

1 Data Prep, EDA, and Theory development

1.1 Variable Selection & Explanation

For the purpose of analyzing the determinants of house (sales) prices in the US a theory was developed based on combining two common valuation strategies in real-estate; "vergleichswert verfahren, sachwert verfahren".

Based on the theory, four categories of regressors were identified in the data, promising to best represent the population regression equation.

- Size related quantities (House size, lot size); garage
- District and Neighborhood dependent variables; Zoning
- type of housing (one family home, apartment, etc)
- Quality and condition of the house; including time since remodeling

To this end, this research assignment draws data from an appraisal project conducted by... in the Ames district, Iowa (USA) (CITE DATA SOURCE HERE!!!). Corresponding to the aforementioned data categories, the following variables were selected to be used in varying degrees in the model. It may be noted, that due to the data being limited to a city in the midwest of the USA, the generalization resulting from this research may only extend to similar cities. However, due to the data originating from one district alone results in the comparability of the sale instances recorded in the data; meaning that stark contrasts in sales prices may be less due to the simple fact that one sale may have been made in Iowa and the other in New York, which naturally yields higher prices.

To start, a total of 1,460 house sales were recorded between 2006 and 2010 for the district of Ames, Iowa (USA). The dependent variable was identified to be SalePrice. As can be observed in Table 1, the mean sale price of a house was \$180,921.20 (SD = 79,442.50). Combined with the range [34,900, 755,000] a positive skewness was to be expected (skew = 1.881), considering that the outcome variable is of financial nature.

Following, the first category of data pertains to size related dimensions of the property sold. More specifically, the total living area (tot_living_area)¹ displays a mean of 2,572.89 square feet (SD = 823.598) in addition to a large range of values [334, 11,752]; suggesting that the sales were conducted in neighborhoods (Neighborhood) included range from urban to (partially) rural. To this end, the second data category encompasses the zoning classification (MSZoning) which identifies neighborhoods and the corresponding sales as rural or not. Neighborhood consists of 25 distinctions and zoning of eight categories², which will be adjusted to three categories to decrease the complexity of the data analysis (see Appendix for a contingency table). Additionally, the number of bedrooms

¹defined as summing above- and below- ground or base living.

²only 5 categories actually contain data.

above ground level (mean = 2.866, SD = 0.816) (BedroomAbvGr) and the number of bathrooms (mean = 1.990, SD = 0.732) are included (tot_bathrooms)³.

Moreover, the third class of data was selected to balance size and neighborhood related associations by considering building type (BldgType), which consists of five categories. Interestingly, the majority of sold homes were one-family homes (n = 1220); this variable was adjusted to reduce the complexity of the data analysis and remove confusion about the definition of building type.

The fourth category contains quality and condition related variables. Both variables are on a discrete scale from one to ten. Quality displays values for each quality rating (mean = 6.099, SD = 1.383), while the condition ranges from one to nine (mean = 5.575, SD = 1.113).

Table 1:

Statistic	N	Mean	St. Dev.	Min	Max
SalePrice	1,460	180,921.200	79,442.500	34,900	755,000
YearBuilt	1,460	1,971.268	30.203	1,872	2,010
YearRemodAdd	1,460	1,984.866	20.645	1,950	2,010
LotArea	1,460	10,516.830	9,981.265	1,300	215,245
GrLivArea	1,460	1,515.464	525.480	334	5,642
TotalBsmtSF	1,460	1,057.429	438.705	0	6,110
BedroomAbvGr	1,460	2.866	0.816	0	8
BsmtFullBath	1,460	0.425	0.519	0	3
FullBath	1,460	1.565	0.551	0	3
PoolArea	1,460	0.005	0.069	0	1
GarageCars	1,460	1.767	0.747	0	4
OverallQual	1,460	6.099	1.383	1	10
OverallCond	1,460	5.575	1.113	1	9
tot_living_area	1,460	2,572.893	823.598	334	11,752
tot_bathrooms	1,460	1.990	0.732	0	6
Adjacent_features_bool	1,460	0.137	0.344	0	1

It is notable that upon selecting the aforementioned variables, no preprocessing in the form of imputation or data deletion had to be applied. However, in order to decrease the complexity of the interaction term, the variable MSZoning was binned into (rural, mixed rural, and urban) based on the corresponding zoning categories⁴.

³The correlation between house size and number of bedrooms and bathrooms will be addressed later

⁴<https://www.kaggle.com/competitions/home-data-for-ml-course/data>

1.2 Exploratory Data Analysis

⁵ A scatter plot matrix is provided in the appendix for the numeric variables. The EDA shows the four data categories with respect to the sale price of the property. Thus, the plots represented, inter alia, drove the development of the hypothesis down the line in combination with the aforementioned valuation strategies.

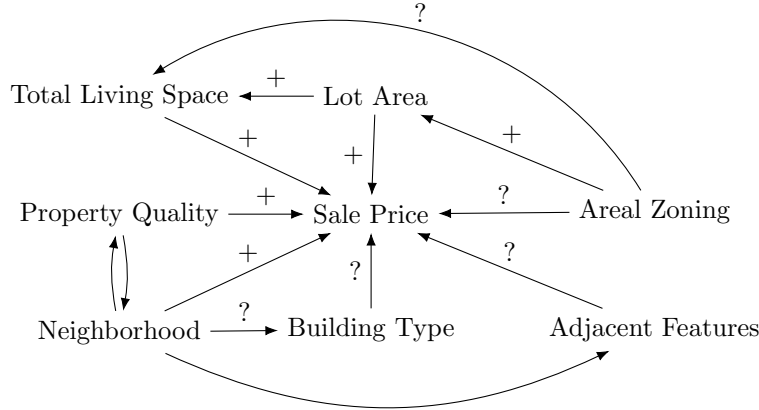
first analysis: Size of living area to sales price with respect to building type

Second analysis total rooms and sales price with respect to size zoning

Third analysis quality and condition to sales price

2 Theoretical model and OLS assumptions

Plot 1: Causal relationship Scheme

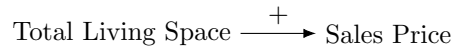


Based on the valuation strategies discussed above, a theory was set up to explain the variation in sales prices and the corresponding causal relationship scheme can be seen in Plot 1. When combined with the EDA in part 1, the following hypothesis were posed.

As can be reasoned from **PLOT XXX**, which displays the assumed direct positive association between Total Living Space (IV) and Sale Price (DV). Consequently, we assume that:

Hypothesis 1 (H1): *Total Living Space has a positive effect on Sales Price.*

Plot 2: Hypothesis 1



⁵The theory underlying the choice of the variables will be further elaborated upon in Section 2

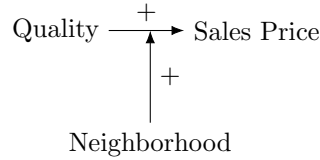
Moreover, upon further investigation, the zoning was taken into account in order to reflect administrative borders for the district of Ames. As these borders/ zones are commonly used for calculating local property taxes, the type of zone a specific property falls into promises to explain further variation not only in Sale Price itself, but also moderate the direct effect of Total Living Space and Sales Price.⁶ Subsequently, the follow-up hypothesis investigates whether the geographic separation of the districts of Ames into categories ranging from densely to less densely populated areas impact the association of

Hypothesis 2 (H1): *Zoning moderates the direct effect of Total Living Space and Sales Price, while having itself an impact on the Sale Price. Moreover, less densely populated zones have a more positive association with Sales Price than more densely populated zones.*

Thirdly, it is intuitive that the Quality (IV) of a construction at least in part explains its valuation. However, as was discovered during the EDA in part 1 as well as the suggestions made in the reviewed valuation strategies, such an association commonly clusters. Thus, Neighborhood (IV) is assumed to moderate the direct effect of Quality on Sales Price, while itself displaying a positive effect on Sales Price; the argument being that richer households group together and create as a cluster more qualitative (expensive) homes, which then results in an increase sales price

Hypothesis 3 (H1): *Neighborhood of a construction moderates the relationship of Quality on Sales Price, while displaying a positive relationship itself; thus,*

Plot 4: Hypothesis 3



The first category of data pertains to the size dimension of the house in question. Here the size of the house (1stFlrSF + 2ndFlrSF), combined with further information regarding the of bathrooms (BsmtFullBath + FullBath), Bedrooms (Bedroom), and Kitchen explain the overall living space of a house or apartment. Additionally, the lot size (LotArea) of the property and the garage (GarageCars/GarageArea) specification complement this category.

The Second category describes neighborhood and location related characteristics of the property. School districts (indirectly included as unobservable!!!) and affluent neighborhoods naturally have a large impact on the saleprice. Additionally, neighborhoods may, thus, function as cluster correction for similarities

⁶It is notable that of all 1460 observations in the sample, 1151 are attributable to less densely populated areas while 218 records pertain to more densely populated neighbourhoods

in the error term when correcting for heteroscedasticity; assuming that sales in the same neighborhood share similar underlying variation. Finally, the neighborhood may control for the size of the house; we would generally assume that big houses are more expensive. However, if we consider New York downtown, to large houses in the country side of Iowa, small flats (in new york) might induce that small properties cost more than large properties.

The third category of data distinguishes in the type of housing that was recorded as a sale in the data (MSSubClass, BldgType).

The fourth category focuses on the quality and condition aspect of the property as a function of years since remodeling (YearRemodAdd), building finalize date (YearBuilt), and the overall rating of quality (OverallQual) and condition (OverallCond) of the property.

Note, variables such as central heating have been discarded as those usually are contained in the type of house (apartments tend to have central administered heating from the overall building).

MAKE A CAUSAL SCHEME!!!! HErE IN LATEX