Explaining Property Values:
Quantitative evidence from Sweden

Terance J. Rephann
Senior Research Fellow
Spatial Modelling Centre
Box 839
S 981 28 Kiruna, Sweden
e-mail: tre@smc.kiruna.se
http://www.smc.kiruna.se

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Abstract: This paper describes progress in developing a property value module for a dynamic spatial microsimulation model called SVERIGE (System for Visualising Economic and Regional Influences Governing the Environment). It suggests using a hedonic price framework for estimating the value of residential property at different locations. The paper discusses the rationale for developing a property value module and problems encountered in specifying its equation(s). Determinants of property value are divided into several categories, including: (1) dwelling features, (2) land attributes, (3) neighbourhood characteristics, (4) regional or residential market features, and (5) public policy. The paper reports preliminary estimates of hedonic price equations for Sweden, with particular attention to geographical sources of variation in property values. It concludes with a discussion of ways the property value module might interact with other modules within the microsimulation model.

1.0 Introduction

Microsimulation was first introduced over four decades ago in a paper by Guy Orcutt (Orcutt 1957) and has experienced somewhat of a revival in social science research over the past decade. However, regional applications of the method have been rare (see Merz (1991) and Graham (1996) for descriptions of recent applications in this area). This paper describes on ongoing effort to develop a dynamic spatial microsimulation model for Sweden and, in particular, progress on developing a module to explain single family home property values. Although residential property value is an important topic in urban and regional analysis, it has not appeared in any microsimulation model. The potential usefulness of property value in microsimulation and ways to endogenize it are described in this paper. The paper also describes how hedonic price theory may be used in building the model and presents some estimates of hedonic price equations for residential properties in Sweden.

The model under construction (dubbed SVERIGE or *System for Visualising Economic and Regional Influences Governing the Environment*) is unique in several respects. It is one of the first truly spatial microsimulation models. Therefore, once completed, it will be permit an analyst to study the spatial consequences of various public policies. Assisting the model building effort is a unique database comprising information on every resident, employer, land parcel, and building in Sweden. The objects or microunits in this database are identified by spatial coordinates and have information available for an uninterrupted eleven year time period, beginning in 1985 and ending in 1995. Therefore, it is possible to estimate behavioural equations on various geographical scales and to track complex dynamic spatial relationships.

The paper is divided into several sections. The first section describes the SVERIGE microsimulation model and outlines its unique characteristics. The second section explains the rationale for including a property value module in SVERIGE. The third section describes the types of property value data that are available from Swedish agencies. The fourth section outlines hedonic price theory and some specification issues to recognise when developing hedonic price equations. The fifth section describes the data used in this study. The sixth section provides some preliminary hedonic price equation estimations using recent Swedish property value data. The seventh section describes how the property value module can be linked with other modules within the microsimulation model. The paper concludes with a discussion of areas that require further work.

2.0 Model history and unique characteristics

SVERIGE is a dynamic economic-demographic-environmental spatial microsimulation model for Sweden. By microsimulation is meant that the model represents lifetime events and choices of individual units (or objects) as a combination of structural factors (usually included in discrete choice models as independent variables or used to organise transition matrices) and random disturbance (a Monte Carlo randomisation component). By dynamic is meant that microunit ageing and development occurs in a life cycle pattern, with initial microunit conditions being changed for subsequent periods by counters and sequenced model equations. Its core is based upon CORSIM (Cornell Microsimulation Model), which itself is a modification of Guy Orcutt's DYNASIM (Dynamic Microsimulation Model), the first dynamic microsimulation model of its kind (Caldwell and Keister 1996). CORSIM has since sired other children as well, including a Canadian model named DYNACAD (Dynamic Microsimulation Model for Canada) (Morrison 1997).

SVERIGE will differ in several important respects from its CORSIM parent and DYNACAD sibling. First, SVERIGE is a Swedish model and thus must explain behaviour in a different institutional context than either the CORSIM and DYNACAD North American models. The model core of CORSIM (see figure 1) consists of nine modules (mortality, fertility, marriage, divorce, re-marriage, leaving home, education, employment and earnings, and immigration) that describe the human life cycle. Each module consists of equations that describe the behavioural responses of individuals as a function of their socio-economic characteristics. Although these module equations appear to be informed by economic theory, such as Becker's theories of marriage, divorce, education, fertility, and labour force participation, they are quite sensitive to cultural and institutional peculiarities. Thus, one cannot simply transport the specifications and parameters used by CORSIM to Sweden. For instance, power relations between men and women, the degree of class distributional equity, the elaborateness of social support mechanisms, and the varieties of social groupings (e.g., married couples, cohabitants, families, households) define the social context in which individual decisions are made and constrain the ways in which microactors interact. Therefore, while the life-cycle model that constitutes the CORSIM core will remain the same, the equations that explain transitions between various stages of the life-cycle may vary considerably between the North American and Swedish contexts.

Second, SVERIGE is a spatial model while CORSIM is not. In fact, SVERIGE will be the first national-level spatial microsimulation model. Geographical environment and distance play no role in aspatial models. However, SVERIGE will model individual spatial transitions (such as internal migration) and model life-cycle transitions described by the model core within a spatial context. In addition, certain geographical objects (including land parcels, neighbourhoods, and labour markets) will have attributes that influence the attributes of objects such as individuals, households, employers, and homes (see figure 2. for a full listing of objects and their attributes) and vice versa. For instance, property values, pollution levels, and housing characteristics will change and, in turn, modify choices made by other microactors (or objects) within the microsimulation model. Furthermore, because objects have geographical attributes, the model will be capable of generating geographically detailed reports that may interest regional scientists and policymakers.

Third, SVERIGE is an environmental model. An important premise of the model is that non-production, non-point, household consumption activities generate many unsafe emissions such as heavy metals, carbon monoxide, and sewage. This orientation arose for both empirical and practical reasons. The empirical justification is that if current trends are continued into the future, consumer generated pollution will make up a substantial proportion of overall pollution levels. This is expected to occur because point pollution is technologically and financially easier to reduce than non-point emissions (Tietenberg 1988). There are also practical reasons for not extending the model to production point emissions sources, because to develop modules that explain large firm behaviour would introduce unmanageable complexity and require proprietary firm-level data that are unavailable to the project.

3.0 Rationale for building a property value module

There are several good reasons to create a property value module for SVERIGE. First, one of the chief motivations of the project is to "... study human driving forces related to environmental change and implement findings into systems models allowing for policy relevant impact analysis . . . [including the areas of] air and water pollution, *land degradation*, climate change, and shortage of land, food, water, energy and minerals, and waste production and circulation" (SMC 1997). Initially, it was thought that "land degradation" could be examined by studying transitions in land use. However, on closer inspection, staff researchers found that reliable data for distinguishing between residential, industrial, commercial, agricultural, and forestry land uses are not available for the whole of Sweden (Abrahamsson 1997). Land use property parcel attributes, on the other hand, are available for most private properties. Together with property sales data for samples obtained from the same sources, it should be is possible to impute property values for every private property parcel in Sweden. Therefore, property values may be the best vehicle to link human driving forces to land use changes.

Second, property value, along with the internal migration, housing, and transportation choice modules, will give the model much of its spatial character. These topics are of interest also because they form the basis of much theoretical and empirical research within regional science. Indeed, a property value module should be easier to construct because of the substantial theoretical and empirical groundwork already laid by regional scientists in the area. Third a property value module is necessary because it will form conceptual and empirical bridges among several other modules of the model, including the housing, migration, and environmental modules, and possibly a wealth module. The ways in which these links are forged are explained in the remainder of this paper. Fourth, property value can be used to determine the pecuniary effects of alternative policies (e.g., infrastructure, education, and environmental policies). Property values are ideal for this purpose because various amenity, accessibility, and economic values are at least partially capitalised into property prices. Therefore, simulations that alter these quantities will concomitantly alter property values as well. This enables one to conduct elementary social cost-benefit analyses and thereby evaluate changes in economic efficiency that result from different policies.

4.0 Types of property markets

Property may be divided into several different categories based on its characteristics. One way to distinguish property is by its functional characteristics. Property is usually an intermediate input for production in manufacturing or farming. However, it is directly consumed by end-users when it is used for residential purposes. Therefore, demand for residential property will be determined by utility rather than profitability considerations. The functionality of land may further be differentiated by the nature of the productive activity occurring there. For instance, a property can be used to farm crops, harvest timber, exploit for minerals, produce manufactured goods, or to house and sell goods and provide services; these different productive activities utilise property characteristics in different ways. For instance, soil fertility is important to farmers, while the quality and quantity of underground deposits are important to mining companies. Property may also be distinguished by owner characteristics. A property may be occupied by its owner, leased or rented, publicly owned, or have quasi-public ownership. Categorisation may also be made on the basis of government zoning ordinances, which serve to restrict property uses in order to limit land use fragmentation and control spatial externalities. Finally, property markets may be distinguished by region because there exist distinct regional nodes around which economic activity organises, and these nodes are surrounded by boundaries which limit the feasibility of productively utilising property beyond these limits. Each of these characteristics, functionality, owner, government regulation, and region play a role in defining distinct property markets.

On the basis of these characteristics, it is possible to distinguish markets that would be pertinent to analytical and empirical work regarding property values. However, the Swedish Tax Office has constructed its own property classification system with categories that correspond to its own internal property assessment formulas. The following categories (also listed in figure 3) are distinguished: (1) Single family homes, (2) Apartment buildings, (3) Agriculture, including fields, pasture, and buildings, (4) Forest, (4) Industry, including commercial and manufacturing, (5) Utilities, (6) Special properties, including nursing homes, sports facilities, schools, churches, communication, and defence installations, (7) Vacant land, and (8) Other (Lantmäteriverket 1997). This information is collected from comprehensive surveys that are administered to property owners every six years.

For each of these property types, the Swedish Land Survey (Lantmäteriverket) has collected a different array of property attributes, based on property assessment formula data input needs (Lantmäteriverket 1996). For instance, attributes collected to evaluate forestland include quality of forest, total wood stock, percentage of wood stock that is hardwood, percentage of wood stock that is softwood, and percentage of trees that is large. Farm attributes include field drainage, type of farm building, and size of farm building. Industrial buildings are assessed on the basis of two competing formulas, one that relies on a production cost method and another that utilises a profit method. The former formula uses new building cost and replacement cost, while the latter uses quality and area of inventory, office, and production facilities. By far the most detailed property information is available for single family homes. Information concerning property access to water and sewerage, proximity to beach, exterior house characteristics, interior characteristics, energy efficiency, kitchen quality, bathroom and sanitation facility characteristics, amount of living area, and year of construction are available. Several property attributes are common to each property category, including property location co-ordinates and property area.

The existence of distinct property markets calls for a variety of modelling approaches. However, the focus of this paper is on the values of family homes, in part because of the importance this market plays in the Swedish economy. Almost half of Swedish residential dwelling units are single or double family homes and housing wealth accounts for approximately two-thirds of aggregate wealth (Swedish Institute 1996; Englund, et al. 1995). In addition, private housing markets are interesting from a theoretical and methodological standpoint because housing is a very differentiated product that defies standard microeconomic modelling.

5.0 Hedonic price theory and estimation issues

Basic microeconomic theory assumes that goods are homogeneous, but sometimes they are not. Automobiles are the classic example. In urban and regional analysis housing is the closest equivalent. Houses and apartment dwellings differ in dwelling characteristics, location, and other ways that are important to consumers. Houses have numerous characteristics, and, furthermore, the myriad ways in which these innumerable characteristics can be combined assures that no two houses will be exactly the same. This situation cannot be depicted using ordinary microeconomic theory because complete heterogeneity means that there is not a single market for n homogenous houses but rather j implicit markets, one for each characteristic. However, by making some additional rigid assumptions regarding consumer and producer behaviour, hedonic price theory shows that one can disentangle or impute the implicit market-clearing prices of the individual characteristics (Rosen 1974, Freeman 1979; Sheppard 1997). The simple procedure is to regress market property price (P) on those features (z_1, z_2, . . .z_m) that differentiate the properties:

(1) $$P_i = F(z_{i1}, z_{i2}, ..., z_{im}) \quad i=1, 2, \ldots, n.$$

Since hedonic theory is used primarily for residential property market analysis, this section will focus only on those features that typically distinguish residential properties. For organisational purposes, it may be useful to distinguish several categories (figure 4) of residential property characteristics: (1) dwelling factors – characteristics of the house itself, (2) land factors – characteristics of the lot on which the structure is built, (3) neighbourhood factors – characteristics of the structures, land, and residents in the vicinity of a particular residential property, (4) public policy factors – instruments of public policy such as zoning laws, public expenditures, and taxes that affect local property markets. A final category, regional factors, describes characteristics of a region, metropolitan area, or municipality that may affect property values. These factors are sometimes thought of as regional amenity characteristics but are also represented as equivalent to variables from a reduced form equation for aggregate supply and demand for homogenous housing (Wigren 1987; Turner 1995). They are invoked to explain intermetropolitan differences in levels of housing prices.

In order to study the variable specification issue further, a sample of fourteen representative hedonic price studies were collected and the housing characteristics utilised in each study were tallied into the aforementioned categories.[1] These articles are based on studies of American, Swedish, and British residential property markets. Figure 5 below shows the eight most frequently used variables in the sampled studies. The figure shows that dwelling factors are the most common, with age and size of the structure appearing in most studies. Next common was lot size, a land characteristic. Dwelling characteristics, such as garage and exterior finish, as well as neighbourhood and public policy features, ethnic composition and educational quality, were cited by half of the sampled studies. Regional characteristics are relatively uncommon because most hedonic studies focus on only one residential property market.

Proper variable specification is always an issue in assessing hedonic analyses. Stahl (1985) discusses the difficulty of accurately measuring all of the dimensions used by consumers in making their choices, particularly dwelling characteristics such as layout or architectural style. Sheppard (1997) argues that dwelling characteristics have been overemphasised while locational and neighbourhood factors have been neglected. In fact, the literature collated here does not appear to support either assertion. Architectural features have been introduced as categorical variables in several studies, and locational features are not uncommon in recent studies. Furthermore, the features chosen by any hedonic study will invariably be affected by the nature of the market being studied. For instance, studies of residential markets in which certain features are "standard" should not include these features since they will add little additional information and possibly create collinearity problems. In some areas, major structural characteristics (e.g., age, size, lot area) may capture most of the variation in property prices, while in others minor characteristics (e.g., porches, decks) may play a more important role (Palmquist et al. 1995). As Palmquist, et al. (1995) argue the attributes to include "depends on the market." Therefore, whether a particular dwelling or locational feature is important or not should be decided a priori but rather on a study-by-study basis.

Functional form is another important consideration, though perhaps not as urgent as proper variable specification (Sheppard 1997). The early hedonic literature employed primarily linear regression equations, but this specification has certain conceptual, practical, and econometric drawbacks. The conceptual problem is that a linear equation assumes that the marginal willingness to pay for any characteristic is the same. Yet, diminishing marginal utility is a more accurate depiction of consumer behaviour. This characterisation calls for a non-linear functional form such as the log linear or semi-log specifications. The practical problem is that hedonic price equations generate price data for estimating individual property attribute demand equations only when the hedonic price equation is non-linear (Rosen 1974; Palmquist 1984). If a linear functional form is chosen, the implicit prices are the coefficient estimates themselves and hence will not vary with different quantities demanded of the attribute. The econometric problem arises from the frequent occurrence of heteroscedacity in regression. This problem is ultimately a specification issue, but one that cannot be resolved easily with the limited data available for most hedonic studies. Therefore, variable reweighting schemes or, in some instances, selecting a log linear functional form (to reduce the error variance) are the best approaches to improving the efficiency of the parameter estimates (Cobb 1984). Increasingly, researchers have resolved the functional specification question by choosing flexible functional forms utilising the Box-Cox-Jenkins technique.

Another problem in econometric estimation arises because of the difficulty in identifying proper markets for analysis. Property markets can be "stratified" in different ways, including by region, by clusters of individuals with similar demographic and socioeconomic characteristics, and by time (Cobb 1984). Stratification implies that there is a lack of mobility between the various levels because of distance impedance, institutional constraints, or differences in demand-supply parameters. Thus, one cannot assume that hedonic price equation parameters will be homogenous across space and time. One way to acknowledge this possibility is to estimate separate equations for the various groups, using variable specifications tailored to the conditions of each individual market (for an example see Nelson (1981)). Another way is to incorporate dummy variables that represent the various strata and introduce interaction terms for those variables where coefficient estimates are thought to be particularly sensitive to stratification (for examples see Gamble and Downing (1982), Cobb (1984), Wigren (1984), Palmquist et al. (1995), and Geoghegan et al. (1997)). A third approach is to identify those factors that differentiate the markets and introduce them as correcting variables in the hedonic regression (for examples see Wigren 1987 and Turner 1987).

6.0 Data

The data used here are derived from two sources. Property prices and information about property features are obtained from the Swedish Land Survey's property register for 1995. The register contains information for all property sales in a given year, including: the buyer, seller, co-ordinates of the property, and sales price. In addition, for each property, certain lot features are described, such as access to central water and sewer, proximity to waterfront, and lot size. Additional features of the family home itself are also available, including quality evaluations for the exterior, interior, energy systems, kitchen, and sanitation facilities, type of house, number of floors, presence of basement, and date of renovation or addition. There are approximately 50,000 private home sales in the register for the study year. However, several thousand sales were deleted when the sales price deviated from the assessed value by an exceptionally large margin.

Data concerning economic, demographic, and housing features of various geographical units were obtained from a Statistics Sweden micro database housed at the Spatial Modelling Centre in Kiruna. The database identifies the location of individuals, workplaces, and housing with geographical co-ordinates measured at a resolution of 100 m^2, making it possible to aggregate individuals into user-specified regional boundaries. Two regional units are used here: labour market regions and neighbourhoods. Sweden is divided into 108 separate labour market areas (also known as "LA regions") according to 1990 definitions developed by Statistics Sweden. The labour market boundaries crudely represent maximum commuting distances for residents to the center of the labour market and for the purposes of this analysis are assumed to roughly approximate regional residential markets also. Neighbourhoods are defined as kilometre squares. A grid of neighbourhood squares is imposed on the built-up areas of Sweden, ensuring that each house is associated with a unique neighbourhood. Aggregate demographic, economic, and housing characteristics are computed from the micro database on the basis of these boundaries.

Variables used in the empirical section and their definitions are listed in table 1. They are 1995 figures unless otherwise indicated in the table. Several categories of attributes are listed here, including individual dwelling attributes, land attributes, neighbourhood characteristics, and labour market features. The regional wage rate is included as a regional level indicator that can represent aggregate demand, cost-of-living, or regional socio-economic amenities. The other variables are features of the individual property and its immediate surroundings. The expected sign of each attribute is listed in the right hand margin. New houses (**AGE1**) are expected to have higher values. However, the signs for **AGE2** and **AGE3**, used to represent intermediate aged housing, are hypothesised to be negative because previous studies have found vintage effects in the Swedish housing market (Wigren 1984, 1987). The remaining coefficients are hypothesised to have the same signs as those found in the mainly American studies cited earlier.

Table 2. shows the average values for each of the study variables. The table shows that the average Swedish house sold for 661,000 SEK in 1995 (approximately $82,000). Most homes are less than 35 years of age, single family homes, and single story. They contain, on average, approximately 120 m^2 of living space and 42 m^2 of additional space. There is substantial variation in housing prices among the municipalities (see figure 6). The highest prices are observed in the South and coastal areas of Sweden, which are more urban and industrialised, but prices are lowest in the rural interior and northern municipalities. The ratio of highest municipal price to lowest is over 4:1.

7.0 Exploratory analysis of single family home values

Several competing hedonic price equations were estimated for Sweden in order to test for the sensitivity of the results to specification, functional form, and regional disaggregation. The first is a full linear model, including each of the variables listed in table 1. The second is a linear model with 107 regional labour market dummies to represent unspecified individual labour market features. The third through fifth are linear regression equations with determinants grouped into (1) dwelling and land, (2) neighbourhood, and (3) labour market area categories. The sixth and seventh are log linear and semi-log functional forms. The remaining regressions use the basic linear model for each labour market area.

Table 2. below lists the results for a full linear model. Most of the coefficients have the anticipated signs. For instance, newer homes have higher values than older homes, with the exception that homes older than sixty years apparently exhibit vintage effects that make them more valuable than homes built during the 1940s-1970s. Housing space (**YTABOST** and **YTABI**) and lot space (**AREALTMT**) have positive implicit prices as do four of the dwelling quality indicators (**STDENG**, **STDINT**, **STDKOK**, and **STDSAN**). Also positive are the coefficients for dummy variables indicating single family homes (**SINGLE**), freestanding homes (**FREE**), and linked homes (**LINK**), as well as neighbourhood characteristics such as population density (**POP**), average earnings (**AVGEAR**), and percentage college educated (**PED**). Percentage immigrant (**PIMM**) has the expected negative sign. The coefficient on labour market earnings (**PROPE**) is positive, which is consistent with it representing regional amenities, differences in regional demand or cost-of-living differences. Several variables have signs that depart from the values found in international hedonic studies. For instance, dummy variables for two story dwellings (**TWOFLOOR**), dwellings with basements (**BASEMENT**), and dwellings with central water and sewer access (**WATSEW**) are negative. Neighbourhood quality indicators, reflecting the age (**PHNEW**) and tenure (**PHSMA**) characteristics of area housing, do not have the anticipated positive coefficients, perhaps because of the prevalence of mixed housing development in Sweden, the presence of strong vintage effects for some older housing, and possibly weaker class-based differences in housing tenure patterns than are found in the United States.

In order to check the robustness of the results and explore the possibility that additional regional variables were excluded, two spatial explorations were conducted. First, residuals from the linear regression were computed and averaged for each Swedish municipality. These averages are plotted in figure 7. The map shows two distinct spatial clusters, the first is primarily urbanised municipalities in southern Sweden and the second is relatively sparsely populated municipalities in the central interior. It is difficult to identify any features that these areas share in common.

The second method consists of replacing the **PROPE** residential market indicator with regional dummy variables that represent each of the labour market regions (less one baseline region--the northernmost Kiruna labour market region). Table 3, column (b) shows the results of this regression, excluding the parameter estimates for the regional dummy variables. All but a handful of the parameter results maintain the same sign, magnitude, and statistical significance. Exceptions are renovation year (**ADDYR**), central water and sewer (**WATSEW**), and dwelling energy efficiency (**STDENG**), each of which becomes statistically insignificant. In addition, waterfront proximity (**BEACH**) and neighbourhood ethnic composition (**PIMM**) become positive and statistically significant.

Figure 8 maps the labour market regions that have both statistically significant positive and negative dummy variable coefficients. Positive coefficients are obtained for the largest labour market regions in the country, including those centered on the cities of Stockholm, Malmö, and Göteborg as well as Linköping in the South and Umeå in the north. But urbanisation is not the only distinguishing factor because positive coefficients are also obtained for an area in mid central Sweden and the Island of Gotland (along the southern coast). In addition, several fairly urbanised labour market regions in southern Sweden exhibit negative coefficient values. When viewed side by side, figures 7 and 8 suggest that the explanatory power of the basic linear model might be improved somewhat by identifying structural demand determinants that are present in the industrialised southern rim. However, the exact nature of these underlying determinants is open to speculation.

Table 4. shows regression results when the variables are divided into three separate categories: (1) dwelling and land attributes, (2) neighbourhood characteristics, and (3) regional (i.e., labour market) features. It shows that the seven neighbourhood characteristics have the most explanatory power, followed by the individual housing attributes. The housing attribute equation differs in a few ways from the general linear equation; for instance **BASEMENT** and **TWOFLOOR** are now positive while dwelling quality indicators **STDENG** and **STDINT** are negative.

Table 5. reports the results of log-linear and semi-log regression models. Logged variables are indicated by an “L” before the usual variable label. The results are reasonably robust to these alternative specifications. For the log linear model, a handful of variables switch signs. **AGE2, BASEMENT,** and **LPHNEW** now have positive and statistically significant coefficients. **YTABI** and **STDEXT** go from being not statistically significant to positive and statistically significant. For the semi-log regression, **BASEMENT**, **TWOFLOOR**, and **WATSEW**, which had unexpectedly negative and statistically significant signs before, are now statistically significant. In addition, **LPHNEW** is now both positive and statistically significant. While the semi-log form has lower explanatory power than the linear model, the log-linear model is higher. Judging by this criterion alone, the log-linear model would be preferred.

Table 6. summarises the results for the basic linear model when it is estimated for each of seventy-five labour market areas having a sufficient number of observations. The table reports the average value for each parameter, its standard deviation, and range. The basic linear equation estimated using all of the data from table 2. is reported again in the right column for comparison purposes. Two points are worth making. First, not surprisingly, most of the coefficients (all but four of the twenty-eight) have the same signs as the equation estimated using all of the data. Second, there is enormous variation in parameter estimates among the individual equations. Indeed, only living space (**YTABOST**) has a mean coefficient value that is more than 1 ½ times the value of its standard deviation. These results suggest that there is marked variation in the regional results and that it is difficult to impute hedonic prices for the individual markets in Sweden by using a single national equation

The results obtained here offer some additional insight into the issues discussed in section 5.0. First, the results are relatively robust to alternative functional forms and specification. Based on explanatory power alone, one would conclude that the log-linear model provides the best model. This conclusion would be consistent with the findings of other recent hedonic price studies of the housing market. Second, among the different single family housing attributes, neighbourhood and secondly regional attributes have more explanatory power than dwelling and land attributes. Therefore, it would appear that Sheppard (1997) is correct in observing that failure to include neighbourhood attributes may severely undermine the validity of hedonic studies. Third, the results vary considerably from residential market to residential market in a way that calls into question the usefulness of a national hedonic regression equation, even when an effort is made to control for regional level variation. Housing attributes appear to be traded off in individual markets in a very heterogeneous manner.

8.0 Property value and the microsimulation model

Property value should be modelled in a way that is consistent with the microsimulation model's basic structure. Therefore, the module should consist of a reduced form equation (or series of reduced form equations) that relies on input data generated by the demographic core and spatial extensions. Based on the previous sections, it is clear that a property value equation can draw on the model in several different ways (see figure 9). First, neighbourhood characteristics are important determinants of property values. If internal migration and life-cycle processes alter the demographic and economic character of neighbourhoods (e.g., age, income, ethnicity, educational levels), this will have a concomitant effect on property values. Second, population growth and mobility mean that nearby population centres can grow or shrink and that the local distribution of population will change. These changes would alter property values by affecting neighbourhood density, accessibility to population centres, and labour market characteristics.

With modules currently under development, however, the list of causal variables will grow. For instance, the development of an environmental pollution module (which describes relationships among lifecycle, consumption activities, and pollution) will create another path through which property values can be affected. A housing module that simulates housing construction and depreciation would alter the built-up characteristics of residential property and affect property values as well.[2]

Property values might be endogenized within SVERIGE by creating a personal wealth module.[3] Housing equity makes up a substantial part of the Swedish household wealth portfolio. Therefore, when housing equity increases through accumulation, improvements, and appreciation, it will increase overall household wealth. Economic theory suggests that household wealth, in turn, should play an important role in several core modules used here, including labour force participation, education, and fertility decisions. Therefore, property values could be completely endogenized within SVERIGE through its effect on life cycle decisions.

9.0 Conclusions, issues, and further work

The hedonic equation approach described here is one way to obtain property value estimates for single family homes. However, it is obviously in the formative stage and suffers from a number of theoretical, empirical, and practical shortcomings. First, the specification and underlying theoretical justification for using hedonic price equations to describe residential property market prices is a bit nebulous. Hedonic price theory has been used as a way of imputing market equilibrium prices for various non-tradeable features of heterogeneous goods. The earliest applications were concerned with heterogeneous goods such as automobiles, but, housing is a distinctly different type of heterogeneous good because it is locationally fixed and has characteristics (e.g., environmental and amenity attributes) that are available only in certain localities. Automobile markets are not geographically constrained in the same way. It is not clear if using selected regional housing market "reduced form" indicators, incorporating regional dummy variables, or dividing the national market into regions and conducting multiple regressions is the best way to represent these geographical differences. In addition, since hedonic price theory attempts to impute equilibrium implicit prices, it may not be an appropriate framework to draw on for a dynamic forecasting model in which regional housing supplies and demands are likely to adjust and change along with their underlying determinants (i.e., regional economic and demographic variables). Second, there are inconsistencies in the empirical estimates as discussed in section 7.0 that need to be explored more fully. Regression parameter estimates are very sensitive to regional disaggregation and it is important to know what causes these varied results.

Aside from these problems, the property value module is still very incomplete because of the need for additional data and the sequential manner in which various modules are being introduced into the SVERIGE model. Single family homes are only one type of residential land use. Furthermore, residential land uses are only one of several competing alternative land uses. The task remains to model these remaining land uses and to do so in a fashion that allows the land uses themselves to change in response to competing valuations. Unfortunately, only the demographic core modules of the SVERIGE microsimulation model are currently operational. Therefore, even if a working property value module were available, the model could generate only certain neighbourhood and regional variables for the module. Eventually, however, environmental, housing, and property value modules will create a richer and more realistic microsimulation model.

Endnotes

[1] Studies included Bender and Hwang (1985), Berger, et al. (1988), Benson, et al. (1998), Cobb (1984), Cheshire and Sheppard (1995), Gamble and Downing (1982), Geoghegan, et al. (1997), Harrison and Rubinfeld (1978), Izraeli (1987), Nelson (1981), Palmquist (1984), Palmquist et al (1995), Tiwari and Turner (1998), and Wigren (1984).

[2] See Oskamp (1997) for an example of a housing microsimulation model.

[3] The property value hedonic equations could make an indirect contribution to the microsimulation model by providing prices for various attributes of property, such as the age, size, and space of a residential dwelling. These “implicit prices,” as they are called, could be utilised as input data for estimating housing attribute demand equations in a fashion described in Rosen (1974) and Linneman (1982).

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Table 1. List of variables, definitions, and expected signs

Variable	Definition	Expected sign
Dependent variable		
KOPSUM	Purchase price (1,000s of SEK)	--
Dwelling attributes (D)		
AGE1	House age between 1 and 15 years (1=Yes, 0=No)	(+)
AGE2	House age between 16 and 35 years (1=Yes, 0=No)	(–)
AGE3	House age between 36 and 60 years (1=Yes, 0=No)	(–)
ADDYR	Years since addition/renovation	(–)
BASEMENT	Presence of basement (1=Yes, 0=No)	(+)
TWOFLOOR	Two story dwelling (1=Yes, 0=No)	(+)
SINGLE	Single family dwelling (1=Yes, 0=No)	(+)
FREE	Freestanding dwelling (1=Yes, 0=No)	(+)
LINK	Linked building (1=Yes, 0=No)	
YTABOST	Size of living area (square meters)	(+)
YTABI	Size of storage area (square meters)	(+)
STDEXT	Quality index for house exterior	(+)
STDENG	Quality index for house energy efficiency	(+)
STDINT	Quality index for house interior	(+)
STDKOK	Quality index for house kitchen	(+)
STDSAN	Quality index for house bathrooms and sanitary facilities	(+)
Land attributes (L)		
AREALTMT	Lot size (square meters)	(+)
BEACH	Proximity to waterfront (1=Yes, 0=No)	(+)
DISTANCE	Distance to population centroid of labour market region (kilometers)	(–)
WATSEW	Access to central water and sewer (1=Yes, 0=No)	(+)
Neighbourhood attributes (N)		
AGEVAR	Average age of residents	
POP	Population density (residents per square kilometer)	(+)
AVGEAR	Average individual earnings (100s of SEK)	(+)
PIMM	Proportion of residents who are immigrants*	(+)
PED	Proportion of residents over 25 years of age with University education	(+)
PHSMA	Proportion of dwelling units that are family homes, 1990	(+)
PHNEW	Proportion of dwellings that are 15 years of age or less, 1990	(+)
Region attributes (R)		
RROPE	Average individual earnings (100s of SEK)	(+)

*Immigrants from countries other than Western Europe and North America.

Table 2. Descriptive Statistics

Variable	Mean	Std Dev	Minimum	Maximum
KOPSUM	662	459	35	16000
AGE1	0.130	0.336	0	1
AGE2	0.387	0.487	0	1
AGE3	0.232	0.422	0	1
ADDYR	37.621	24.951	3	396
BASEMENT	0.319	0.466	0	1
TWOFLOOR	0.139	0.346	0	1
SINGLE	0.941	0.235	0	1
FREE	0.787	0.409	0	1
LINK	0.095	0.294	0	1
YTABOST	119.479	41.110	0	1100
YTABI	42.389	42.744	0	1100
STDENG	7.102	1.376	0	14
STDEXT	5.309	1.933	0	14
STDINT	1.537	1.558	0	9
STDKOK	6.251	2.556	0	16
STDSAN	7.438	2.112	0	17
AREALTMT	1493.32	2943.55	1	260086
BEACH	0.031	0.174	0	1
DISTANCE	17.619	13.929	0.091	138.110
WATSEW	0.796	0.403	0	1
AVGEAR	1474	292	2	5991
PIMM	0.051	0.039	0	1
PED	0.217	0.129	0	1
PHSMA	0.659	0.191	0	1
PHNEW	0.211	0.163	0	1
PROPE	1447	134	1075	1696

Table 3. Results for linear model and regional dummy variable model

Variable	(a) Full linear model Parameter Estimate	t	(b) Dummy variables Parameter Estimate	t
INTERCEPT	-1847.090	-64.241***	-880.833	-23.439***
AGE1	104.997	20.658***	102.722	20.635***
AGE2	-20.733	-4.682***	-16.736	-3.854***
AGE3	-31.384	-7.451***	-27.046	-6.553***
ADDYR	-0.004	-1.746*	-0.002	-0.652
BASEMENT	-7.711	-1.977**	-10.422	-2.738***
TWOFLOOR	-29.940	-6.350***	-25.825	-5.606***
SINGLE	91.323	11.950***	87.249	11.697***
FREE	127.402	22.036***	139.060	24.607***
LINK	43.814	6.820***	52.029	8.296***
YTABOST	3.440	79.352***	3.455	81.553***
YTABI	0.313	7.052***	0.380	8.775***
STDENG	1.931	1.693*	1.664	1.498
STDEXT	1.302	1.624	2.641	3.356***
STDINT	33.300	32.370***	31.580	31.385***
STDKOK	8.629	12.318***	8.606	12.606***
STDSAN	7.924	9.267***	8.452	10.137***
AREALTMT	0.007	13.251***	0.007	14.733***
BEACH	303.715	38.433***	314.729	40.783***
DISTANCE	-1.959	-16.787***	-3.330	-25.631***
WATSEW	-16.605	-3.887***	1.736	0.413
AGEVAR	6.984	24.776***	7.223	25.881***
POP	0.001	7.989***	0.001	2.971***
AVGEAR	0.253	33.519***	0.249	33.591***
PIMM	-401.452	-9.970***	227.548	3.053***
PED	966.428	62.059***	841.237	52.766***
PHSMA	-279.947	-28.768***	-273.192	-28.084***
PHNEW	13.465	1.337	7.282	0.735
PROPE	0.755	51.642***	--	--
R^2	.618		.640	

*** α=.01, ** α=.05, * α=.10

Table 4. Results for nested models

Variable	(a) PROPERTY Parameter Estimate	t	(b) NEIGHBORHOOD Parameter Estimate	t	(c) LABOUR MARKET Parameter Estimate	t
INTERCEPT	-141.540	-7.649***	-163.106	-8.509***	-1635.180	-79.607***
AGE1	108.796	16.820***	--	--	--	--
AGE2	-43.456	-7.653***	--	--	--	--
AGE3	-27.883	-5.079***	--	--	--	--
ADDYR	-0.022	-6.742***	--	--	--	--
BASEMENT	17.061	3.356***	--	--	--	--
TWOFLOOR	27.642	4.506***	--	--	--	--
SINGLE	173.606	17.457***	--	--	--	--
FREE	-33.364	-4.543***	--	--	--	--
LINK	6.480	0.773	--	--	--	--
YTABOST	4.227	75.953***	--	--	--	--
YTABI	-0.017	-0.293	--	--	--	--
STDENG	-7.007	-4.722***	--	--	--	--
STDEXT	-12.220	-11.743***	--	--	--	--
STDINT	58.060	43.764***	--	--	--	--
STDKOK	13.441	14.738***	--	--	--	--
STDSAN	14.519	13.041***	--	--	--	--
AREALTMT	0.002	3.508***	--	--	--	--
BEACH	353.432	34.787***	--	--	--	--
DISTANCE	-3.704	-27.341***	--	--	--	--
WATSEW	104.536	19.833***	--	--	--	--
AGEVAR	--	--	4.925	14.988***	--	--
POP	--	--	0.001	1.915*	--	--
AVGEAR	--	--	0.473	60.158***	--	--
PIMM	--	--	-657.100	-14.727***	--	--
PED	--	--	1216.286	65.538***	--	--
PHSMA	--	--	-446.848	-38.927***	--	--
PHNEW	--	--	13.526	1.159	--	--
PROPE	--	--	--	--	1.587	112.306***
R^2	0.344		0.403		0.216	

*** α=.01, ** α=.05, * α=.10

Table 5. Results for non-linear models

Variable	(a) Log-linear model Parameter Estimate	t	(b) Semi-log model Parameter Estimate	t
INTERCEPT	-15.061	-81.075***	-15957.000	-97.992***
AGE1	0.228	35.086***	91.781	16.114***
AGE2	0.101	17.845***	-27.393	-5.522***
AGE3	-0.023	-4.269***	-47.330	-10.148***
ADDYR	-0.001	-8.842***	-0.006	-2.245***
BASEMENT	0.016	3.571***	-2.750	-0.680
TWOFLOOR	-0.019	-3.159***	8.359	1.611
SINGLE	0.122	12.632***	86.672	10.219***
FREE	0.047	5.578***	63.494	8.671***
LINK	0.023	2.807***	19.326	2.660***
LYTABOST	0.454	67.414***	373.846	63.320***
LYTABI	0.001	0.257	1.954	1.935*
LSTDENG	0.105	9.876***	19.038	2.043**
LSTDEXT	0.064	13.598***	2.425	0.580
LSTDINT	0.102	33.230***	86.957	32.171***
LSTDKOK	0.092	18.939***	42.992	10.104***
LSTDSAN	0.181	22.132***	110.213	15.407***
LAREALTMT	0.066	18.548***	60.678	19.587***
BEACH	0.281	28.025***	333.323	37.884***
LDISTANCE	-0.080	-34.791***	-50.450	-25.144***
WATSEW	-0.061	-9.047***	-8.328	-1.406
LAGEVAR	0.234	18.034***	274.980	24.171***
LPOP	0.034	17.628***	5.031	2.978***
LAVGEAR	0.253	25.143***	286.912	32.473***
LPIMM	-0.021	-8.274***	-33.491	-14.772***
LPED	0.184	61.257***	118.231	44.849***
LPHSMA	-0.175	-33.044***	-122.800	-26.486***
LPHNEW	0.023	9.850***	5.964	2.854***
LPROPE	2.080	83.985***	1528.707	70.424***
R^2	.653		.541	

*** α=.01, ** α=.05, * α=.10

Table 6. Results for labour markets

Variable	Mean	Std Dev	Minimum	Maximum	Full linear model Estimate	t
INTERCEPT	-290.604	305.797	-1380.53	419.398	-1847.090	-64.241***
AGE1	140.229	119.533	-106.489	951.851	104.997	20.658***
AGE2	54.207	63.990	-244.157	198.725	-20.733	-4.682***
AGE3	-0.501	46.839	-198.656	160.488	-31.384	-7.451***
ADDYR	-0.006	0.025	-0.063	0.051	-0.004	-1.746*
BASEMENT	-5.543	32.590	-65.232	113.282	-7.711	-1.977**
TWOFLOOR	-16.821	75.078	-522.176	220.727	-29.940	-6.350***
SINGLE	28.466	164.932	-1143.84	298.049	91.323	11.950***
FREE	60.523	71.542	-186.721	196.826	127.402	22.036***
LINK	21.623	83.897	-296.882	241.005	43.814	6.820***
YTABOST	1.859	0.966	-0.680	7.023	3.440	79.352***
YTABI	0.223	0.396	-0.633	1.292	0.313	7.052***
STDENG	5.878	12.334	-25.583	37.635	1.931	1.693*
STDEXT	5.457	6.665	-17.414	23.777	1.302	1.624
STDINT	16.754	14.335	-35.631	51.128	33.300	32.370***
STDKOK	9.910	6.123	-6.275	26.718	8.629	12.318***
STDSAN	9.801	6.698	-14.679	28.965	7.924	9.267***
AREALTMT	0.008	0.013	-0.033	0.056	0.007	13.251***
BEACH	151.199	181.428	-108.358	776.937	303.715	38.433***
DISTANCE	-5.131	4.771	-19.029	7.678	-1.959	-6.787***
WATSEW	6.203	60.063	-236.250	282.498	-16.605	-3.887***
AGEVAR	3.406	4.570	-5.253	27.096	6.984	24.776***
POP	0.003	0.004	-0.012	0.016	0.001	7.989***
AVGEAR	0.040	0.113	-0.213	0.549	0.253	33.519***
PIMM	1804.89	8166.72	-8401.87	63647.94	-401.452	-9.970***
PED	424.982	326.697	-747.577	1128.91	966.428	62.059***
PHSMA	-80.523	152.660	-692.998	370.762	279.947	-28.768***
PHNEW	41.084	144.486	-386.529	513.566	13.465	1.337

*** α=.01, ** α=.05, * α=.10

Figure 1. The Sverige Model

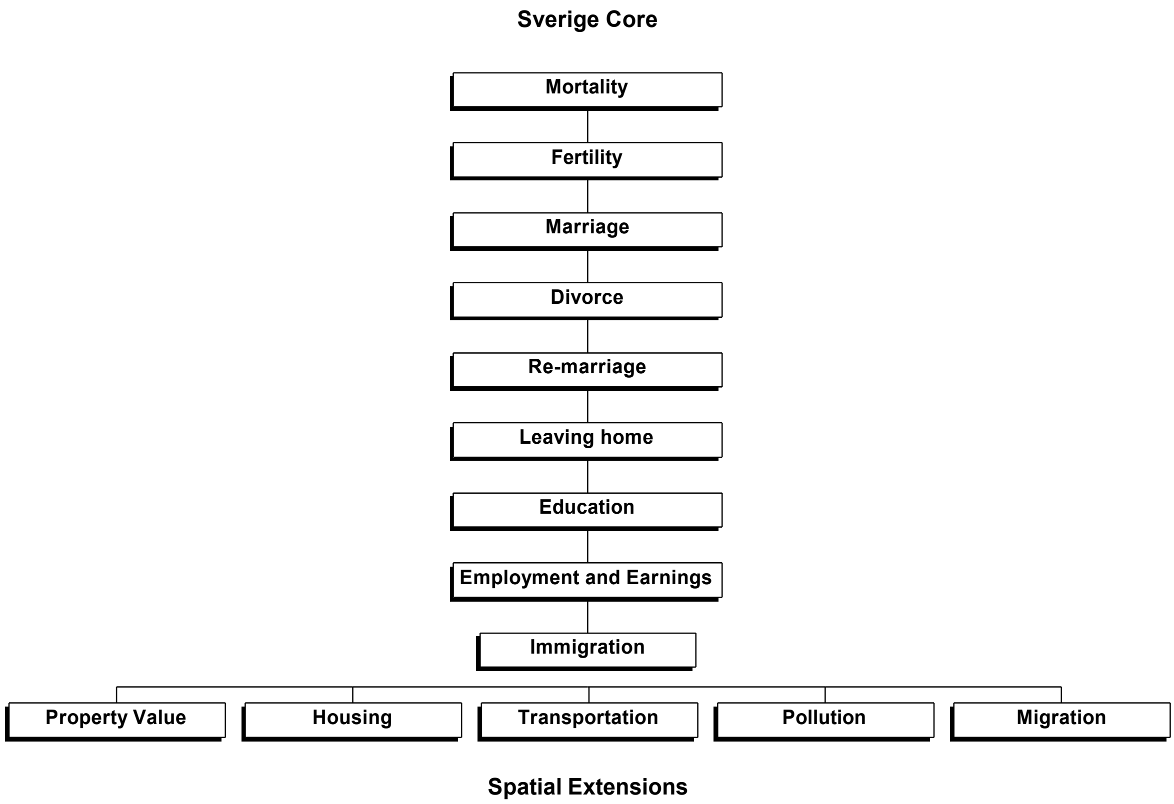


Figure 2. Relations between objects and attributes

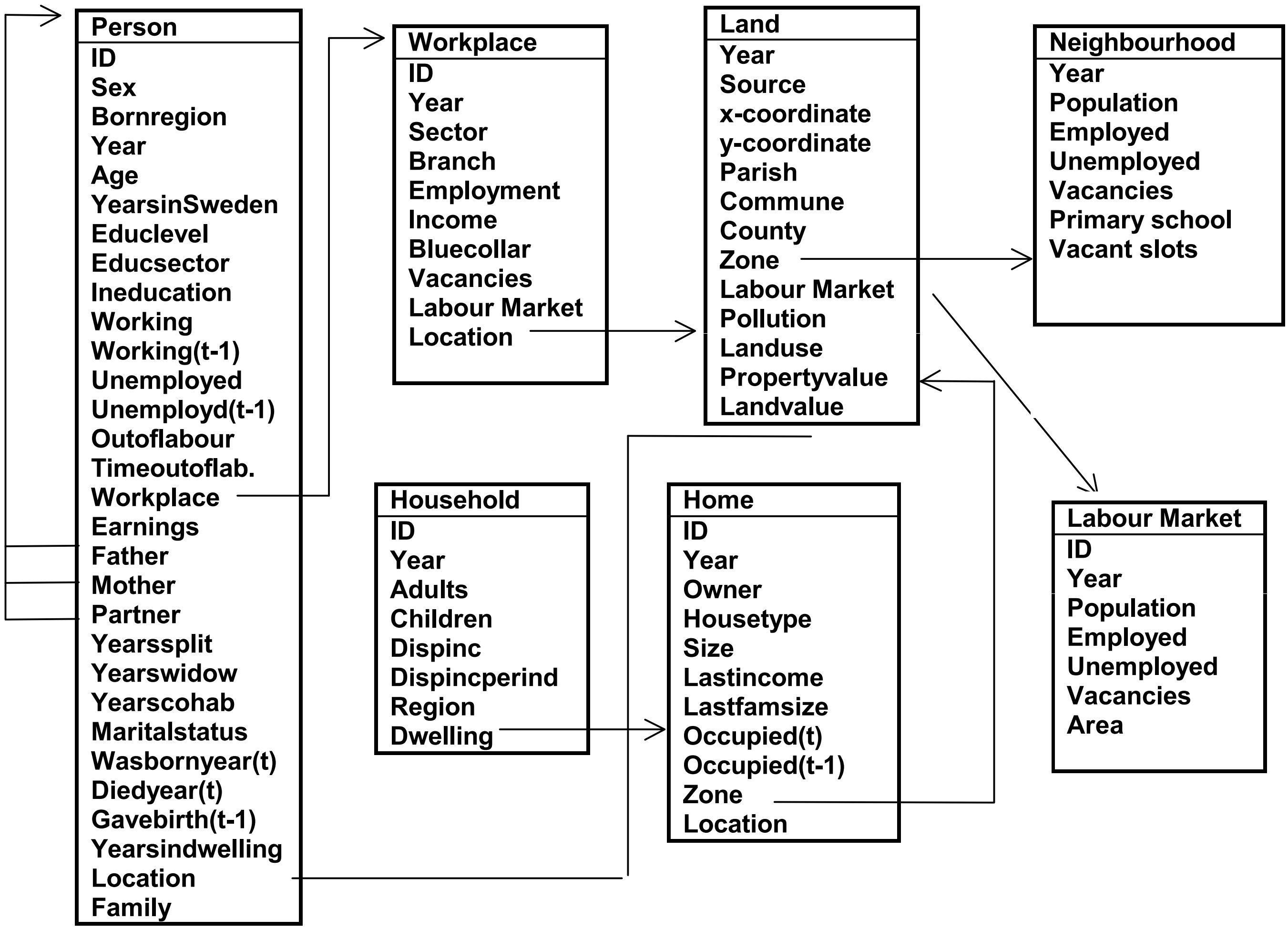


Figure 3. Property data land use categories.

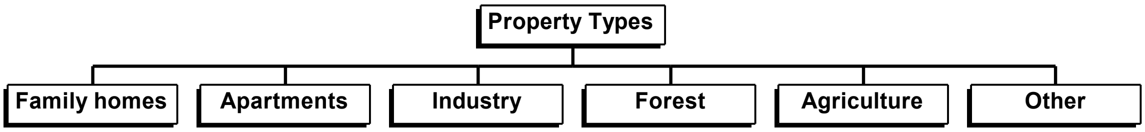


Figure 4. Residential property value determinants

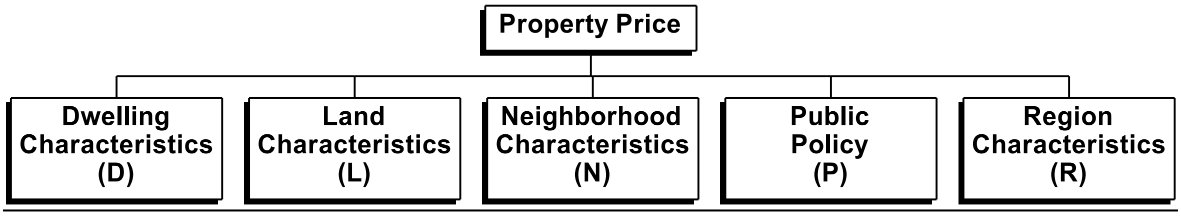


Figure 5. Property characteristics, frequency of occurrence

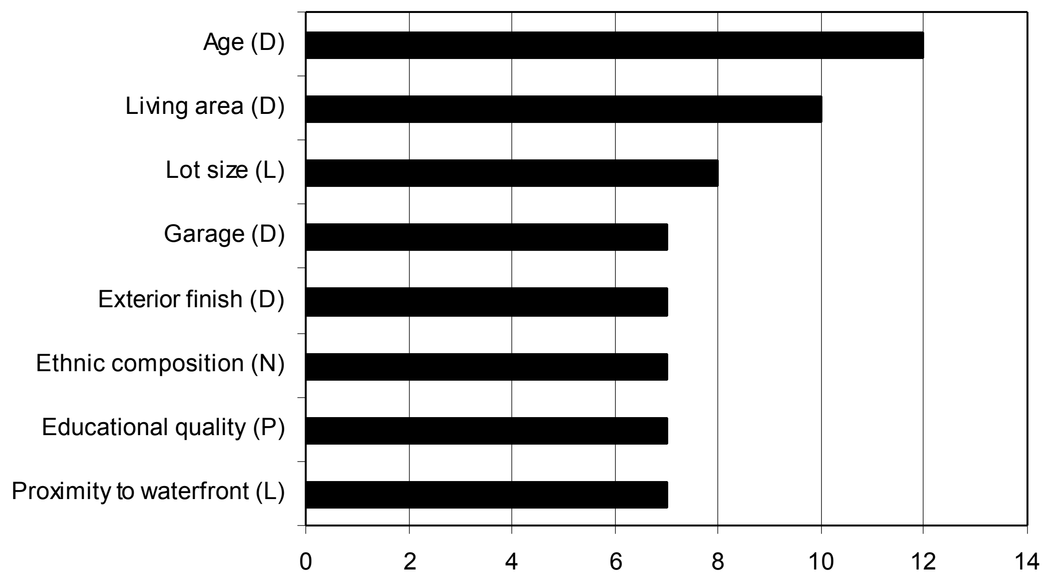


Figure 6. Residential Property Values, 1995

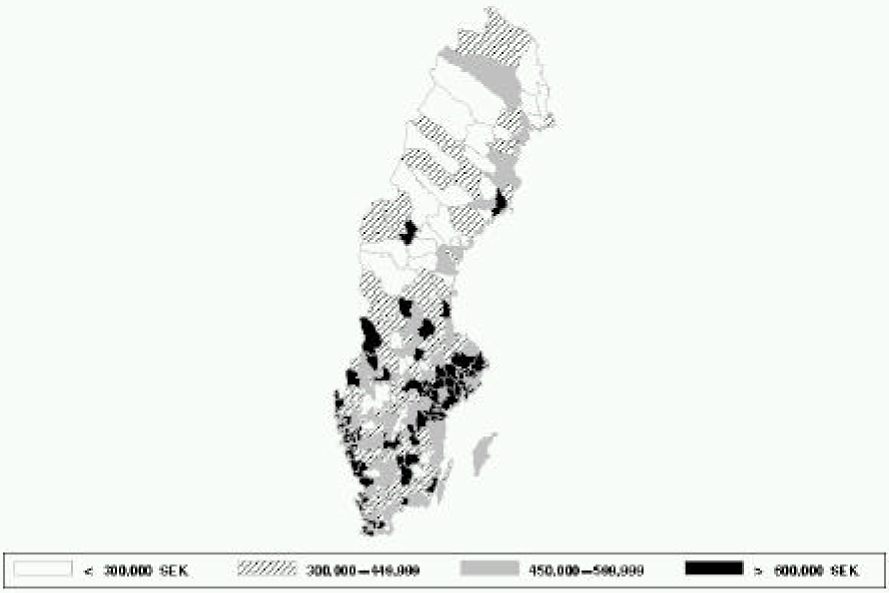
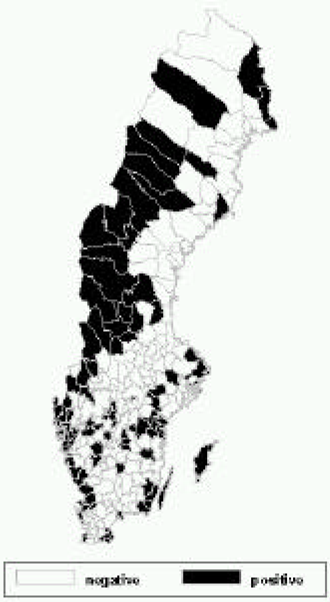


Figure 7. Residential Property Value Residuals



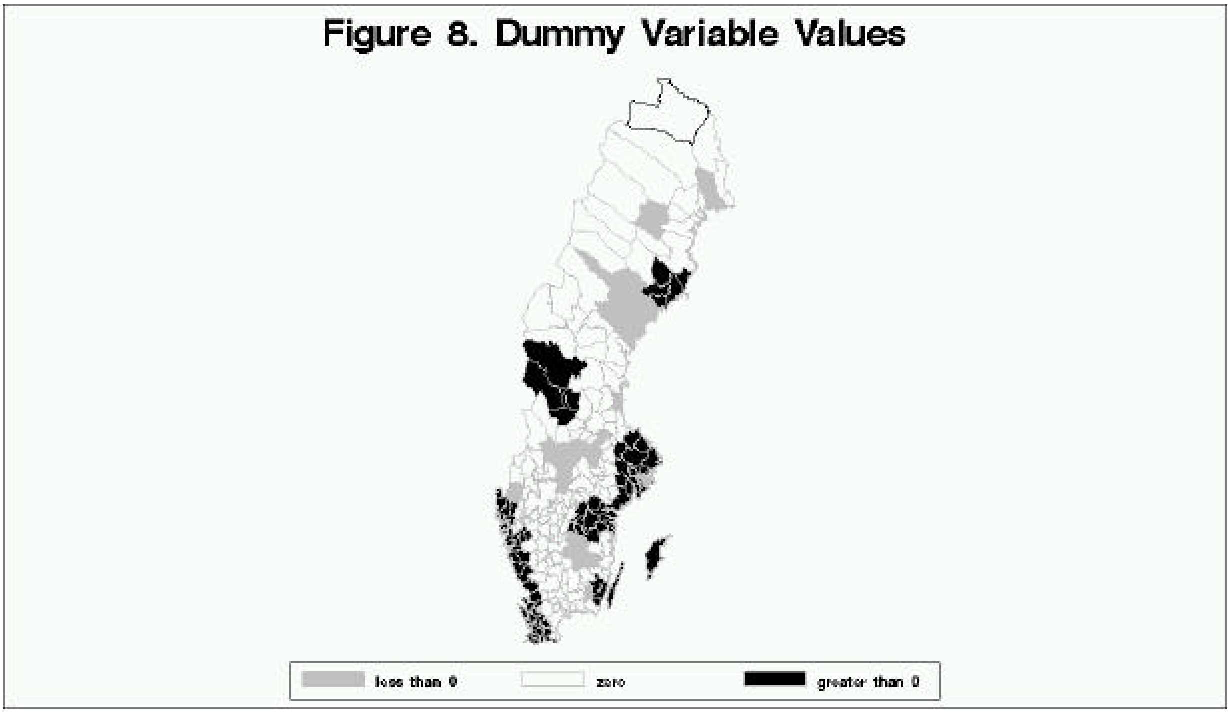


Figure 8. Dummy Variable Values
less than 0
zero
greater than 0

Figure 9. Possible interactions between property value module and other modules