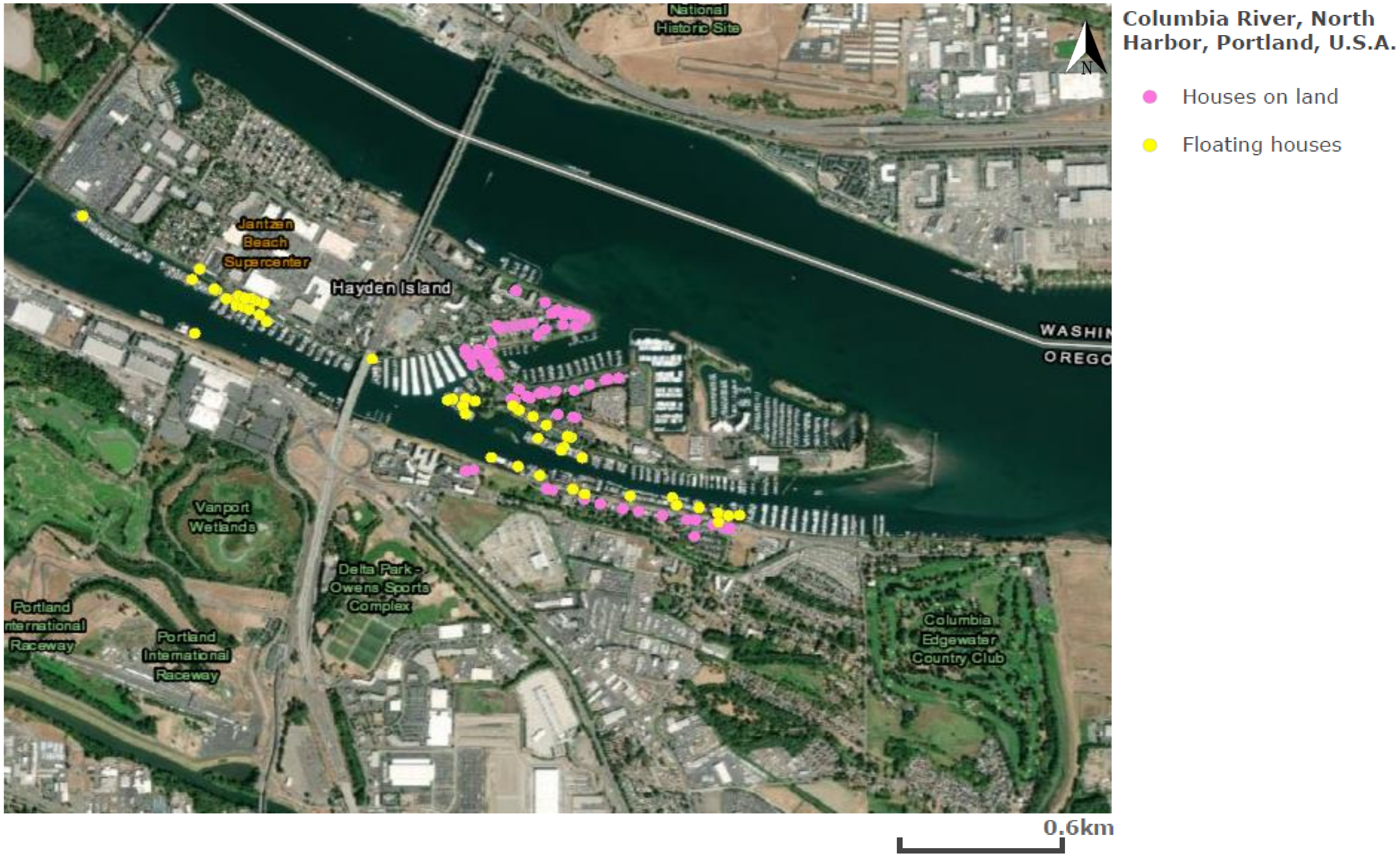


Figure 1a)i): Columbia River, North Harbor area

* Houses on land and Floating houses mapped by dots in the figure may represent 2+ neighboring properties each, due to absence of neighborhood numbers of many properties in the dataset. GIS Software has been used.

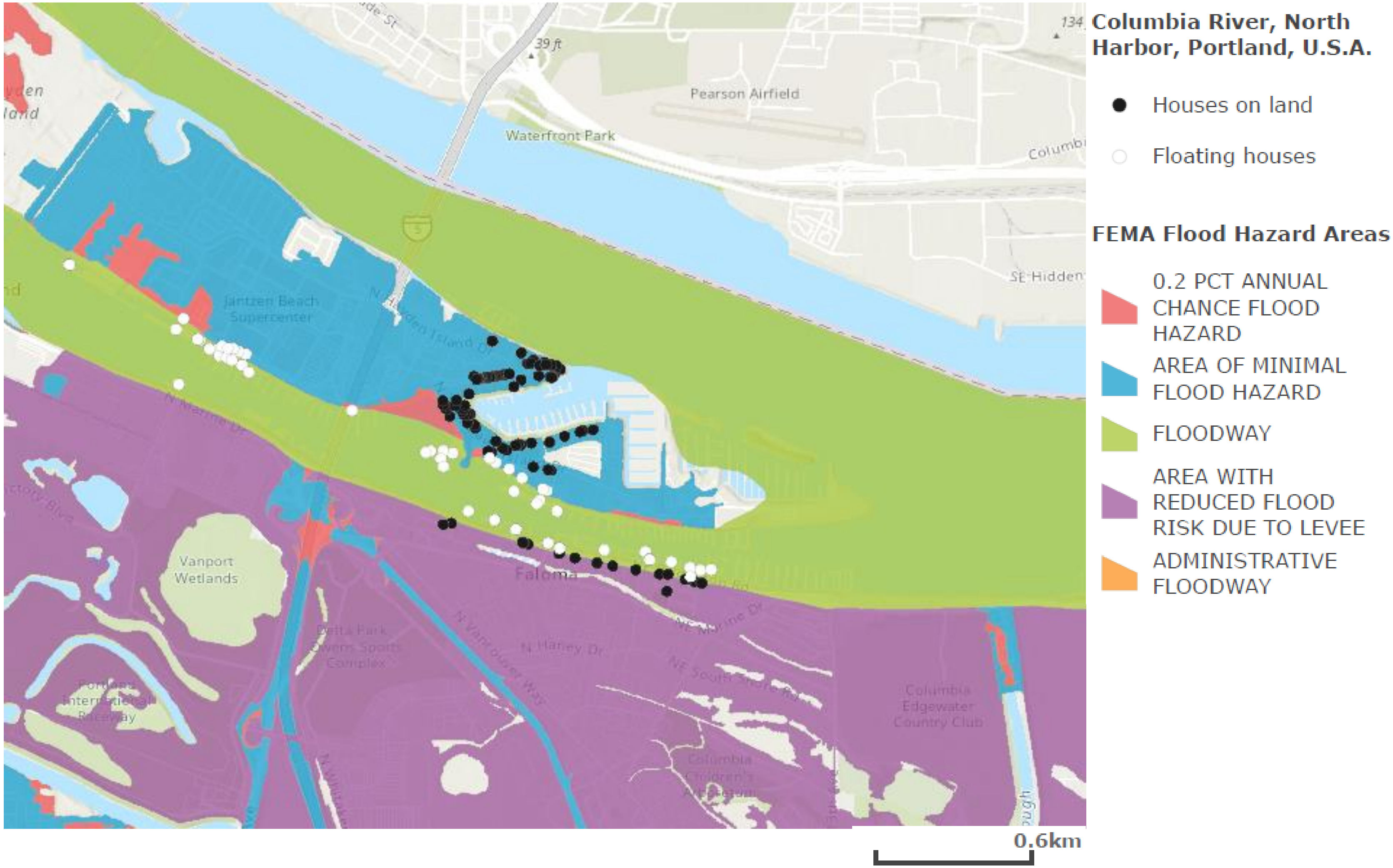


Figure 1a)ii): Columbia River, North Harbor area & flooding risk

* Houses on land and Floating houses mapped by dots in the figure may represent 2+ neighboring properties each, due to absence of neighborhood numbers of many properties in the dataset. GIS Software has been used.

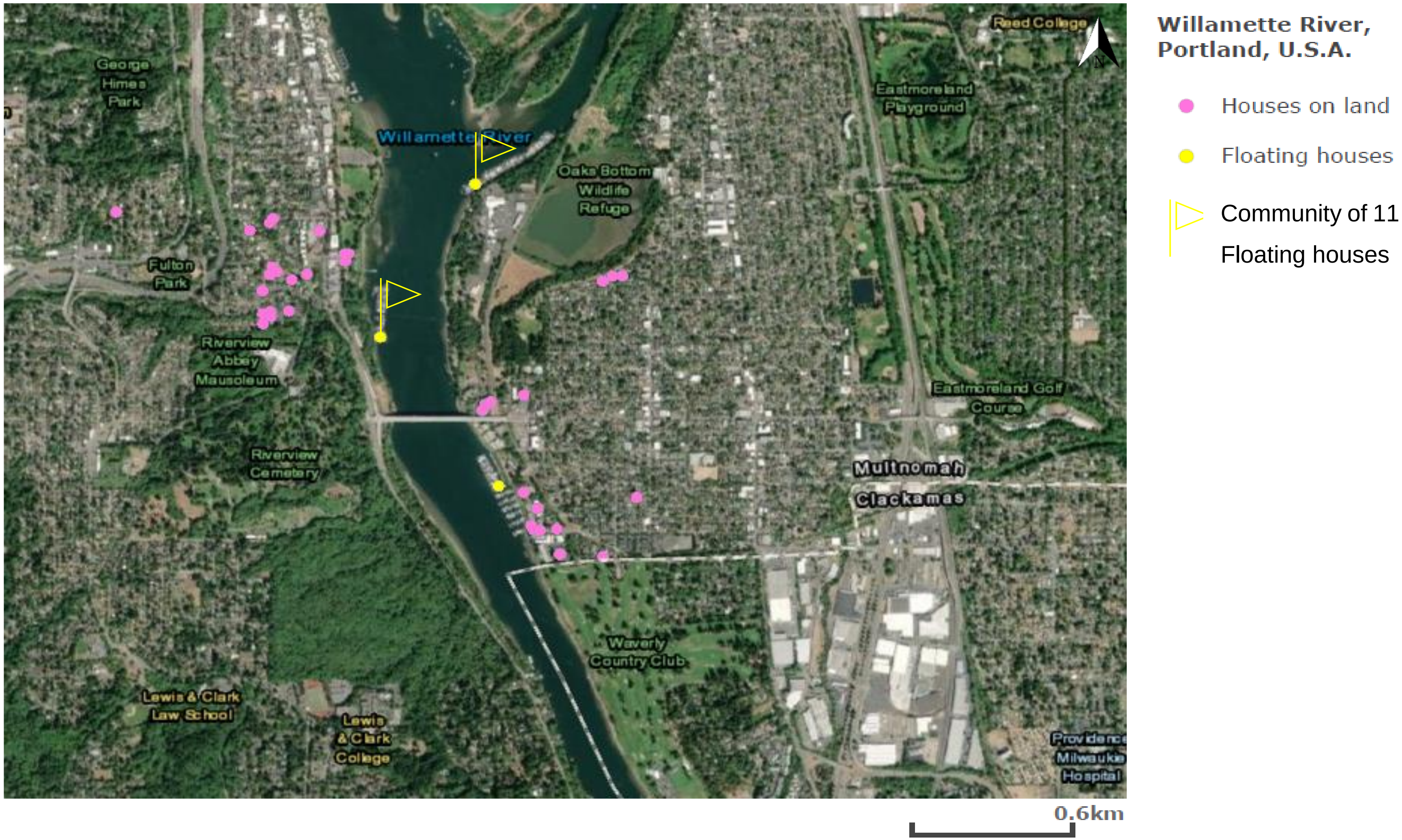


Figure 1b)i): Willamette River area

* Houses on land and Floating houses mapped by dots in the figure may represent 2+ neighboring properties each, due to absence of neighborhood numbers of many properties in the dataset. GIS Software has been used.

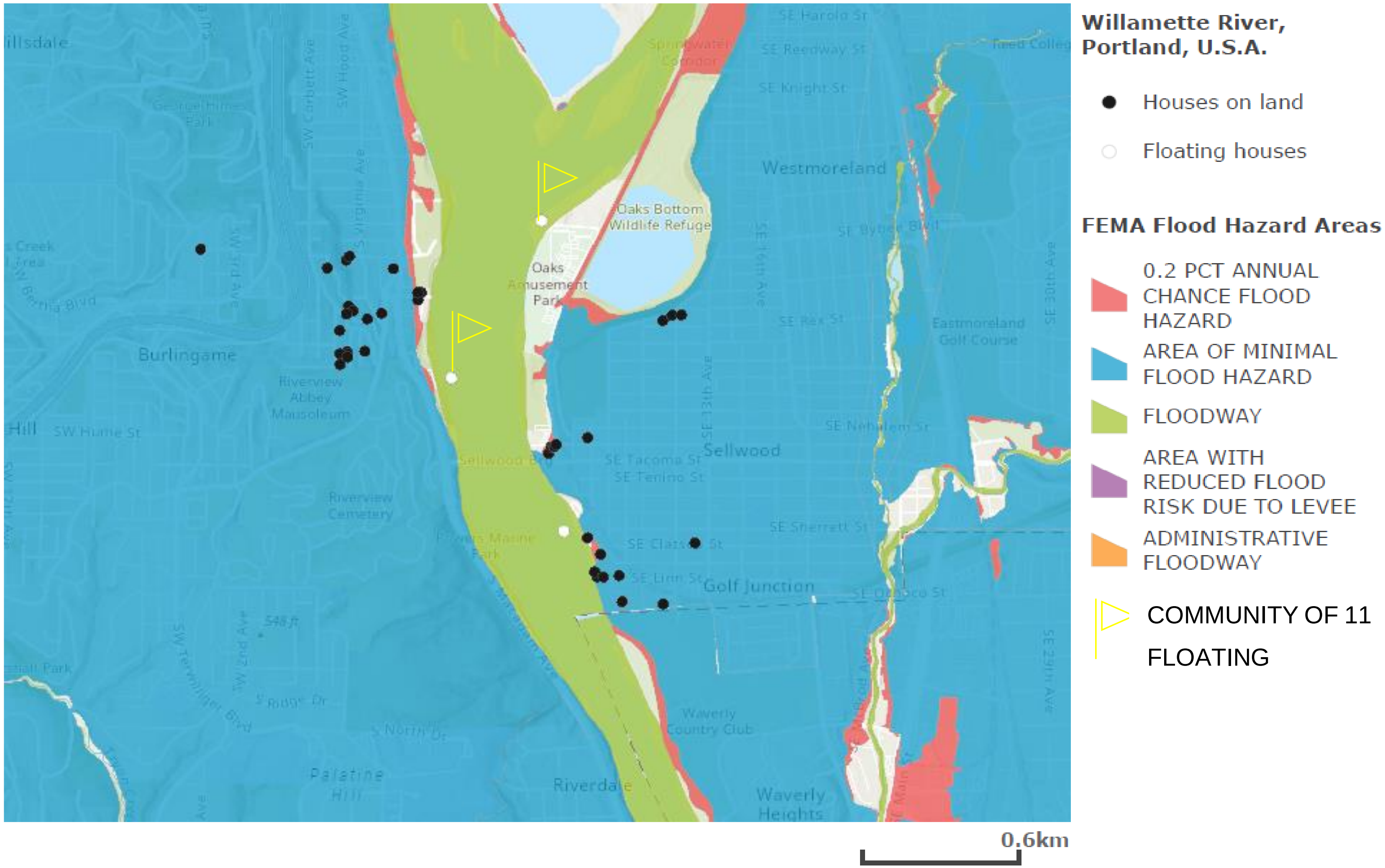


Figure 1b)ii): Willamette River area & flooding risk

* Houses on land and Floating houses mapped by dots in the figure may represent 2+ neighboring properties each, due to absence of neighborhood numbers of many properties in the dataset. GIS Software has been used.

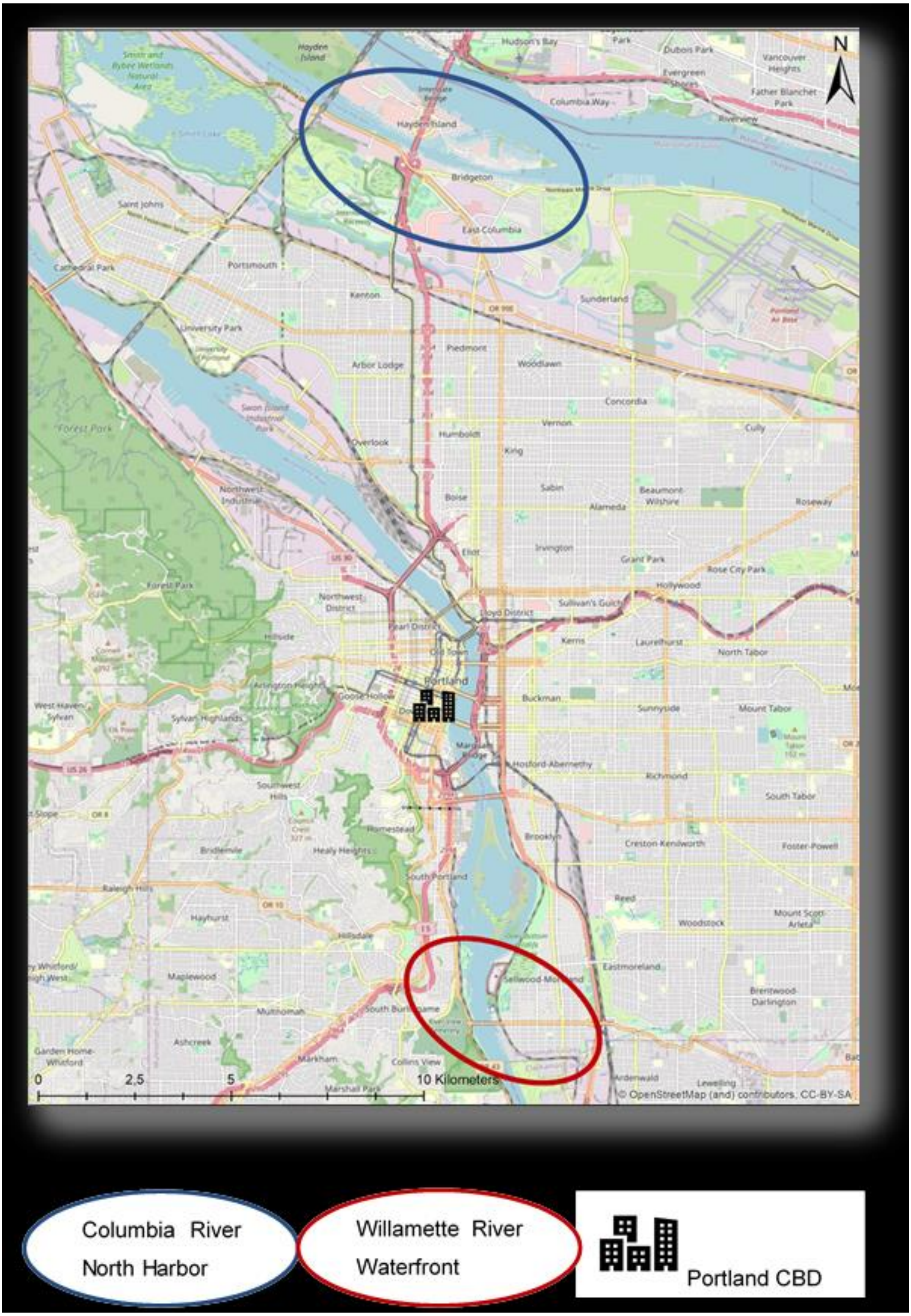


Figure 2 – Study area, City of Portland

GIS Software

3.2 Data & variables definition

The data used in this study are drawn from the real estate agency Premier Property Group LLC. The data allow us to examine the sales prices of floating houses (2019-2022) relative to the sales prices of on-land housing within the study area (Figure 2). The Columbia River North Harbor and the Willamette River waterfront facilitate the purpose of this study – to examine the price differentials of floating houses compared to houses on nearby land – since, on average, on-land houses stand 450 meters away from the floating houses communities (Figure 1). Information regarding sales prices and house characteristics such as surface area have been retrieved by the agency from sources such as tax records, appraisals, floor plans, developers, sellers, agents or had been publicly available. More specifically, the data offer information regarding property characteristics and sales transactions. Insights in terms of address, construction year, total surface area, floors, presence of garage, material of exterior construction, and main energy consumption fuel of each property are provided. Whether properties are located at the Columbia or the Willamette River waterfront is also noted. Information with respect to each sale transaction includes details such as properties' listing price, closing price, purchase type and year of sale (2019-2022). The dataset includes complete information for 222 on-land houses and 109 floating houses located at the Columbia River North Harbor and the Willamette River waterfront.

Floating status - The Floating status of houses constitutes our variable of interest (1= floating, 0=on land). Using information from the dataset in terms of whether properties float on one of the two rivers or are standing on land, the floating status variable is generated.

Property characteristics - Since this work focuses on the impact of the floating status on properties' sales prices, the sales closing prices are used to form the dependent variable (ClosePrice). The price distribution is skewed to the right, so the natural logarithm of closing prices is used in the empirical analysis (Appendix B). Further, the year of construction of properties (1900-2022) and the year of sale (2019-2022) are taken into account to control for the age of houses, which relate to differences in construction methods or property quality and time-effects respectively, which may influence sales prices (Bervaes & Vreke, 2004; DePaul University, 2016; Turnbull & Van Der Vlist, 2022). Similarly, data on properties' total surface area (TotalSF) along with the number of bedrooms (Bedrooms), number of stories (Floors) and housing main energy consumption fuel are used in this work's analysis as independent variables since they influence sales price (Bervaes & Vreke, 2004; DePaul University, 2016; Miszewska-Urbanska, 2016). The binary variable Elect (1=Electricity, 0=Gas) is generated to reflect the properties' main energy fuel. The natural logarithm of the total surface area of properties is used in the analysis (lnSF) (Appendix B), to correct for the rightward skewness of the original variable TotalSF. The development cost aspects arising from the materials used in construction may be critical for generating price differences between floating and traditional houses (Bervaes & Vreke, 2004). Specifically, Bervaes & Vreke (2004) find that floating houses are associated with more expensive prices relative to on-land houses and they suggest that a fundamental cause for this result is the more expensive materials and methods of construction. Thus, we use properties' material of exterior construction as an indicator of construction costs, since the main construction material is not provided in the data. The range of materials used for the exterior of properties in the dataset, such as Culstine, Brick, Cedar, Vinylsid, Stucco, Panel and Plywood are grouped into the classifications stone, wood, metal or manmade which are generated as 4 binary variables representing each family of materials. Only the main material of exterior construction is chosen, so that each observation is only classified in one of the described family of materials. Since 48% of properties have exterior made up of materials classified as Manmade, the binary variable Manmade (1 = yes, 0 = stone, wood or metal) is used in the empirical analysis to indicate the material of exterior construction. Furthermore, following the implications of Miszewska-Urbanska (2016), the housing style is taken into account to capture the influence of social perception on sales prices. Houses with a contemporary housing style are more likely to be associated with a 'luxury' label and 40.42% of properties in the dataset entail this style (Table A.1 – Appendix A). Thus, the respective binary variable Contemp (1 = contemporary style, 0 = bungalow, cottage, crafts-made, custom or midcom) is generated out of the housing styles provided in the dataset to reflect a possible influence of the housing style on sales prices. The variables selected for the empirical analysis are defined in table A.2 - Appendix A.

3.3 <u>Descriptive statistics</u>

Raw data

Table 1 reports the descriptive statistics for the sales of properties over 2019-22 for the two subsamples – On-land and Floating houses. Table 1a (raw data) indicates that the mean sales price is $510,944 for traditional houses and $383,436 for floating houses. The average price per square foot is $279.61 for on-land houses and $285.69 for floating houses. Floating houses entail a range of 1-3 floors and 1-4 bedrooms, whilst houses on land entail 1-4 floors and 1-6 bedrooms. As indicated by the 2-sample t-test with equal variances (table 1a) all t-values except the ones for price/sq.ft. and year bought exceed the critical value of 1.96, which implies that the rest of the variables are incomparable amongst floating and on-land houses.

Table 1a - Descriptive Statistics per subsample - Raw Data									
	(1)On-Land Houses				(2)Floating Houses				2-sample t-test with equal variances
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	t-value
ClosePrice ($)	510.944.220	258.230.240	174000	2187500	383.436.280	235007	73000	1650000	4.35
TotalSF (sq. ft)	1.896.995	935.580	724	10278	1.371.955	562.466	592	3254	5.45
Priceperft	279.607	72.892	131.451	512.573	285.685	128.332	51.398	765.625	-.55
Floors	1.788	.787			1.587	.531			2.45
1	.432				.431				
2	.351				.550				
3	.212				.019				
4	.005				0				
Bedrooms	2.356	.869			2.028	.726			3.40
1	.14				.229				
2	.459				.532				
3	.329				.221				
4	.054				.018				
5	.013				0				
6	.005				0				
YearBuilt (number)	1.986.392	20.291	1900	2018	1.960.856	189.334	1900	2021	2.00
Yearbought	2.020.270	.887			2.020.376	.803			-1.10
2019	.230				165				
2020	.333				.330				
2021	.374				.468				
2022	63				.037				
Main Fuel									-2.05
Elect (1 = yes)	.495				.615				
Main Material of exterior									
Manmade (1 = yes)	.491				.469				2.40
Housing style									
Contemp (1 = yes)	.500				.220				5.15
Location									2.35
Harbor (1 = yes)	.680				.798				
Number of observations	222				109				

Table 1b - Descriptive Statistics per subsample - Final Data

	(1)On-Land Houses				(2)Floating Houses				2-sample t-test with equal variances
Variables	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	t-value
ClosePrice ($)	447.604.840	153554.69	174000	1222000	393.538.630	199139.92	112500	1185000	2.45
TotalSF (sq. ft)	1.690.033	555.327	728	2787	1.425.644	480.173	742	2730	3.85
Priceperft ($/sq.ft)	275.557	69.950	131.451	482.432	283.334	125.665	51.398	765.625	-.65
Floors	1.659	.768			1.611	.513			.55
1	.522				.400				
2	.297				.589				
3	.181				.011				
Bedrooms	2.225	.720			2.156	.634			.80
1	.137				.122				
2	.533				.611				
3	.297				.256				
4	.033				.011				
YearBuilt (number)	1.990.341	13.468	1941	2014	1.982.456	20.644	1940	2020	3.80
Yearbought	2.020.247	.916			2.020.322	.791			.51
2019	.253				.178				
2020	.319				.344				
2021	.357				.456				
2022	.071				.022				
Main Fuel									
Elect (1 = yes)	.533				.578				-.70
Main Material of exterior									
Manmade (1 = yes)	.555				.400				2.40
Housing style									
Contemp (1 = yes)	.505				.233				4.40
Location									-1.50
Harbor (1=yes)	.714				.800				
Number of observations	182				90				

Properties' comparability & final sample

Comparability amongst floating and on-land houses is critical for the determination of our coefficient of interest. To prevent measurement error in our regression analysis, we need to improve the comparability amongst the property characteristics of the two subgroups of floating and on-land housing. Thus, to mitigate the detected heterogeneity with respect to dwelling type (table 1a – 2 sample t-test with equal variances), atypical properties in terms of sales prices (1% outliers), total surface area (5% outliers), as well as properties with more than 4 bedrooms (4 properties) and of more than 3 stories (1 property) are excluded from the sample (table 1b). Additionally, houses older than 2 years are selected, since younger houses may entail specific home warranties or other amenities which are unobserved (Turnbull & Van der Vlist, 2022). Also, observing that properties built between 1900 and 1935 (10 traditional houses and 4 floating houses) demonstrate atypical price distributions in comparison with the rest; they are excluded from the final sample (table 1b). After performing the described adjustments, the properties' number of bedrooms, floors, main energy source and main material of exterior construction become comparable amongst the two subsets, in addition to the year of property sale, as indicated by the relevant column on the right side of table 1b.

After the aforementioned adjustments, the final sample (272 properties – 182 on land and 90 floating) is described by table 1b. The table indicates that the mean sales price is $447,605 for on-land houses and $393,538 for floating houses. The average sales price per square foot is $275.56 for houses on land and $283.33 for floating houses. Information regarding the structural property characteristics of the final sample such as the total surface area (on average 1,690 sq. ft. for on-land houses and 1,425.64 sq. ft. for floating houses) the number of floors, number of bedrooms, year or construction (the average is 1990 for on-land housing and 1982 for floating houses), year of purchase, main energy fuel (for 53.3% of traditional and 57.8% of floating houses is electricity), main material of exterior construction (55.5% of traditional houses and 40% of floating houses have material classified as manmade) and housing style (50.5% of traditional and 23.3% of floating houses have a contemporary style) is provided. The average number of floors is 1.66, the average number of bedrooms is 2.23 and the average year of purchase is 2020.25 for houses on land. Floating houses have on average 1.61 floors and 2.16 bedrooms and their average year of purchase is 2020.32. Furthermore, 71.4% of the houses on land are located at the North Portland Harbor waterfront (28.6% are situated at the Willamette River waterfront) and 80% of the floating houses are found at the North Portland Harbor waterfront (20% are located at the Willamette River waterfront). Tables A.1a - raw data and A.1b - final sample (Appendix A) demonstrate descriptive statistics for all properties as a whole rather than in subgroups.

3.4 Empirical Models

Hedonic model

The empirical model applies a hedonic model framework to measure the price differential between floating and on-land houses, while controlling for the influence of other price determinants. In the estimation, Ordinary Least Square (OLS) approach is used, whose assumptions are tested and noted in Appendix C. Our dependent variable - the natural logarithm of sales prices - is a linear function of the floating status (variable of interest), other property characteristics, location and fixed time effects (year of property sale), or:

$$ln(price) = \beta_0 + \beta_1 Floating + \beta_2 lnSF + \beta_3 Floors + \beta_4 Bedrooms + \beta_5 YearBuilt + \beta_6 Elect + \beta_7 Manmade + \beta_8 Contemp + \beta_9 Harbor + \beta_{10} Yearbought + \varepsilon \quad (2)$$

Parameter β_1, the coefficient of interest, provides information about the effect of the floating status on prices by comparing the two subgroups – floating (Floating = 1) and on-land housing (Floating = 0). We find the percentage difference in sales prices between floating and on-land houses using the exponent of the coefficient of interest, in the following way: $(e^{\beta 1} - 1) * 100\%$. The term ε is the stochastic error. Essentially, the effect of the floating status marks whether residents may be willing to pay a price premium, or a price discount for a floating house rather than a nearby on-land house, ceteris paribus. Independent variables representing property characteristics are also included in the model to prevent unobservable bias from being taken up by the coefficient of the floating status. Parameters $\beta_2 - \beta_8$ provide information about the effect of properties' natural logarithm of total surface area, number of floors, number of bedrooms, year of construction, electricity as a main energy consumption fuel, manmade material of exterior construction and contemporary housing style on sales prices respectively.

The variables $Harbor_i$ and $Yearbought_i$ (categorical) controlling for location and time fixed effects respectively are added to the model and variations of the baseline model are estimated. Parameter β_9 measures the effect of being situated at North Portland Harbor Waterfront compared to being situated at Willamette River on sales prices. Parameter β_{10} provides information about the effect of a property's purchase year (2019-22) on sales prices. Incorporating both the effects of property characteristics and time and location fixed effects allows for β_1 to reflect a more pure effect of the floating status on sales prices in relation to the baseline model 1, without carrying omitted bias from exogenous variables.

Robustness

Chow-test

Primarily, we start with examining whether including the effect of the floating status on sales prices in a regression analysis generates statistically different results compared to the case of not accounting for it. We conduct a chow-test (table B.1 – appendix B) with a pooled model that does not include the floating status and two unrestricted models that account for the floating status, one with the latter binary variable being equal to 1 (floating houses) and one with the floating status being equal to zero (on-land houses). The result of this test indicates whether significantly different sales prices are observed when the effect of the floating status is considered by the unrestricted models, compared to the pooled model. If this is indeed the case, the floating status has a meaningful impact on sales prices, which validates the purpose of this study.

Propensity-score matching

The condition of comparability amongst floating and on-land houses needs special attention. We now aim to improve the comparability amongst floating and on-land houses that are included in our sample to ensure that our results' reliability is not undermined by the heterogeneity between the two groups. We acknowledge that properties' sales prices, total surface area, year of built, material of exterior construction and housing style remain incomparable amongst traditional and floating properties after excluding atypical values from our selected variables (table 2b). To combat this limitation we predict the propensity-score of variables amongst floating and on-land housing and we only keep observations which do not deviate by more than 1% (caliper) from the propensity matching score range (removing 82 observations). As a result, 78 floating and 112 comparable houses on land (190 in total) form the matched sample. We then run a regression using the matched properties sample to check the robustness of our previous results with model 3 (table 3). However, after the aforementioned changes total surface area and housing style remain incomparable as indicated by formal t-testing (table B.2 – appendix B). To mitigate the risk of the remaining heterogeneity generating an error in our results, we restrict our sample further, using a different approach. We run a logit model, with the floating status as the dependent variable (table B.3 – appendix B), based on which we predict the propensity score. We then exclude observations, which deviate by more than 1% (caliper) from the propensity score matching range. Specifically, we remove 21 observations from the sample and 169 observations (68 floating and 101 houses on land) make up the sample of the final regression model (model 4 – table 3). As table B.4 (Appendix B) indicates, all variables used in the model share comparable features amongst floating and traditional houses. In addition, we conduct a balancing test (table B.5) which indicates that homogeneity has sufficiently improved amongst the two groups (floating and on-land housing) whilst the observations in each group are matching. If our prior regression results (model 3 – table 3) are sustained by model 4, this will project the robustness of this study's findings.

Dependent variable alteration

As another form of sensitivity analysis, we alter the operationalisation of our dependent variable from the natural logarithm of sales prices to the natural logarithm of sales prices per square foot (table B.6 – Appendix B). This is because we notice that although the average sales prices of on-land houses exceed these of floating houses, the price per square foot is relatively higher for floating houses (Table 1). This begs the question whether the effect of the floating status on sales prices varies when the natural logarithm of sales prices per square foot becomes the endogenous variable. The dependent variable is a linear function of the floating status property characteristics, location and fixed time effects, or:

$$ln(pricepft) = \beta_0 + \beta_1 Floating + \beta_2 lnSF + \beta_3 Floors + \beta_4 Bedrooms + \beta_5 YearBuilt + \beta_6 Elect + \beta_7 Manmade + \beta_8 Contemp + \beta_9 Harbor + \beta_{10} Yearbought + \varepsilon \quad (5)$$

If the effect of the floating status on sales prices with a strictly comparable sample (Table 3 – model 4) persists after the dependent variable alteration, this will strengthen our results' robustness.

Chapter 4: Estimation Results

4.1 Regression analysis results

We now report the main results of our analysis. Estimates of equation (2) leave out location and time effects in model (1) – table 2. Comparing the final model (2) with model (1), we observe an important difference for the impact of the floating status on prices, which indicates the importance of including the control variables.

Table 2 – Baseline models

	(1)	(2)
Variables	Ln(price)	Ln (price) - (Fixed effects)
Floating	-0.100**	-0.071*
	(0.045)	(0.037)
lnSF	0.731***	0.680***
	(0.084)	(0.071)
Floors = 2	-0.001	0.032
	(0.044)	(0.038)
Floors = 3	-0.113	-0.184***
	(0.072)	(0.060)
Bedrooms = 2	-0.029	-0.047
	(0.068)	(0.056)
Bedrooms = 3	-0.067	-0.058
	(0.087)	(0.073)
Bedrooms = 4	-0.148	0.001
	(0.156)	(0.131)
YearBuilt	0.003**	0.003***
	(0.001)	(0.001)
Elect	-0.028	-0.121***
	(0.041)	(0.035)
Manmade	-0.052	0.020
	(0.042)	(0.036)
Contemp	-0.063	-0.040
	(0.041)	(0.034)
Harbor		-0.401***
		(0.039)
Yearbought = 2020		0.078*
		(0.043)
Yearbought = 2021		0.161***
		(0.042)
Yearbought = 2022		0.236***
		(0.075)
Constant	2.216	1.605
	(2.530)	(2.094)
Observations	272	272
R-squared	0.432	0.622

*The dependent variable is the natural logarithm of sales prices. The models include property characteristics as listed in Table 2. See table 1 for variable definitions. The reference category for Floors consists of single-story properties, and for the Year of purchase (Yearbought) is 2019. For Bedrooms it is of a Bedrooms number equal to one, for Fuel it is Gas as a main energy source and for year of purchase it is 2019. Standard errors in parentheses with ***, **, * indicating significance at 1%, 5% and 10% respectively

Following, we interpret the results of our baseline models focusing on the effect of the floating status on sales prices. In addition, remarks are made regarding the cohesion of our results with findings from established literature. As indicated by model 1 in the first column of table 2, houses of a floating status are on average related to sales prices that are by 9.52% lower compared to prices of on-land housing. This effect is statistically significant at 5%. Nevertheless, one may note that this model does not include fixed location and time effects; its explanatory power towards the dependent variable is 43.2%. By incorporating the binary variable Harbor to reflect in which of the two areas (Harbor and Willamette) each property is situated to capture location effects, and the year of purchase of the property (2019-2022) to control for time effects, model 2 explains 62.2% of the variation in sales prices. The floating status of houses still demonstrates a negative effect on sales prices but of a smaller magnitude. Specifically, floating houses are on average associated with sales prices which are 6.84% lower than prices of on-land housing nearby. This result is only significant at a 10% level of statistical significance. Both of the above findings regarding the effect of the floating status on sales prices are contradicting with the majority of established literature, which suggest a positive association of floating houses with a price premium due to their unsinkability advantage (Turnbull, 1991; Turnbull, 1994; Turnbull et al., 2013; Bervaes & Vreke, 2004; Rijken, 2005). However, a negative impact on sales prices is consistent with the findings of Morgan (2007) and with remarks from Penning-Roswell's (2020) explanatory analysis.

Furthermore, as indicated by model 1, a unitary percentage increase in total surface area is associated with a 0.73% increase in sales prices, on average ceteris paribus. This effect is statistically significant at 1% and it is in line with literature (DePaul University, 2016). The effect of a 1% increase in total surface area on sales prices sustains its statistical significance also in model 2. The impact of a 1% increase in size (total surface area) on sales prices only diminishes slightly (by 0.05%) in model 2; specifically a unitary percantage increase in surface area is related to a 0.68% increase in sales prices. Moreover, in model 2, 3-story houses are on average associated with 16.81% lower sales prices compared to houses with a single floor, keeping the rest constant. This effect is significant at 1%, whilst model 1 does not indicate a statistically significant effect of houses having 3-stories on sales prices compared to houses with a single floor. Having two floors rather than one does not exhibit a statistically significant impact on sales prices neither in model 1 or 2. Furthermore, A unitary increase in the year of property construction is associated with a statistically significant (at 5%) increase in sales prices by 0.28% in model 1 and with an increase in sales price by 0.34% in model 2. The latter effect demonstrates a higher level of statistical significance (at 1%). Using electricity rather than gas as a main energy source relates to a decline by 11.40% in the sales prices of properties, which contradicts with cited works (Penning-Roswell, 2020, Rijcken, 2005). Similarly, finding no statistically significant effect for the material of exterior (manmade) on sales prices also contradicts with the aforementioned literature. Moreover, properties located at North Portland Harbor waterfront are on average associated with sales prices that are by 49.33% (2.d.p.) lower compared to sales prices of properties at the Willamette River waterfront. This association is significant at 1%. This difference may arise due to the closeer proximity of the area examined at the Wilamette River waterfront to the central business district of Portland (~8km) compared to the study area at the North Portland River which lies on the northern outskirts of portland (~16km from the CBD). Lastly, houses purchased in 2021 and 2022 are on average related to 17.47% and

26.12% higher sales prices respectively, compared to properties sold in 2019. Both effects are statistically significant at 1%, whilst buying a property in 2020 generates a price premium of 8.04% compared to properties bought in 2019. Nevertheless this effect is only signficant at 10%.

4.2 *Robustness*

We now report the main results of our sensitivity analysis. Estimates of equation (2) are used to form models (3) and (4) whilst their sample entails relatively more comparable (model 3 – 190 observations) and strictly comparable (model 4 – 169 observations) floating and on-land houses. Comparing model 4 with model 2 (table 2), the effect of the floating status on sales prices sustains its direction and significance and slightly increases.

Table 3 – Sensitivity analysis

	(3)	(4)
Variables	Ln(price)- (Matched sample)	Ln(price) - (Logit-matched sample)
Floating	-0.084*	-0.084*
	(0.045)	(0.048)
lnSF	0.742***	0.826***
	(0.097)	(0.114)
Floors = 2	0.009	0.018
	(0.050)	(0.053)
Floors = 3	-0.211**	-0.239**
	(0.094)	(0.103)
Bedrooms = 2	-0.120	-0.160*
	(0.079)	(0.089)
Bedrooms = 3	-0.159	-0.237**
	(0.010)	(0.119)
Bedrooms = 4	0.081	-0.017
	(0.314)	(0.329)
YearBuilt	0.003**	0.003**
	(0.001)	(0.002)
Elect	-0.141***	-0.142***
	(0.047)	(0.052)
Manmade	0.027	0.035
	(0.047)	(0.051)
Contemp	-0.044	-0.034
	(0.050)	(0.053)
Harbor	-0.404***	-0.399***
	(0.050)	(0.053)
Yearbought = 2020	0.083	0.093
	(0.060)	(0.066)
Yearbought = 2021	0.157***	0.163**
	(0.057)	(0.063)
Yearbought = 2022	0.246**	0.216**
	(0.098)	(0.106)
Constant	1.729	1.301
	(2.602)	(3.018)
Observations	190	169
R-squared	0.608	0.570

*The dependent variable is the natural logarithm of sales prices. The models include property characteristics as listed in Table 2. See table 1 for variable definitions. The reference category for Floors consists of single-story properties, and for the Year of purchase (Yearbought) is 2019. For Bedrooms it is of a Bedrooms number equal to one, for Fuel it is Gas as a main energy source and for year of purchase it is 2019. Standard errors in parentheses with ***, **, * indicating significance at 1%, 5% and 10% respectively.

Propensity-score matching & Logit regression

This section reports on findings based on matched samples. After limiting our sample to 190 observations (model 2 – table 3) excluding most incomparable observations amongst traditional and floating houses, we find that the effect of the floating status on sales prices sustains its direction and exhibits a slightly bigger magnitude compared to model 2. Presicely, floating houses are on average associated with 8.03% lower prices compared to houses on land, ceteris pariubus. This effect is significant at a 10% level. Since the negative impact of the floating status on sales prices does not deviate from previous findings (approximately 1% greater than in model 2), this strengthens the argument in favour of óur results' robustness. Model 3 explains 60% of variation in sales prices. The sample in model 4 (table 3) is further limited and includes only comparable observations formed with a more strict matching approach as described in chapter 3; heterogeneity is no longer present (table B.4 – Appendix B) between floating and on-land housing. Model 4 explains 57% of variation in the dependent varable (lnprice). As indicated by model 4, the floating status is on average associated with a discount of 8.73% in sales prices, ceteris paribus. This effect is significant at 10%. This effect is very similar to our prior findings, which underlines that our results are robust.

Furthermore, a unitary percentage increase in total surface area is associated with a 0.74% increase in sales prices on average (significant at 1%) in model 3 and with a 0.83% average increase in model 4 at 1% level of significance, whilst 3-story properties are related to sales prices that are 19.02% lower compared to single-story houses on average in model 3 and 27% lower in model 4, ceteris paribus. This latter effect slightly exceeds the one found in model 2 by about 2% and by 10%, in models 3 and 4 respectively, however it is significant at a 5% rather than at 1% significance level as in model 2. Likewise, the effect of a unitary change in construction year declines in significance from 1% to 5%, however it is very similar in size and maintains its direction. Specifically, a unitary change in the year of built is on average related to a 0.3% increase in sales prices, ceteris paribus in both models 3 and 4. In a similar manner, houses with electricity rather than gas as a main energy fuel, houses bought in 2021 or 2022 rather than 2019, and residing at Columbia River North Harbor in comparison to living at the Willamette River waterfront, on average all exhibit approximately the same effects on sales prices as in model 2 in terms of significance, size and direction. The only effects which demonstrate a remarkable difference in model 4, are the effects of having 2 bedrooms rather than a single bedroom and of having 3 bedrooms rather than a single bedroom, ceteris paribus, on sales prices since they are only statistically significant in the fourth model. Specifically, 2-bedroom houses are on average associated with 17.4% lower prices compared to single-bedroom houses, ceteris paribus (significant at 10%); whilst 3-bedroom houses are associated with 26.7% lower prices relative to single bedroom houses on average, keeping the rest constant (significant at 5%).

4.3 Discussion

This study finds that floating houses are priced relatively lower than comparable on-land houses in close proximity. This effect contradicts with the suggestions of established works (Turnbull, 1991; Turnbull, 1994; Turnbull et al., 2013; Bervaes & Vreke, 2004; Rijken, 2005). An important factor for the formation of the expected price differential is the unsinkable nature of floating houses in comparison to on-land housing prone to flood risk. Nevertheless, most of the works cited suggest that consumption risk mitigation may be aligned with a price premium in areas that exhibit greater risk for on-land houses compared to the areas surrounding the North Portland Harbor and the Willamette River – which mostly bear minimal flooding risk (Figure 1). Although our study area consists of a FEMA Special Flood Hazard Area (100-year), the risk of water reaching on-land houses within the next 30 years is only 0.2% (Floodfactor.com). It may thus be argued that the relatively low 30-year flooding-risk may relativise the unsinkability advantage of floating houses.

On the other hand, our results are aligned with implications from the works of Morgan (2007), Penning-Rowsell (2020) and Endangsih & Ikaputra (2020). Morgan (2007) finds that the advantage of living close to the water – or in houses that have a view at the water like the on-land properties in our study – is linked to a price premium despite any associated consumption risk. If flooding risk is not a price discounting factor for on-land properties in floodplains, floating houses will not sell at a premium as a result of flooding risk mitigation. Additionally, Penning-Roswell (2020) hints at the fact that floating houses may not be for everyone. The writer suggests that for some consumer groups residing in a floating house may not be a convenient alternative, such as residents who find traditional housing more comfortable or do not deem living that close to natural habitat attractive. The limits in the demand for floating houses could explain sales at a price discount, on average, for these properties relative to the sales prices of comparable nearby houses on land.

An important parameter that needs to be discussed to assess the reliability of our results is the comparability amongst floating and on-land housing. Although our observations of the two housing types initially entailed incomparable features (table 1 & table B.1), we limit our sample to 169 strictly comparable observations (table 3 – model 4) after running a logit model (table B.3) and excluding observations that deviate from a propensity score matching range of 1% caliper. As indicated by table B.4 (Appendix B), all variables used in model 4 (table 3) regard floating and on-land housing observations that share comparable features, whilst one may note the two groups (floating and on-land housing) demonstrate sufficient homogeneity as indicated by a balancing test (table B.5). Observing that our results in table 2 are to a great extent sustained in table 3 - model 4 (matched sample), we argue that comparability amongst floating and on-land housing is eventually sufficient and does not limit our results.

Moreover, it is interesting to observe how the rest of our results compare to findings from established literature. Bervaes & Vreke (2004) and Rijken (2005) suggest that the construction costs for developing a floating house are more expensive compared to developing a house on land, leading to more expensive prices for the floating houses. However, since their research was conducted 18 and 17 years ago respectively, their findings may have been affected by the less efficient methods of construction and more complicated installation procedures for floating houses of the time. Our study finds the properties' main material of exterior construction to have a statistically insignificant effect on sales prices, which acts as a proxy for the importance of construction material. Evaluating, one may argue that the main material of exterior construction may not be a sufficient indicator for the materials and processes used for the overall construction of a property, which can mark a limitation of this study. Furthermore, the contemporary housing style is not found to have a statistically significant impact on sales prices in comparison to more traditional designs. This contradicts with Miszewska-Urbanska's (2016) work, which suggests that the 'resort' label, arising from modern housing style and luxury amenities, has a positive impact on sales prices. Although the housing style has been accounted for, specific house characteristics/amenities that may signal a 'resort' label, such as architecture and furniture quality or the provision of a fireplace, jacuzzi or a swimming pool have not been provided in our data set. The contemporary housing style alone may not sufficiently reflect a ‘resort’ label.

Further, purchasing a property in 2021 and 2022 is associated with 17.47% and 26.12% higher prices respectively, compared to purchasing a property in 2019. Both positive effects on prices are significant at 1%. Buying a property in 2020 however exhibits a smaller positive effect (8.04%) on sales prices of a lower statistical significance (10%). Lastly, as observed in our baseline results, properties located at the North Portland Harbor are on average 49.33% cheaper than properties located at the Willamette river waterfront. This may be explained by the relatively greater proximity of the Wilamette River waterfront study area to the central business district of Portland.

Chapter 5: Conclusions

The focus of this work has been to identify price differentials between comparable floating and on-land houses, which are stimulated by the floating status. This study contributes to established literature by isolating the effect of the floating status on sales prices, rather than only observing price differences amongst floating and on-land houses. As our regression analysis, based on strictly comparable floating and on-land housing sample indicates in chapter 4 (table 3 – model 4), the floating status has a negative impact on prices, of a non-negligible magnitude (approximately 8%), which is statistically significant at 10%.

Inspired from established works' implications regarding price differentials between floating and on-land houses, we control for property characteristics, location and time effects to focus on the effect of the floating status on sales prices. To examine the robustness of our results, we limit our final sample initially from 272 to 190 and then to 169 observations so that it only entails comparable floating and on-land houses. Following, by running a logit model (table B.3 – Appendix B and by removing observations that exceed a 1% propensity score range, we observe that the two subgroups (floating and on-land houses) exhibit strictly comparable characteristics (table B.4 – Appendix B). Since our prior results (table 2 – model 2) maintain their direction and significance and exhibit a similar magnitude, this strengthens the argument in favour of our results' reliability.

It is important to note that our study entails a number of limitations, which can be addressed by future research. Firstly, we use a relatively small sample in our regression analysis, especially for the matched-properties samples in models 3 and 4 (table 3 – model 4: 169 observations). Future works may focus on areas that host a greater number of floating houses communities in proximity to on-land houses, such as Amsterdam, to incorporate a greater sample. In addition, by focusing on areas that entail a greater flood hazard than our study area (entails minimal flood hazard – Figure 1) such as waterfronts in Georgia, Massachusetts or North Carolina may be useful for assessing whether the effect of the floating status on sales prices varies with different levels of flooding risk. In such areas, awareness regarding housing consumption risk may be at a greater scale and thus floating houses may constitute a more viable – and perhaps preferred - alternative to traditional housing. Therefore, the floating status would be expected to have a positive impact on sales prices in such areas (Turnbull et al., 2013). Furthermore, one may argue that using two different areas – over 20 km apart from each other – can be another limitation to our analysis since the two areas may share different characteristics, such as distance from the CBD (Figure 2) and demographics. Nevertheless, we control for location effects in our models and one may note that the traditional houses are on average in close proximity (450m) from the floating community in each area. Furthermore, one may argue that our results' robustness could be enhanced if our model entailed more variables controlling for property features such as maintenance costs, which may differ for floating houses compared to on-land houses due to their contact with water. Other than this parameter, future works may also account for house amenities which are not provided in our dataset in detail, since Miszewska-Urbanska (2016) suggests that characteristics that can reflect a property's 'resort' label can influence sales prices.

References

Bach, J., 2021. Portland State University researcher: Oregon land-use planning rules 'abused' for 40 years. *Portland Business Journal*, August 4 Retrieved from: www.bizjournals.com/portland/news/2021/08/04/gerard-mildner-portland-state-university housing.html

Bervaes, J. C. A. M., & Vreke, E. J., 2004. De invloed van groen en water op de transactieprijzen van woningen (The influence of green and water on transaction prices of houses), *Alterra rapport 959*, ISSN 1566-7197. Wageningen: University of Wageningen Landscape Center.

Bin, O. and Polasky, S., 2004. *Effects of flood hazards on property values: evidence before and after Hurricane Floyd*. *Land Economics*, 80(4), pp.490-500.

Brooks, C. and Tsolacos, S., 2010. *Real estate modelling and forecasting.* Cambridge University Press.

Endangsih, T. & Ikaputra, 2020. Floating Houses Technology as Alternative Living. *IOP Conference Series: Materials Science and Engineering*, Volume 797.

Institute for housing Studies at DePaul University, 2016. Technical Paper: Hedonic House Price Models for Small Geographical Areas. *Insistute for Housing Studies*, 17, October. Retrieved from: https://www.housingstudies.org/media/filer_public/2016/10/31/ihs_measuring_the_impact_of_the_606_technical_paper.pdf

Lalor, A., 2021. Why is there a housing shortage in the Netherlands? The Dutch housing crisis explained. *DUTCHREVIEW*, 11 September.

Lloyd, S. A., 2021. Realtor Confessions: Courtney Cooper of Seattle Afloat and Cooper Cartwright. *SeattleMet*, 18 October.

McPherson, J. W., 2017. Floating Houses – Who, What, Where, When, How, and Why? *Freshwater News*, p. 13., August, Retrieved from https://portlandfloatinghomes.com/all-guides/freshwater-news-august-2017/

Morgan, A. 2007. The Impact of Hurricane Ivan on Expected Flood Losses, Perceived Flood Risk, and Property Values. *Journal of Housing Research* 16: 47–60.

Miszewska-Urbanska, E., 2016. *Modern Management Challenges of Floating Housing Development*. *Real Estate Management and Valuation*, 24(1), pp. 31-40.

Penning-Rowsell, E., 2020. *Floating architecture in the landscapre: climate change adaptation ideas, opportunities and challenges. Landscape Research*, 45(4), pp. 395-411.

Rijcken, T., 2005. *Floating neighbourhoods as they were and will be; why dwellers would want to live on water. In: Doing, thinking, feeling home*. Delft: Delft Technical University, pp. 1-10.

Turnbull, G.K., 1991. The spatial demand for housing with uncertain quality. *The Journal of Real Estate Finance and Economics*, 4(1), pp.5-17.

Turnbull, G.K., 1994. Location and housing demand with endogenous consumption risk. *Regional Science and Urban Economics*, 24(5), pp.543-563.

Turnbull, G.K. and van der Vlist, A.J., 2022. After the Boom: Transitory and Legacy Effects of Foreclosures. *The Journal of Real Estate Finance and Economics*, pp.1-21.

Turnbull, G.K., Zahirovic-Herbert, V. and Mothorpe, C., 2013. Flooding and liquidity on the bayout: The capitalization of flood risk into house value and ease-of-sale. *Real Estate Economics*, 41(1), pp.103-129.

www.portland.gov https://www.census.gov/library/stories/2021/08/more-than-half-of-united-states-counties-were-smaller-in-2020-than-in 2010.html#:~:text=National%20Population%20Change,the%201930s%20(Figure%204)

Appendix A

Descriptive statistics

Table A.1a – All properties raw data

All properties - raw data					**2-sample t-test with equal variances**
Variable	Mean	Std. Dev.	Min	Max	t-value
ClosePrice ($)	469707.080	257349.140	73000	2187500	4.25
Floating	.329	.471	0	1	
TotalSF (sq. ft)	1724.532	866.839	592	10278	5.4
Priceperft ($/sq.ft)	281.608	94.638	51.398	765.625	-.55
Floors	1.722	.719			2.4
1	.432	.496			
2	.417	.494			
3	.148	.356			
4	.003	.055			
Bedrooms	2.248	.838			3.4
1	.169	.375			
2	.483	.500			
3	.293	.456			
4	.043	.202			
5	.009	.095			
6	.003	.055			
YearBuilt	1983.97	21.795	1900	2021	2.9
Yearbought	2020.305	.860			-1.05
2019	.208	.407			
2020	.332	.472			
2021	.405	.492			
2022	.055	.227			
Main consumption fuel					
Elect (1=yes)	.535	.5			-2.05
Main Material of exterior					
Manmade (1=yes)	.483	.5			.4
Housing style					
Contemp (1=yes)	.408	.492			5.05
Location					
Harbor (1=yes)	.719	.45			-2.25

Number of observations: 331

Table A.1b – All properties Final Sample

All properties – final sample					2-sample t-test with equal variances
Variable	Mean	Std. Dev.	Min	Max	t-value
ClosePrice ($)	429715.280	171527.630	112500	1222000	2.45
Floating	.331	.471	0	1	
TotalSF (sq. ft)	1602.551	545.184	728	2787	3.85
Priceperft ($/sq.ft)	278.130	92.020	51.398	765.625	-.65
Floors	1.643	.694			.55
1	.482	.501			
2	.393	.489			
3	.125	.331			
Bedrooms	2.202	.692			.80
1	.132	.339			
2	.559	.497			
3	.283	.451			
4	.026	.159			
YearBuilt (number)	1987.732	16.581	1940	2020	3.80
Yearbought	2020.272	.876			-.65
2019	.228	.420			
2020	.327	.470			
2021	.390	.489			
2022	.055	.229			
Main consumption fuel					
Elect (1=yes)	.548	.499			-.70
Main Material of exterior					
Manmade (1=yes)	.504	.501			2.40
Housing style					
Contemp (1=yes)	.415	.494			4.40
Location					
Harbor (1=yes)	.743	.438			-1.50

Number of observations: 272

Table A.2: Variables Definition

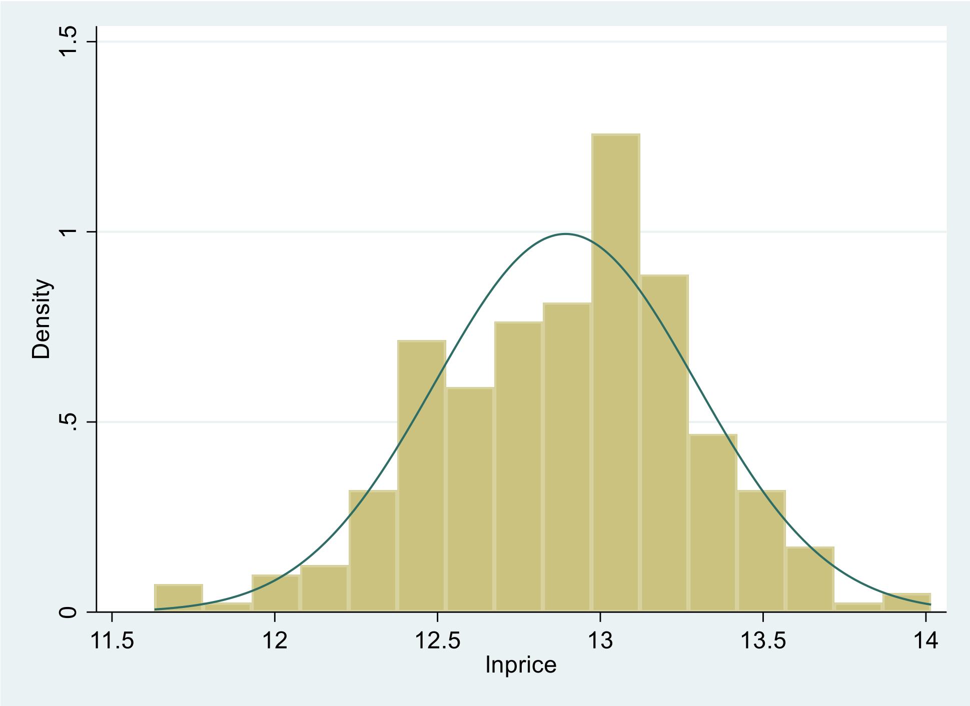
Variable Name	Definition
$ClosePrice_i$	Sales Price ($) of property i
$Floating_i$	Dummy 1 if the property is a floating house, 0 if the property is on land
$TotalSF_i$	Total property surface area in sq. ft
$Priceperft_i$	Sales price of property per square foot (ClosePrice/TotalSF) in ($/sq.ft)
$Floors_i$	Number of floors of the property
$Bedrooms_i$	Number of bedrooms
$YearBuilt_i$	Year of construction of the property
$Elect_i$	Dummy 1 if the main energy source of the property is electricity; 0 if gas
$Manmade_i$	Dummy 1 if the main material of exterior is classified as Manmade, 0 if stone, wood or metal
$Contemp_i$	Dummy 1 if housing style is contemporary, 0 if bungalow, cottage, crafts-made, custom or midcom
$Yearbought_i$	Year of property sale
$Harbor_i$	Dummy 1 if property location is North Portland Harbor Waterfront, 0 if Willamette River Waterfront

Appendix B

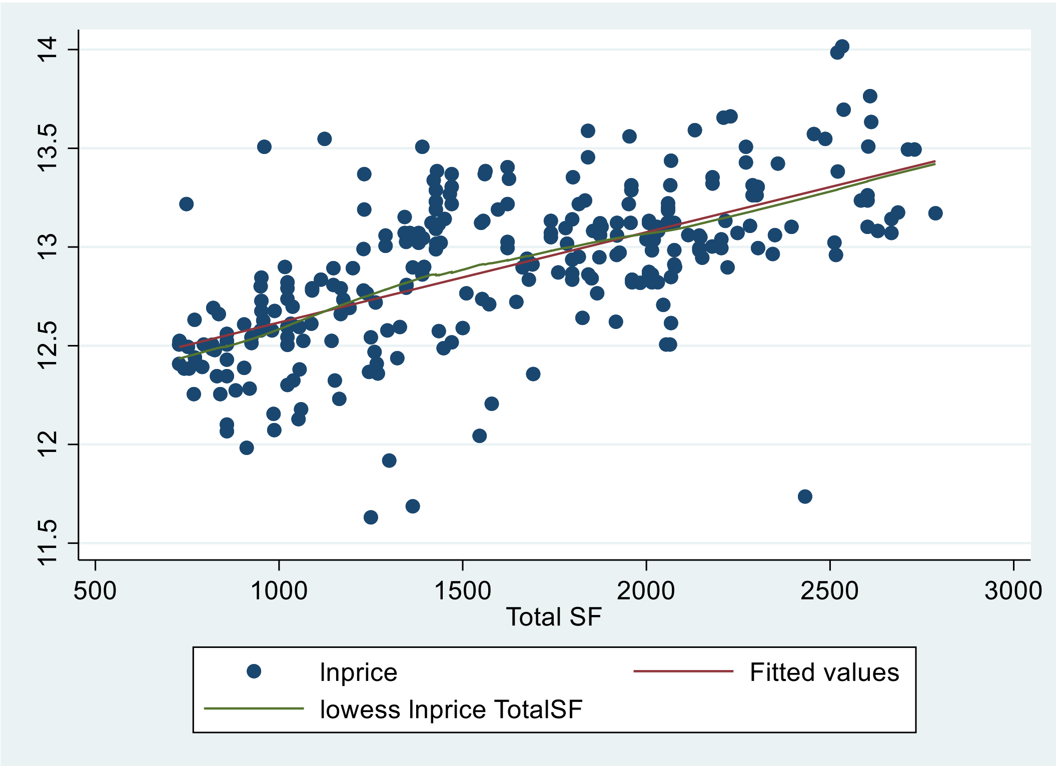
Variables transformation and distribution & Propensity-score matching

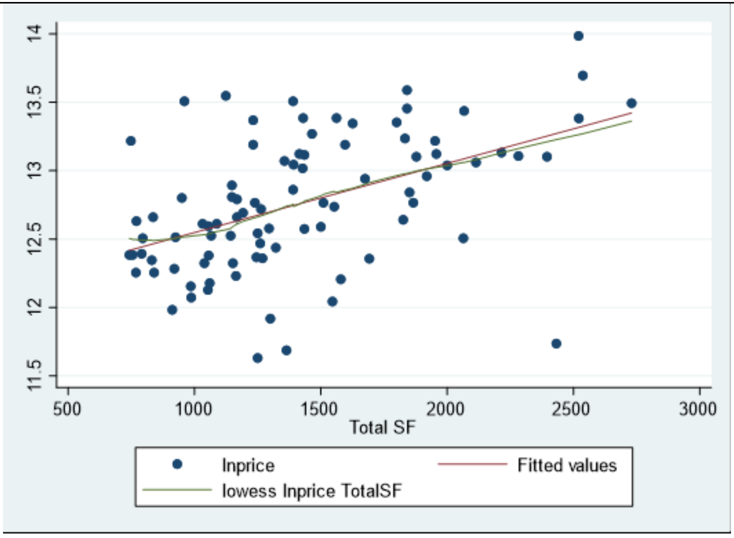
Distribution of the natural logarithm of sales prices – Histogram

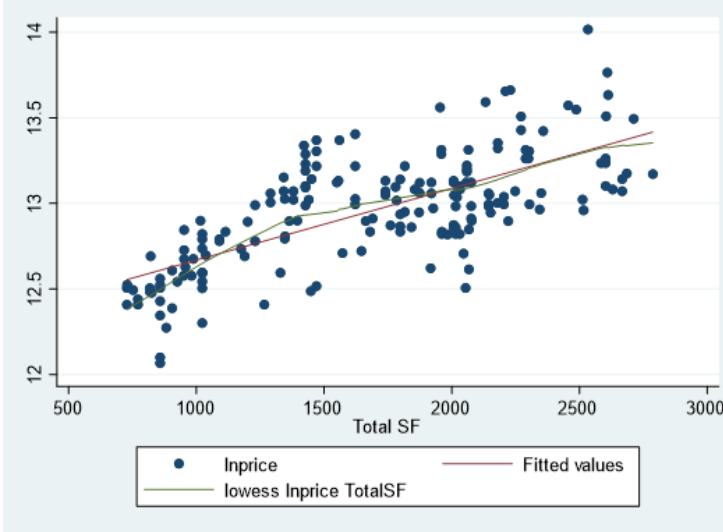
(Histogram lnprice, normal)



Scatterplot of ln(price) and Total Surface Area to assess linearity (twoway (scatter lnprice TotalSF) (lfit lnprice TotalSF) (lowess lnprice TotalSF))



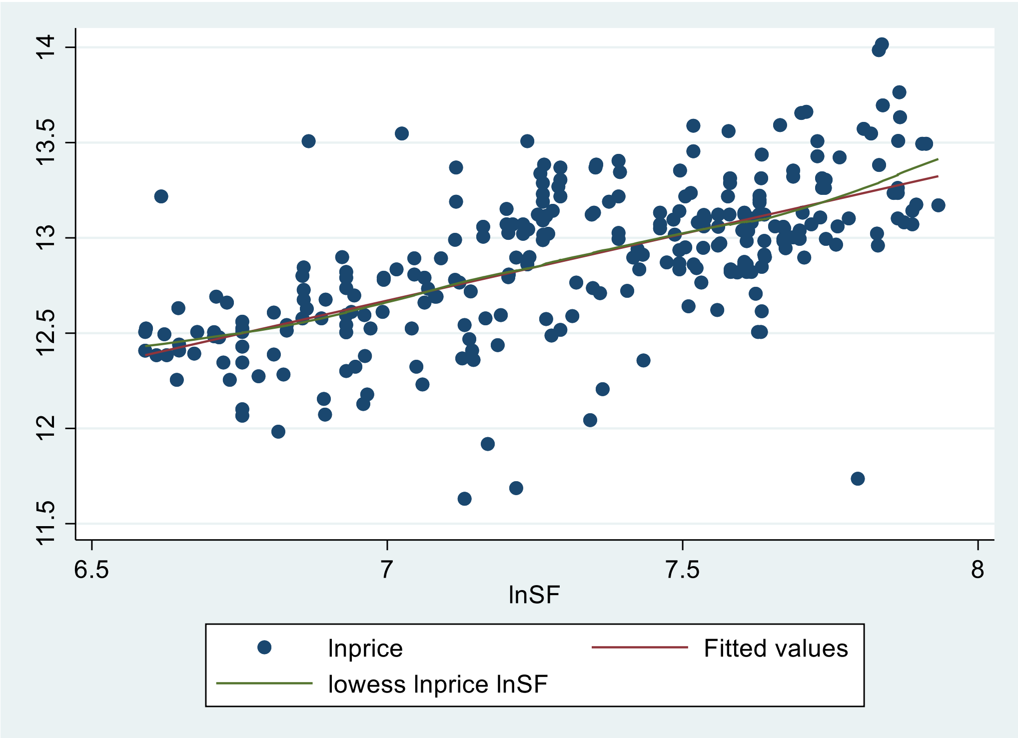


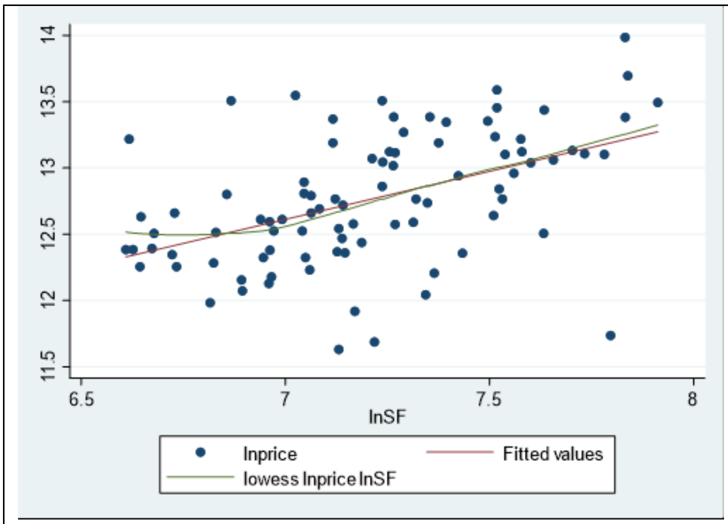
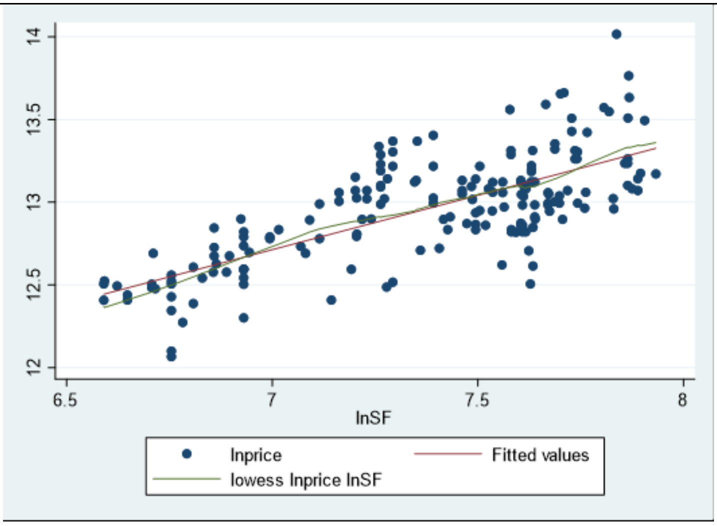


Floating = 1	Floating = 0
Scatterplot of ln(price) and Total Surface Area to assess linearity by group (Floating and on-land houses)	

Transformation of Total Surface Area to its natural logarithm – generation of lnSF

Scatterplot of ln(price) and the natural logarithm of Total Surface area to assess linearity (twoway (scatter lnprice lnSF) (lfit lnprice lnSF) (lowess lnprice lnSF))



	
Floating = 1	Floating = 0

Scatterplot of ln(price) and the natural logarithm of Total Surface area to assess linearity by group (Floating and on-land houses)

Chow-test

We conduct a chow-test which to observe whether the inclusion of the floating status in a model is meaningful – or whether results are not statistically different when we do not include it. Thus, the pooled model does not include the floating status, whilst the two unrestricted include the floating status as equal to 1 (floating houses) or equal to zero (on-land houses), as indicated below

$$ln(price) = \beta_0 + \beta_1 lnSF + \beta_2 Floors + \beta_3 Bedrooms + \beta_4 YearBuilt + \beta_5 Elect + \beta_6 Manmade + \beta_7 Contemp + \beta_8 Harbor + \beta_9 Yearbought + \varepsilon$$

Pooled model

$$ln(price) = \beta_0 + \beta_1 Floating + \beta_2 lnSF + \beta_3 Floors + \beta_4 Bedrooms + \beta_5 YearBuilt + \beta_6 Elect + \beta_7 Manmade + \beta_8 Contemp + \beta_9 Harbor + \beta_{10} Yearbought + \varepsilon$$

Unrestricted model: Floating =1

$$ln(price) = \beta_0 + \beta_1 Floating + \beta_2 lnSF + \beta_3 Floors + \beta_4 Bedrooms + \beta_5 YearBuilt + \beta_6 Elect + \beta_7 Manmade + \beta_8 Contemp + \beta_9 Harbor + \beta_{10} Yearbought + \varepsilon$$

Unrestricted model: Floating =0

F-statistic: $\frac{(RSSp-(RSS_1+RSS_2))\ /\ k}{(RSS_1+RSS_2)\ /\ (Np-2k)}$

F-statistic = $\frac{(16.745-(7.382+5.070))/15)}{(7.382+5.070)/(272-(2*15))} = 5.562$>Critical value =1.67 (at 5% significance)

The outcome of the Chow-test suggests that the pooled model is naïve and its results cannot be generalised. Including the floating status makes up a more meaningful model with higher explanatory power (R^2: 66.1% > 61.6%; 74.1% > 61.6%). The floating status has a meaningful effect on sales prices (see next page)

Table B.1 – Chow - test			
	(1)	(2)	(3)
Variables	Pooled Model	Unrestricted model 1 (Floating = 1)	Unrestricted model 2 (Floating = 0)
lnSF	0.703***	0.584***	0.633***
	(0.0703)	(0.180)	(0.0642)
Floors = 2	0.0186	0.0804	-0.0478
	(0.0370)	(0.0924)	(0.0353)
Floors = 3	-0.177***	-1.884***	-0.148***
	(0.0604)	(0.357)	(0.0450)
Bedrooms = 2	-0.0614	-0.132	0.0726
	(0.0554)	(0.114)	(0.0518)
Bedrooms = 3	-0.0738	-0.106	0.0972
	(0.0715)	(0.157)	(0.0658)
Bedrooms = 4	-0.0209	0.140	0.0615
	(0.131)	(0.371)	(0.105)
YearBuilt	0.00348***	0.00503***	0.000583
	(0.00109)	(0.00179)	(0.00129)
Elect	-0.120***	-0.137*	-0.139***
	(0.0354)	(0.0780)	(0.0324)
Manmade	0.0245	0.0837	0.00805
	(0.0359)	(0.0731)	(0.0337)
Contemp	-0.0265	-0.0634	0.0228
	(0.0332)	(0.0909)	(0.0279)
Harbor	-0.407***	-0.611***	-0.327***
	(0.0389)	(0.0945)	(0.0346)
Yearbought = 2020	0.0747*	0.166	0.0506
	(0.0429)	(0.107)	(0.0352)
Yearbought = 2021	0.158***	0.162	0.142***
	(0.0424)	(0.0989)	(0.0350)
Yearbought = 2022	0.241***	0.440*	0.193***
	(0.0754)	(0.250)	(0.0568)
Constant	1.176	-0.932	7.316***
	(2.093)	(3.678)	(2.502)
Observations	272	90	182
R-squared	0.616	0.661	0.741
RSS	16.745	7.382	5.070
k	15	15	15

The dependent variable is the natural logarithm of sales prices. The models include property characteristics as listed in Table 2. See Appendix A for variable definitions. The reference category for Floors consists of single-story properties, and for the Year of purchase (Yearbought) is 2019. For the number of Bedrooms the reference category is one. Standard errors in parentheses with ***, **, * indicating significance at 1%, 5% and 10% respectively.

Table B.2 - Properties' comparability after propensity score matching: Two-sample t-test with equal variances – matched sample

	obs1	obs2	t value	p value
ClosePrice by Floa~1	112	78	1.75	.078
TotalSF by Floatin~1	112	78	2.20	.029
Floors by Floating~1	112	78	1.60	.106
Bedrooms by Floati~1	112	78	.45	.654
YearBuilt by Float~1	112	78	1.85	.064
Yearbought by Floa~1	112	78	.10	.940
Elect by Floating:~1	112	78	-.35	.741
Manmade by Floatin~1	112	78	.85	.387
Contemp by Floatin~1	112	78	2.70	.007
Harbor by Floating~1	112	78	-1.8	.071

Logistic regression

Table B.3 - Logistic regression with floating status as the dependent variable

Floating	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval	Sig
lnprice	-.811	.55	-1.47	.141	-1.89	.268	
lnSF	-.474	.8	-0.59	.554	-2.041	1.094	
Floors	-.094	.3	-0.31	.754	-.681	.493	
Bedrooms	.36	.352	1.02	.306	-.33	1.051	
YearBuilt	-.006	.01	-0.56	.577	-.025	.014	
Elect	-.085	.358	-0.24	.813	-.787	.617	
Manmade	-.293	.342	-0.86	.392	-.963	.378	
Contemp	-.847	.364	-2.32	.02	-1.561	-.133	**
Yearbought	.028	.19	0.15	.883	-.345	.401	
Harbor	.283	.422	0.67	.502	-.543	1.11	
Constant	-32.376	384.228	-0.08	.933	-785.45	720.698	

Mean dependent var	0.411	SD dependent var	0.493
Pseudo r-squared	0.074	Number of obs	190
Chi-square	18.958	Prob > chi2	0.041
Akaike crit. (AIC)	260.321	Bayesian crit. (BIC)	296.038

*** p<.01, ** p<.05, * p<.1

Table B.4 - Properties' comparability after Logistic regression & propensity score matching:
Two-sample t-test with equal variances

	obs1	obs2	t value	p value
ClosePrice by Floa~1	101	68	.8	.424
TotalSF by Floatin~1	101	68	1.45	.148
Floors by Floating~1	101	68	.55	.574
Bedrooms by Floati~1	101	68	.7	.48
YearBuilt by Float~1	101	68	.8	.412
Yearbought by Floa~1	101	68	-.25	.797
Elect by Floating:~1	101	68	-.05	.956
Manmade by Floatin~1	101	68	.75	.455
Contemp by Floatin~1	101	68	1.6	.108
Harbor by Floating~1	101	68	-1.2	.232

Table B.5 - Treatment-effects estimation
Two-sample t test with equal variances

lnprice	Coef.	St.Err.	t-value	p-value	[95%Conf.	Interv.]	Sig
r1vs0	-.283	.066	4.29	0	-.413	-.154	***
Mean dependent var	12.904		SD dependent var		0.427		

*** p<.01, ** p<.05, * p<.1

Table B.6 - Regression results with the natural logarithm of sales prices per square foot as the dependent variable

Variables	Ln(pricepft)
Floating	-0.084*
	(0.048)
lnSF	-0.174
	(0.114)
Floors = 2	0.018
	(0.053)
Floors = 3	-0.239**
	(0.103)
Bedrooms = 2	-0.160*
	(0.089)
Bedrooms = 3	-0.237**
	(0.119)
Bedrooms = 4	-0.017
	(0.329)
YearBuilt	0.003**
	(0.0015)
Elect	-0.142***
	(0.052)
Manmade	0.035
	(0.051)
Contemp	-0.034
	(0.053)
Harbor	-0.399***
	(0.053)
Yearbought = 2020	0.092
	(0.066)
Yearbought = 2021	0.163**
	(0.063)
Yearbought = 2022	0.216**
	0.092
Constant	1.301
	(3.018)
Observations	169
R-squared	0.40

*The dependent variable is the natural logarithm of sales prices. The models include property characteristics as listed in Table 2. See table 1 for variable definitions. The reference category for Floors consists of single-story properties, and for the Year of purchase (Yearbought) is 2019. For Bedrooms it is of a Bedrooms number equal to one, for Fuel it is Gas as a main energy source and for year of purchase it is 2019. Standard errors in parentheses with ***, **, * indicating significance at 1%, 5% and 10% respectively.

Appendix C

OLS assumptions – **Based on Model 2 (table 2)**

1. Conditional mean of errors = 0 - *E(εt) = 0*

According to Brooks & Tsolakos (2010) this assumption is valid due to the inclusion of a constant term (β_0) in the regression analysis.

2. Constant and finite variance of residuals - *Var(εt)* $=\sigma^2 < \infty$

    Breusch–Pagan/Cook–Weisberg test for heteroskedasticity

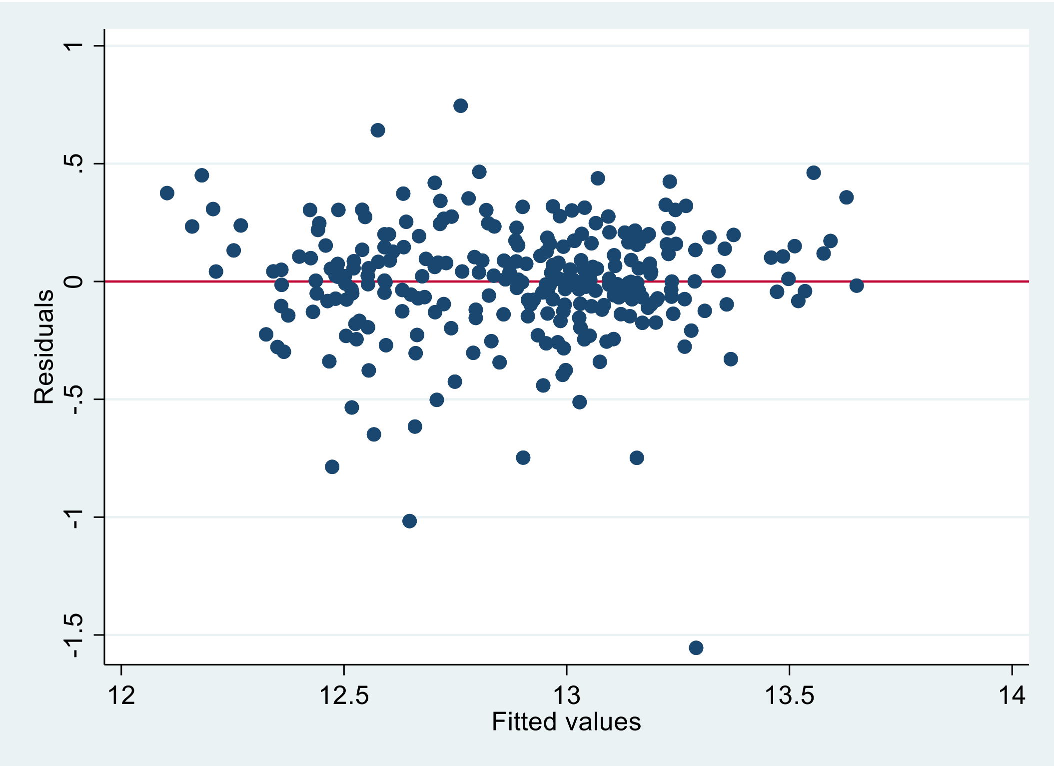
    Assumption: Normal error terms

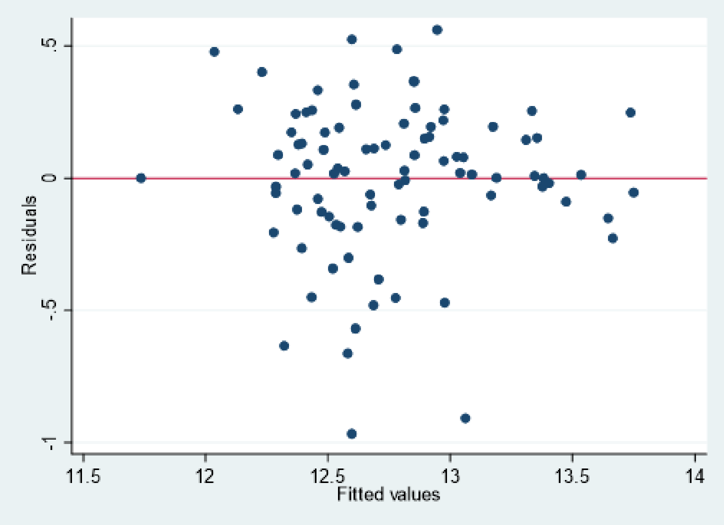
    Variable: Fitted values of lnprice

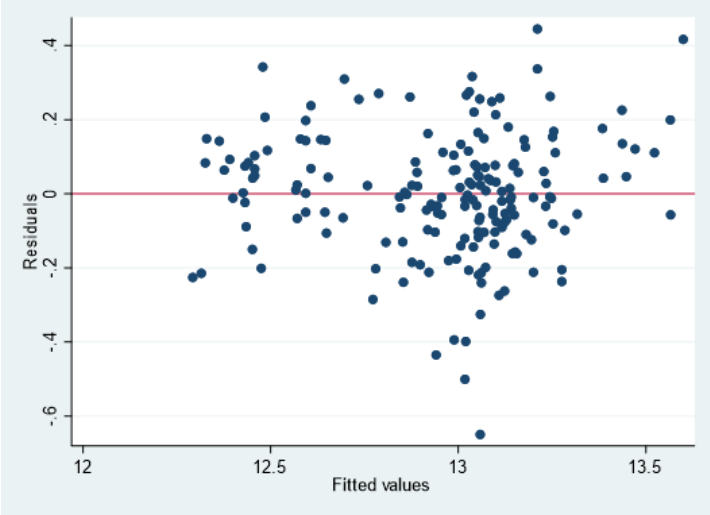
    H0: Constant variance

    chi2(1) =0.18

    Prob > chi2 = 0.6739





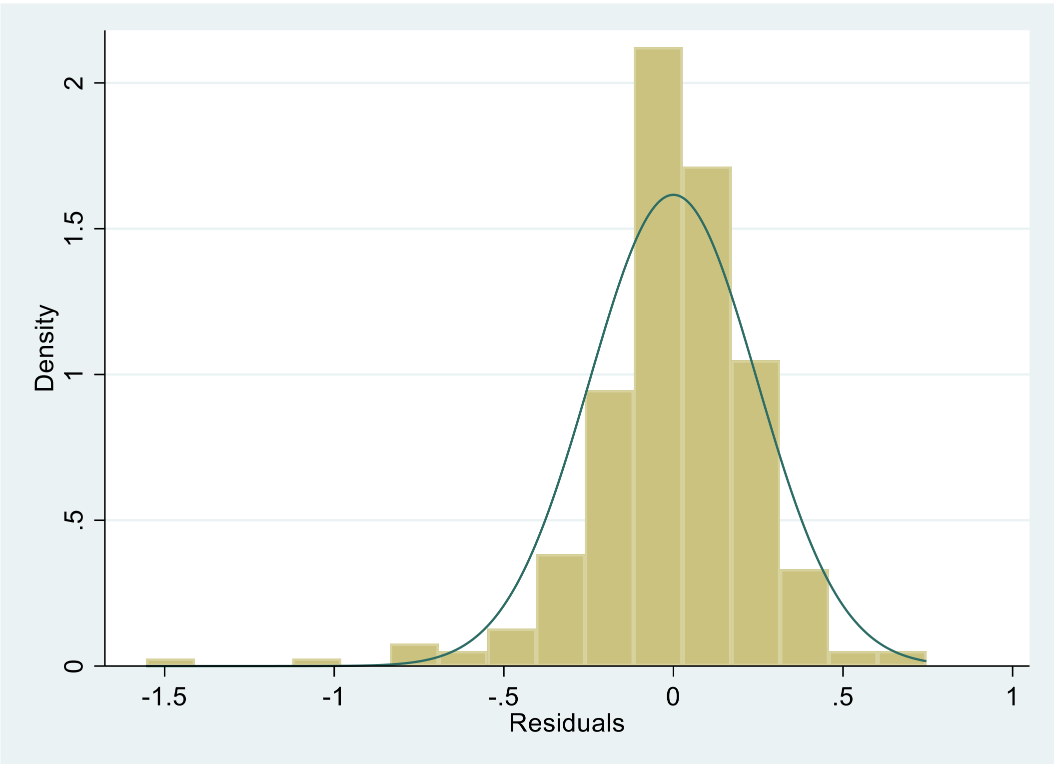


Floating = 1	Floating = 0
Constant and finite variance of residuals - *Var(εt)* =$\sigma^2 < \infty$ by group (floating and on-land houses)	

3. No autocorellated residuals - *Cov(εi, εj) = 0 for i=j*

   This thesis entails cross-sectional observations, and thus the covariance between the residuals eqials zero; there is no issue of autocorrelation in our sample.

4. Normality of residuals



As illustrated above, the residuals follow a normal distribution

Multicollinearity

Multicollinearity occurs when independent variables are collinear to each other (Brooks & Tsolakos, 2010). Multicollinearity issues can be detected by the Variance Inflation Factor. Values greater than 10 indicate the existence of multicollinear factors whilst values higher than 5 signal possible multicollinearity issues. As shown below, we find VIF values lower than 5 while testing for possible multicollinearity amongst the independent variables of model 2, which indicates that there is no multicollinearity amongst them.

	VIF values		
	Model 1	Model 2	Model 3
Floating	1.262	1.274	1.161
lnSF	2.622	2.748	2.967
Floors = 2	1.316	1.418	1.452
Floors = 3	1.624	1.671	1.74
Bedrooms = 2	3.205	3.215	3.495
Bedrooms = 3	4.365	4.39	4.884
Bedrooms = 4	1.746	1.81	1.331
YearBuilt	1.338	1.365	1.188
Elect	1.212	1.294	1.727
Manmade	1.257	1.352	1.809
Contemp	1.154	1.168	1.269
Harbor		1.214	1.258
Yearbought = 2019		1.692	1.269
Yearbought = 2021		1.784	1.214
Yearbought = 2022		1.238	1.225
Mean VIF	1.918	1.842	1.866