

Does quality in multifamily housing matter?

Inga Britt Werner

The objective of this investigation is to estimate the impact of different aspects of interior quality on prices of cooperative flats. Interior qualities of dwellings are here described as visual qualities – space, light, materials and finishings – and functional qualities – lay-out and appliances.

Many published studies have tried to obtain statistical measures of the contribution of specific attributes to the payments for housing or commercial space. There are several American studies on the real estate market [1, 9, 10, 11, 17] which try to do so. All of them state the difficulties of defining and measuring attributes of quality. Those difficulties have been mastered in different ways. In most studies the assessments of quality have been done by classification as in [9] where Hough and Kratz study office buildings which have been awarded prices for good architecture. In [10], a wellknown study, a remarkable effort of studying resi-

dents own assessments of housing quality has been made. However, this survey did not evaluate interior quality in any other respect than the physical condition of the structure.

In Sweden residential rents are controlled since many years. This makes it difficult to estimate the willingness to pay for quality in multifamily rental housing. Housing developers in Sweden have commissioned market surveys [4, 12, 14, 15] to find out what kind of housing qualities residents would prefer and pay for. These studies are all based on interviews or surveys on the residents' stated preferences.

The author of this paper has in her licentiate thesis [18] tried to establish correlations between the architecture of a building and its rate of return in operating. The studied sample comprised 20 residential rental properties. As the payments did not reflect the market value of attributes it was difficult to discern any impact from quality on the economic return.

Cooperative dwellings however are sold on a market¹. This fact has been used to calculate probable market rents [16], if rent control was to be abandoned. There has been a

debate on taxation of cooperative dwellings, which initiated an official study of the pricing of cooperative dwellings [8]. The result of these studies tell little about how quality attributes affect prices or would-be market rents. As the studied samples were gathered from all of Sweden the price differences between local markets seem to have outdone effects of differences in quality.

Aim

The objective of this study is to find out whether there exists willingness to pay for quality in multifamily housing, as well as to refine the pricing models. As the purpose of this study is to assess economic values of some aspects of quality, it is necessary to simplify and operationalize many and complex quality factors to a manageable number of quantitative variables. In this process construction of meaningful quantitative measures for aspects of quality is a second aim.

The expected result of the investigation is an estimation of the effects of both interior and environmental qualities on prices of cooperative dwellings.

Method

An empirical study with quantitative approach

The estimation of prices for different attributes of the dwellings is done through multiple regression analysis (MRA). MRA is a widely used statistic method for the study of many different factors' influence on one dependent variable. The empirical analysis will be based upon samples of cooperative sales in four suburbs of Stockholm. Basic facts about each dwelling, such as number of rooms, area and location within the building as well as the structure's age and number of floors are described in a data base. The qualities inherent in the environment of an individual dwelling have according to all experience a strong impact on price. Here these qualities have been summarized in dummy variables² for the different suburbs in the sample, of different status and distance to CBD.

The interior quality of each dwelling will be assessed by the rating of different aspects of visual, aesthetic and functional qualities. The study will also include a survey with a questionnaire to the buyers of the cooperative flats, about their perception of certain qualities and also

about paid prices. Qualitative interviews with some 10–15 buyers of dwellings in the sample are also planned, to get a perspective on the measuring of quality.

Quantifying quality

The regression analyses demands quantitative measures of housing quality, for example rating on a scale or categorisation into classes. Rating housing quality is problematic. Housing is a very complex object, with many aspects. Families with children make other judgements and choices than young professional singles, not to mention individual tastes and preferences within such roughly defined social categories. When buying a dwelling, you make assessments of a wide variety of quality factors, such as distance to work, main roads, public transport services, shops and schools. The social standing of the neighbourhood is taken into account, that is what kind of neighbours and schoolmates your family is going to have. You may already have bonds in a certain area through friends or relatives. With those factors in mind you also judge the look of the place and the specific qualities of the house or flat. As a buyer of a dwelling you evaluate a 'bundle' of qualities before making your choice, taking into account the whole offer. Depending on personal tastes and circumstances the weighting of quality aspects will differ.

Considering the complexities of describing housing quality, it is important to evaluate many different aspects of the concept. Kain and Quigley are critical towards the use of aggregated data and argue for using information of the individual dwelling unit, starting out with a wide range of quality measures, judged by many evaluators, for subsequent statistical aggregation. They consider this to be a way of obtaining more consistent and meaningful quality measures than the subjective aggregation implicit in obtaining overall quality measures from individual evaluators [10], page 534.

It is true that quality ratings based on objective standards or on expert's judgements can be of limited use when searching for housing qualities that people are willing to pay for, as buyers of cooperative flats have a wide range of preferences. But this study concerns willingness to pay for the kind of housing qualities which are gained through the work of a skilled architect, that is

qualities inherent in the lay-out and section of the dwelling and in the materials and detailing of the structure. The aim is to contribute to architects' knowledge of how their real customers, the residents in multi-family housing, appreciate the product of architects' work. On those premises it is feasible to use quality judgements from the architect's point of view in rating housing quality.

If the statistical analysis show no correlation between such quality ratings and price, it could be a reminder for architects to reflect on their own concepts of quality. Survey and interviews with buyers of flats in the sample will help to tell more about possible discrepancies. It is also an incentive for further research on what kind of qualities residents are willing to pay for.

Description of the quality measures

This evaluation of the implicit market price of interior housing quality uses the so called expert method. This method is based on the use of a large set of criteria for judging different aspects of housing quality. The criteria are linked to points for aesthetical as well as for functional and social qualities of a housing block and its dwellings. The method was evolved by Björklund-Lidmar [2,3] and studied by Westerberg-Eriksson [19]. In the latter study a questionnaire to some 1200 households was used to compare resident's and expert's assessments of quality. It was found that, according to the answered questionnaires, resident's assessments of functional aspects of housing quality were in overall accordance with expert ratings, but that their assessments of aesthetic, visual qualities were not. This study is addressing the same issue from another angle, if there is any correlation between expert's and resident's judgements of quality showing in actual willingness to pay.

Visual and aesthetic interior quality is evaluated in terms of

- *roominess*, i. e., height of ceilings, width of openings between rooms, large living area,
- "*transvisibility*", i. e., if it is possible to see from entrance to facade, from facade to facade, through three rooms in a row near the facade,
- *form of rooms*, i. e. proportion, symmetry, location of doors and windows,
- *daylight*, i. e., if there are windows above average such as windows in bathrooms, hallways. Main orientation towards northerly direction and poor lightening with dark areas within the flat are a minus,
- *outlooks*, i. e., outlooks in three directions, two directions in the same room, living room and kitchen facing opposite directions. It follows that flats facing just one direction are ranked lower in quality.

There are also points for special qualities such as fire-place, baywindows, elaborated stairs, railings and the like.

Functional quality is measured in terms of

- *interrelation of rooms*, i. e., if you have to cross the livingroom to get to the kitchen and the bedrooms or if bedrooms are away from the bathroom,
- "*furnishability*", i. e., assessment of the possibilities to arrange furniture, how bedrooms hold double or single beds and other furniture or if there is room for table and chairs in the kitchen.

All of the above mentioned quality measures are rated on a scale ranging between 1 (bad, non-existent) and 5 (very good)³.

The assessment of qualities is illustrated in figure 1, in which two examples of dwellings with differing rates of quality are shown. Example A is built 1946 and example B 1992. Example A has a high score of functional quality as well as for visual quality. Highly rated "Furnishability" and "Interrelation of rooms" explain this.

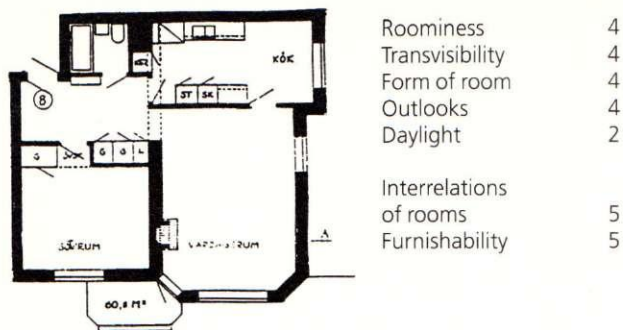


Figure 1 A. High score for visual and functional quality. The flat has "Roominess" not only by lay-out but also by high ceilings

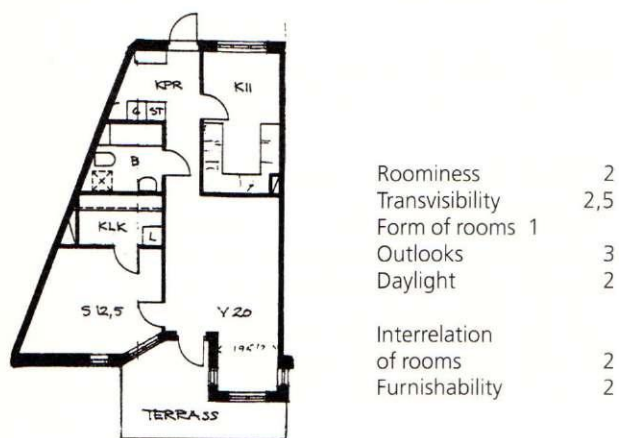


Figure 1 B. Low score for visual and functional quality. The baywindow in the livingroom is, for example, too narrow to be used for a dinnertable or a sofa.

In addition to the above described quality measures, a couple of other functional quality aspects are judged and rated⁴:

- *standard of fittings*, i. e. amount of kitchen appliances, wardrobes, standard of bathrooms and washrooms and if the dwelling has got a balcony,
- *accessibility* for people with a handicap or in a wheel chair, i. e., is there an elevator of appropriate size, are

- the doors in the dwelling wide enough for the passage of a wheel chair,
- *condition*, i. e. to what extent walls, floors and fittings need repairing.

The expert method does not use criteria for the architectural quality of façades, nor for how the volume of a building relates to neighbouring buildings. That is, it holds no criteria for what architecture essentially is about. Quality in this sense is very difficult to describe meaningfully in quantitative measures. Omitting this aspect of quality is also due to the fact that residential architecture is as a rule rather commonplace and not built to be architecturally monumental. This does not mean that people are considered to be unaware of architectural qualities. The individual building has seldom got a strong personality, while a group of buildings or a block can have discernable quality. Probably many people judge the architecture of buildings from the impression they get of the area or block. "Type of block" is the simplified variable used here to describe this.

The measuring of prices

Market prices are proxied by asking prices evaluated by real estate brokers. It is highly probable that brokers' knowledge of their local market makes them competent to target the market prices with high degree of accuracy. To get the most probable price, the advertising for each dwelling unit has been followed until its conclusion. The latest asked price has been noted in the data base. As a consequence, the time of each dwelling on the market has been roughly recorded. To avoid the impact of market fluctuations on prices, the data sample has been gathered during a limited period from September to November 1997.

Asking prices are used as measures for market prices in several studies and is considered to work reasonably well in empirical studies [6]. There is reason to believe however, that high quality tends to be overappreciated in the brokers' evaluation of the price of a dwelling and that adverse influences tend to be underestimated. For some of the units in the sample there are data of paid prices, according to scattered information from brokers. These observations support these apprehensions. There

is also a lag in brokers' adaptation to fluctuating markets, especially in the beginning of a down period. Sellers want to get prices comparable to those of the former market situation, and brokers try to fulfil their expectations until it is proven impossible. By choosing the studied sample from a short period (three months), the effects of market fluctuations are limited.

The lack of data of observed prices is here considered to be a drawback. As the differences in quality can be expected to affect the prices to a much lesser extent than more powerful factors such as neighbourhood, it is all the more important to get information on paid prices. In further research the observed market prices are to be included in at least part of the sample. The necessary data will be gathered by surveying the cooperatives and the buyers of the studied dwellings.

The sample

The sample has been randomly selected, every dwelling unit advertised on the market during a given period located in four given suburbs of Stockholm being included. The total number of studied cases is 176. The rating of the interior qualities is a time-consuming task and the sample is therefore relatively small. It still gives the possibility to carry out regression analyses on a fair amount of variables, without to much loss of degrees of freedom⁵.

The four suburban areas have been chosen to represent different submarkets of Stockholm. Stockholm's housing market is characterized by a leap of prices between suburbs and inner city. The regulated rents for tenant housing have during the last few years driven up the demand and the prices for cooperative dwellings in the inner city. Stockholm City has thus far been excluded from this analyses as the housing market there is so overheated that prices are hardly affected by rather small differences of quality.

In the suburbs there is a more balanced market, but demand can be higher than supply in the areas near the city. There is a division between submarkets north and south of the city and people seldom move from one to the other [14]. With some exceptions the northern submarket contains the more prestigious addresses and prices are higher. The chosen areas are described below.

For background data and statistics of the sample, see box⁶. The sample differs slightly from the main features of the chosen areas, due to the small sample and to the fact that cooperative housing is not quite representative of the total multi family housing stock.

Akalla-Kista is situated in the northwestern part of Stockholm. Housing is mainly built 1975 to 1980, as a last spurt of the "million program"⁷. This area is not a fashionable address, but the fast growing electronic industry in the vicinity may change that. It is connected by subway to the city and the duration of journey is 25 minutes to Stockholm's central station. The average income in this area is the lowest within the sample. Many immigrants live here. The sample from Akalla-Kista consists of 52 dwellings.

Bergshamra is a housing area just north of the inner city. The housing is mainly built from 1950 to 1960 and from 1985 to 1995. The two different age groups of structures are geographically divided through a bypass with heavy traffic. Each part of the area has its own service center with shops and subway station. The duration of the journey is about 15 minutes to Stockholm's central station. This area is an attractive location, near the city but also with the sea and the woods within short walking distance. The sample from Bergshamra consists of 29 dwellings.

Årsta-Gullmarsplan is the counterpart of Bergshamra on the south side of the city. It has a got a main housing stock of blocks built between 1940 and 1950 which is added to by dwellings built during 1990 to 1995. The western part of the area, called Årsta, has no subway station within walking distance. There is a generation shift going on; many residents have lived their active life here, children have grown up and parents have grown old. The sample from Årsta-Gullmarsplan consists of 65 dwellings.

Huddinge-Stuvsta is a small town southwest of Stockholm, now incorporated as a suburb of the metropolitan area. The housing stock is a mixture of newly built residential blocks, older small scale multifamily housing and single family houses, partly with the character of garden city. The town is connected with the city through railway, with a journey of about 20 minutes to Stockholm's central station, but with fewer services per hour than the subway. The sample from Huddinge-Stuvsta consists of 33 dwellings.

Background data of the suburbs

Statistics of the sample

	Inhabitants 1996 agegroups %			of foreign origin %	Average income SEK a year 1995	Asking price/sqm SEK, mean values	
	1-15	16-64	65- years				
Akalla-Kista	23%	66%	10%	A: 40 %, Ki:28 %	164 300		3300
Bergshamra	17%	65%	18%	28 %	175 500		9000
Årsta-Gullmarsplan	12%	60%	28%	13 %	176 000		7000
Huddinge	22%	64%	14%	13 %	202 000		4300
	Dwellings 1996		Share of coops % of units	1990		Rooms/ unit mean values	Sqml/ unit mean values
	Multifamily housing			Number of rooms per flat mean values			
Akalla-Kista	10768		46%		2.5		3,1 76
Bergshamra ⁸	2864		41%		2.6		2,7 71
Årsta-Gullmarsplan	9197		42%		2.3		2,5 65
Huddinge ⁴	4591		14%		2.3		2,4 66
	Age of structures, % of total 1990						
	Built before 1951	1951-1970	1971-1980	1981-	Built after 1986		
Akalla-Kista	0%	0%	98%	1%	0%		
Bergshamra	2%	69%	0%	30%	21%		
Årsta-Gullmarsplan	68%	29%	0%	3%	23%		
Huddinge	23%	47%	13%	17%	52%		

Sources of data

The information on the individual units has been gathered from brokers' advertisements in papers and on Internet, from drawings and from a limited number of inspections. The amount and quality of information in the advertisements vary greatly. In the more remote suburbs of the sample prices are relatively low. As a consequence advertisements in newspapers are very simple and cheap. In many cases the meagre information from paper advertisements has been improved by richer descriptions on Internet. If the available information from these sources did not cover the required minimum of monthly payment, number of rooms, asking price and the address, the dwelling unit has not been admitted to the sample.

Drawings were gathered from the archives of local building authorities. Alterations and refurbishments carried out since the drawings were filed have as a rule not been recorded. As a consequence, the measuring of functional quality according to fittings and equipment is at best approximate. The lay-out

and section of the buildings are seldom altered however, and the assessment of quality is mainly based on them.

Inspections have been relatively sparse, limited to around 20. The inspections have been a kind of participant observation, as the researcher has acted as a would-be customer at the broker's showing of the apartment. Those observations have been very valuable for getting information on the cooperative, the group of customers interested in the particular apartment, the condition and situation of the building, the condition and lay-out of the apartment and of the differences between reality and the picture given by descriptions and drawings.

Result

The distribution and correlation of rated qualities

The database of the sample shows that it is obvious that the set of qualities differ between dwellings of different age. The newer buildings often have more appliances, in particular a

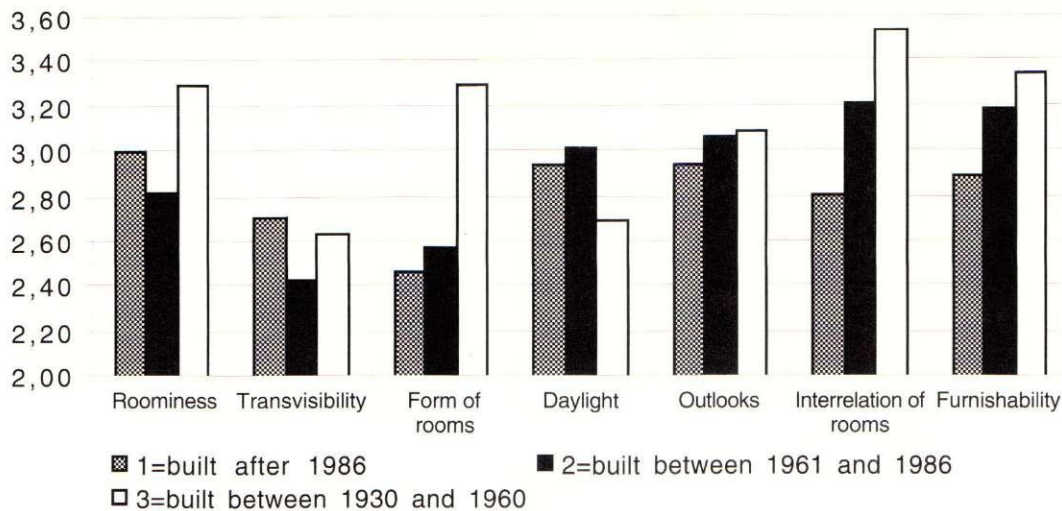


Diagram 1. Rating of quality, mean values related to year of construction

higher standard of bathrooms and balconies. Standard of kitchen equipment is also connected to age of structure, as is the existence of elevator and accessibility. On the other hand the variable "Built after 1986" is negatively related to "Form of rooms" and "Interrelation of rooms". Such qualities are more frequent in the older structures, as are "Roominess" and "Transvisibility". See Diagram 1 for distribution of quality ratings within the sample.

For the regression analysis the variables should preferably be independent of each other. This is not easily obtained, as there are for example obvious correlations between;

- monthly payment to the cooperative and price,
- monthly payment and number of rooms or total area,
- monthly payment and age of structure.

These dependencies between variables can be considered to be fairly stable over time and in the different submarkets, which means that they affect the linear regressions homogenously. Here it is assumed that the monthly payment is closely correlated to the cooperative's amount of dept. As dwelling units recently built naturally have higher monthly payments to the cooperative, due to their share of mortgage for production costs, they get lower asking prices. Apprehended major renovations or the decreasing of subsidies for housing are not considered. A variable which accounts for a forthcoming increase of monthly payments might better the models.

Analysis

The statistical modelling has been carried out as backwards stepwise linear multi variable regressions. The stepwise method is used as a first experiment in order to determine which of the variables have the strongest impact on price. The analyses started out with 31 variables and the dependent variable of asking price. The resulting models which fit the data best are shown in Tables 1 and 2.

The models have also been tried on each subset of data, the samples from the different suburbs. Dummy variables for different locations within the subsets, with differing distances to public transport or green areas, were tried and proved to be significant as predictors of price. But due to the small samples those models did not give very good overall explanations of variations in price.

Some preliminary findings from price regressions

When the whole set of data is analysed together, a picture of a rather stable correspondence between price and variables for

- location,
- monthly payment,
- area (square meters) and
- number of rooms

appears in the resulting models. These dependencies have been proved in other studies [8, 16]. Interviewed real estate

brokers also report that they use those variables as a rule of thumb for evaluating the prices of cooperative dwellings. But beside the basic characteristics mentioned above, several aspects of quality do account for a significant portion of the prices in the statistical models. Below the coefficients of the best fitting model are shown:

	Coefficient ⁹	t _n ⁹	Adj. R ² (⁹)
"Sum of ratings for visual qualities"	7063	2,410	0,84
"Nbr of rooms"	53945	2,858	
"Monthly payment"	- 113	-16,568	
"Akalla-Kista (Dummy)"	- 315658	-14,000	
"Huddinge (Dummy)"	- 199576	-7,701	
"Area (square meters)"	6426	5,958	
"Årsta - Gullmarsplan (Dummy)"	- 63124	-2,967	
"Rating of interrelation of rooms"	- 16715	-2,123	

Table 1

To eliminate the impact of monthly payment on price, a regression of just monthly payment to asking price was carried out. The residuals⁹, that is the differences in price not explained by monthly payment, were used as dependent variable in the next model. In this regression the variables with significant impact on price are:

	Coefficient	t _n	Adj. R ²
"Sum of ratings for visual qualities"	8152	2,471	0,79
"Nbr of rooms"	47240	2,214	
"Akalla-Kista (Dummy)"	- 421862	-15,013	
"Built after 1986"	- 238741	-8,878	
"Huddinge (Dummy)"	- 221218	-7,753	
"Årsta - Gullmarsplan (Dummy)"	- 129928	-5,743	
"Area (square meters)"	2896	2,763	
"Large balcony"	33931	2,068	
"Elevator"	67406	2,929	
"Number of floors"	- 8937	-2,054	

Table 2

The coefficients of the predictors describing visual quality are rather low. That is, price for a dwelling unit is heightened between 7000 and 8000 SEK for each degree on the scale of a dwelling's better "Rating of visual qualities"¹⁰, all other factors alike.

In the second model "Number of floors" has got a negative correlation to price, with the coefficient about -9000. It seems probable that dwellings in highrise buildings, in spite of their ability to supply an attractive view and location near to public transport and commercial service, as a rule are less attractive than those in lower blocks, at least in the suburb.

Some of the functional qualities are significantly related to price in these models. "Large balcony" and "Elevator" have got implicit prices comparable to that of "Nbr of rooms". "Interrelation of rooms", in the expert method defined to be a positive quality, has got a rather substantial negative coefficient in the first model and does not appear in the second. This quality is obviously assessed differently by experts and residents, which is also discussed in [19], where it is shown that the interrelation of rooms is rated differently between types of households. There is also the possibility that "Interrelation of rooms" is correlated to another variable and taking over explanatory power from that. This is though not discernable in correlations to the other variables, measured in correlation coefficients.

Standard of bathrooms and kitchens, as assessed from drawings, are not significantly related to price. One explanation is the collinearity between such qualities and the age of structure and thereby the correlation to monthly payment. Another is that those functional qualities are similar throughout the sample, as dwellings in the older structures often have been refurbished to a fully modern standard. This is as a rule not showing in the drawings.

Conclusion

Does quality matter for the pricing of cooperative dwellings? There are indications that this is the case, as the tentative results presented here show positive correlations between higher quality assessed in accordance to the 'expert method' and asking price. The regression models above show that;

- large balcony and elevator in the building are qualities that have a fairly strong positive impact on price,
- standard of bathrooms, kitchens and storage facilities has little impact on price, with the reservation of problems in measuring those aspects of quality,
- higher overall visual quality seems to have a small positive impact on price,
- high rating of interrelation of rooms has a negative impact of prices, with the reservation that this might be the consequence of correlations to other variables not included here,
- flats in highrise structures seem to have lower prices with the reservation that there are few of them in the sample (25 flats are located in buildings higher than 6 floors).

The variable related to visual quality, which has got the strongest explanatory power, is an aggregated measure of several aesthetic aspects. The fact that the significant quality measure is a summation of different quality aspects makes it less illuminating regarding the implicit prices for different architectural qualities. In the series of regressions tried, there were always several variables of visual quality acting as significant predictors of price, but they kept changing. Aesthetic quality seems to have an implicit price, but it is still not very well defined.

This result does in one respect satisfy the aim of the study, namely to try the hypothesis that visual quality as measured by architect's standards have a monetary value, however small. But the second aim, to construct meaningful measures of quality, is more in doubt of fulfilment.

The thesis work will be continued by the mentioned survey, now under way, with observations of marketprices and the buyers' own ratings of visual qualities. Using the buyer's quality ratings and the expert's ratings of the same qualities in parallel regression analyses to observed prices

will be a test to the former models, as the coefficients and t-values of the models can be compared.

Other methods of analysing data, apart from regression analysis, will also be used. Preliminary tabulation of data from the survey shows that people seem to judge quality in obvious covariance with their paying more, less or exactly the asked price. The latter data describe the demand for the dwelling at the time of purchase and can also be seen as a measure of how attractive the dwelling is on the market.

Regarding the evolving of adequate quantitative measures of housing qualities, the author is now carrying out qualitative interviews with buyers of flats in the sample. The interviews will contribute to the knowledge of how residents conceive and describe functional and aesthetic quality in their dwellings and of what role such qualities play for their decisions to buy at a certain price. The measuring of quality can then be discussed more thoroughly, as well as the weighting of exterior and interior qualities. Multiple regression analyses alone does not solve the question of how quality and price are related.

Notes

1. In Sweden condominiums and cooperative dwellings are sold to market prices. Condominiums are scarce but cooperatives common.
2. See *Explanation of some technical terms*
3. The rating scales described above are not exactly the same as in the original 'expert method'. For the purpose of statistical modelling they have been transformed to be homogenous for several variables.
4. Measures of functional qualities in the 'expert method' are based on the former, now abandoned, Swedish regulations for housing quality. Thanks to this strong regulation of quality the functional and technical standard of Swedish housing is comparably high and even. All of the flats in this study have bathroom, central heating, hot water and full kitchen equipment.
5. See *Explanation of some technical terms*
6. Source is tract data for 1996, by the Office for Surveying and Statistics of Stockholm City
7. The term is used for housing built from 1965 to 1975, when the political goal was to build one million new dwellings during ten years. There are many highrise buildings within this housing stock, now considered to be problem housing.
8. All data from 1990
9. See *Explanation of some technical terms*
10. These ratings mean for example higher ceilings than average or a livingroom with windows facing two directions or that the rooms have nice proportions.

Explanation of some technical terms

Linear regression; if you have a number of observations characterized by different values of the variables Y and X, you can, under certain conditions, construct a linear regression model to estimate the value Y_n of an observation with the value X_n . A description of the expected relationship between the random variables Y and X takes a linear form, that is

$$E(Y/X) = a + bx.$$

"Defining $u=Y - E(Y/X)$, we have the following relationship between Y and X, which is the standard specification of a simple linear regression model that relates a variable Y to a variable X.

$$Y=a + bX + u$$

The random variable Y is referred to as the *dependent variable* ... X is referred to as the *independent variable*... The variable u is stochastic and is referred to as the *error term*..." (pg 251, Ramanathan, R, *Statistical Methods in Econometrics*)

Multiple linear regression; a model that relates Y to several independent variables (X_1, X_2, \dots, X_n). It is specified in the equation:

$$Y= a + b_1X_1 + b_2X_2 + \dots + b_nX_n + u$$

The unknown parameters b_n are referred to as the *regression coefficients*. These show the change in the value of the dependent variable Y for each change of value in the variable X_n .

t-value; a test-value used to try the hypothesis that a regression coefficient, see above, significantly is not equal to zero. In other words if b_nX_n really has got an impact on the value of Y. As a rule of thumb, t-values higher than 2 (in absolute

terms, depending on the sign of the coefficient the t-value could be negative) show that coefficients significantly are not equal to zero.

Adjusted R^2 ; a measure of how much of the variation of Y-values that is explained by the actual multiple regression model. "Adjusted" stands for the adjustment of the measure of R^2 to the number of degrees of freedom, see below. The nearer the value of Adj. R^2 is to 1.00 the better, that is the more of the variation is explained by the model.

Residual; the difference between observed value and estimated value. The residuals tell how good a certain regression model is at explaining the relationship between Y and X_1, X_2, \dots, X_n .

Degrees of freedom; the difference between the number of observations and the number of independent variables in a regression model. If you have many independent variables in your model and it is based on few observations, the estimated values will be insecure.

Dummy variable; a variable that categorizes whether an observation has got a characteristic or not. If it has, the dummy variable has the value of 1, if it has not the dummy variable has the value of 0.

Multicollinearity; two or more of the X-variables are strongly correlated, which makes the regression model work less good if you are interested in estimating the regression coefficients with accuracy.



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Interior from Case Study Stumholmen. Photo: Göran Peyronsson