Valuation modelling within thin housing markets. Case study: Arab housing market in Israel

1. Introduction

Residential property is a multidimensional and unique commodity characterised by heterogeneous attributes and spatial fixity (McCord et al., 2012). The factors influencing house values are numerous; driven by not only property characteristics, but also incorporating locational context, infrastructural developments, and environmental quality. It is important, therefore, that in the field of valuation, statistics, social policy and economics, the estimated values of housing properties may be included in every record in the Dwelling Registers database. These details are especially important in a country such as Israel, where residential segregation and segmentation are historically inherited features, and where idiosyncratic nature has taken physical form, dividing housing into Jewish and Arab sectors.

Conventionally, in any segmented market, estimation techniques based on registered data for the entire stock of residential properties should account for the impact of externalities on market segmentation and segregation effects, accounting for the effect of locality on the structure of the urban housing market (Crompton, 2001; McCluskey, et. al., 2013). In Israel, however, estimations of residential property values based on data pertaining to sale transactions have only been undertaken for the Jewish urban sector, while dwelling values for the entire Arab sector population have not yet been fully estimated, because of the low frequency of housing transactions and the lack of data on the Arab localities (Fleishman and Gubman, 2015). This is an important issue, as the Arab population comprises approximately 20% of the entire population of Israel (CBS, 2013); thus, the housing market needs to be evaluated at a multi-dimensional level, incorporating Arab localities and accounting for mixed cities effects.

Theoretically, the application of regression hedonic analysis to the estimation of property values relies on the availability of information concerning the physical and locational characteristics of properties (Brundson, et. al., 2002). This technique supports an estimation of the values of individual property attributes, and, from these, it is possible to construct estimates regarding the value of properties with known characteristics. In thin housing markets, however, the lack of detailed data regarding open market transactions, and limitations of the statistical properties of regression equations could create potential problems (Dunse and Jones, 1998; Anenberg, 2016).

According to the relevant literature, a thin real estate market describes a situation in which the number of transactions is low, resulting in a lack of availability of comparable properties when undertaking an appraisal (McMillen and Weber, 2008, Genesove and Han, 2011). Moreover, a number of additional factors, such as demography, population, economic base, and income, affect housing demand and supply, meaning all property types may contribute to determining a thin market conditions (Junainah, 2011). Alongside these factors, and in view of the special characteristics of the housing market in Arab sector (i.e., limited housing mobility, multigenerational family compounds, religious affiliations and specific requirements for housing finance arrangements), and the limited number of sales transactions and insufficient information concerning the dwelling characteristics (Almog, 2009; Khamaisi, 2013), one can refer to it as a thin market. It is important, therefore, to apply methodology which would diminish thin market effects, allowing to account for every record in the Dwelling and Building Register in the Arab housing sector in Israel (Fleishman and Gubman, 2015).

This paper contributes to the field of study by addressing mass appraisal issues and suggesting appropriate valuation modelling technique applicable to the estimation of property values for every record in the Arab housing sector in Israel. To accomplish this task, empirical estimations of mixed cities and Arab localities employed data on transaction prices and subjective valuations from the Israel Tax Authority (ITA) and the Household Expenditure Survey (HES) respectively. Thereafter, two values for each dwelling have been imputed: one based on transactional data, and the other on self-valuation reports provided by property owners. Finally, using these results, the average property values for all dwellings in the Arab sector were established, having been weighted by special optimization procedure.

The paper is structured as follows. The next section analyses relevant literature, while the third section reviews the housing market in the Arab sector. The fourth section presents the methodological framework applied in the paper. The fifth section describes the data. The penultimate section presents the main findings and results, while the final section forms the conclusion.

2. Literature Review

2.1. Mass appraisal valuation: methodological issues

Mass appraisal might be defined as the systematic appraisal of groups of properties using standardized procedures (Kauko and d'Amato, 2009). Conventionally, mass appraisal techniques refer to the estimation of values according to either a sale transaction, a subjective estimation by the owner of the property, an assessor's estimate, hedonically adjusted sales prices or the average valuation of specific geographical units according to property type (Goodman and Thibodeau, 2003; Borst and McCluskey, 2008; Wersing, 2011; Epland and Kirkeberg, 2012; International Association of Assessing Officers IAAO, 2013; Windsor et al., 2015). When transaction data are unavailable, the asking prices listed in media advertisements can be also used as alternative sources of information (Benjamin et al., 2004; Lozano-Gracia and Anselin, 2012). Nevertheless, the use of asking (list) prices can skew empirical results, due to disparities between asking and transaction prices relating to whether the market is in a boom or bust period (Haurin et al., 2013).

Another important concern is the thin market price bias, meaning that property's current market price may not reflect current market conditions, and therefore should not be used as a guide (Lin, 1998; Mueller, 1996; Gallimore and Wolverton, 1997). It has been found that the prices in a thin market are primarily downward biased. For example, a study conducted in Malaysia (Junainah et al., 2011) revealed a large gap between actual selling prices and improved assessment values, as obtained from the local authority: actual selling price was found to be much lower than the improved value. Another concern is that having access to only a minimal number of comparable transactions in a thin market increases uncertainty in the housing market and opens up opportunities for market manipulation (Nelson and Turner, 1995; Mc Millen and Weber, 2008; Hendel, et. al., 2009; Bernheim and Meer, 2013).

Given the potential for uncertainty in the thin housing sectors, it is important, therefore, to estimate how lack of information on transaction prices affects self-valuations and potential sellers' behaviour (Anenberg, 2011). Understanding these relationships is imperative because it supplies information on estimated values and adds efficiency and transparency to the housing market. This is specifically relevant in nowadays, as informative databases are becoming available and data providers (e.g. zillow.com) need to evaluate demand for appraisal techniques, which may account for self-reported valuations in addition to the transaction or listed prices (Anenberg and Bayer, 2013).

Referring to the accuracy of self-reported owners' valuations of their properties, previous studies show that, on average, owners tend to overestimate the value of their dwellings by 5% relative to a market valuation (e.g., Kain and Quigley, 1972; Robins and West, 1977; Ihlanfeldt and Martinez-Vazquez, 1986; Goodman and Ittner 1992). This can be attributed to the phenomenon whereby people tend to overvalue what they own, and value what they do not own less. In other words, people often demand much more in financial terms to 'give up' an object (Willingness-to-Accept - WTA) than they would be willing to pay to acquire it (Willingness-to-Pay – WTP) (Kahneman et al., 1991). This effect was termed the endowment effect by Thaler (1980), and it could potentially drive home owners to attach excessively high values to their properties (Huck et al., 2005). Thus, people value their own houses above the level justified by what the market will pay. In Israel an upward bias in homeowners' valuations was found to be even higher among the Jewish and Arab sectors (Romanov, et al. 2012).

At a micro level data literature there are arguments that sellers tend to adjust house prices downwards, even under stable market conditions; however, these models are inconsistent with the predictions of existing search, as these are stationary models which do not account for the duration dependence in owners adjustments (Anenberg, 2016; Carrillo, 2012; Novy-Marx , 2009). A number of studies found that the longer duration of residing in a given property, the higher deviation between the self-reported values and market prices (Cruijsen, et. Al., 2018). This is specifically relevant to the Israeli case, where Arab localities are characterized by the low degree of mobility and life long stay residence in the owned house.

In practice, various techniques could be applied to understand thin markets, such as the contingent valuation method (CVM) or asking for rental values. Primarily, CVM is widely used as a nonmarket valuation method in cost–benefit analyses and environmental impact assessments, such as to assess the effects of environmental contamination and positive amenities on proximate residential real estate property values (Simons, 2002). Asking for rental values is not ideal, as they are typically sticky, and thus are a somewhat stale measure of real estate markets (Case et al., 2000).

In official statistics, which is mainly based upon the information in housing census data, estimated dwelling values are mainly used to estimate inequality and welfare levels, or to impute property value data for municipal taxation purposes (Ruiz and Vallejo, 2010). In Israel, the population census includes a housing census, but in its current form does not provide information about the entire body of housing stock nationally (Flieshman and Gubman, 2015). Moreover, in Israel the property taxation procedure is currently largely based on property size (and not on property value); although, the option of using property value as a basis for municipal taxation purposes is under serious consideration by the relevant governmental institutions. From this perspective, successfully providing data about the values of all housing stocks at the national level is a very important issue, because the residential market is subdivided into Jewish and Arab sectors. Therefore, the availability of a registry data on market value for the entire stock of residential properties would provide greater accuracy of information by ameliorating local aspects influencing the housing market's structure (Schulz et al., 2014).

2.2 Valuation modeling: methodological issues

Benjamin et al. (2004) discuss the mass appraisal estimation techniques of dwellings and compare the traditional assessment methods with multivariate regression methods, concluding that wherever a large number of properties is being evaluated, the use of statistical methods is most suitable. Geltner and Ling (2006) and Bourassa et al. (2007) propose that a marginal contribution to the property value of the amenities, the characteristics of the property, its location and segregation are important to be considered in the hedonic models for producing property value estimates. In simple terms, the hedonic models aim to analyze the value that is associated to each of the attributes. One of the merits of the hedonic models is the ability to control for housing quality, i.e., combine attributes of demand or supply side observations and capture the influence of each attribute reflected by the property price (Tse, 2002; McCluskey et al., 2013). Hedonic modelling approach suggests employing a number of factors that affect the value of a dwelling, and can be aggregated in three principal groups: (1) physical characteristics (Zabel and Kiel, 2000; Emrath, 2002); (2) environmental characteristics (Zabel and Kiel, 2000; Emrath, 2002; Nijland and Wee, 2008); and (3) locational characteristics (Arguea and Hsiao, 2000). Thus, the accuracy of the statistical results, based on the hedonic modelling approach, varies in relation to the availability and quality of the data applied in empirical experiments.

The implicit theoretical analysis of the multidimensional nature of housing asserts that homebuyers assess the houses they buy according to a set of characteristics they value (Watkins, 2001). Thus, house price should be determined by the implicit values of these characteristics, where price is established by consumer bid curves and seller offer curves according to an assumed market equilibrium. Given that the implicit price of different housing attributes can vary between different submarkets, the value associated with hedonic house price models in urban housing markets can account for the submarket features and locational attributes (Farber and Yates, 2007). A number of studies have also suggested that socio economic effects and ethnic segregation are important factors forming causal relationships between the socio cultural attachments, house prices and economic outcomes (Gibbons, 2004).

The majority of studies on local housing market analysis have been conceptualised housing markets as a set of independent quasi sub-markets, where submarkets comprise dwellings that offer close substitutes for potential buyers (McCord et al., 2012). Recent works have recognised the importance of segmentation in defining submarket features (Goodman and Thibodeau, 2003; Ball, 2013). As proposed by Sirmans et al. (2005), any statistical analysis of housing market segmentation depends largely on price prediction techniques and understandings of housing market structure (Kauko et al., 2002; McCord, et al., 2012).

In conventional modelling approach, the variable explained in the valuation model is the logged value of dwelling price or logged price per square metre (Epland and Kirkeberg, 2012; Lozano-Gracia and Anselin, 2012). In each specific estimation of a dwelling value in imputation model, the set of explanatory variables varies commensurate with availability, integrity, and the marginal contribution to estimation accuracy, suggesting that a distinction should be made between the valuation and any predictive models (Shmueli, 2010).

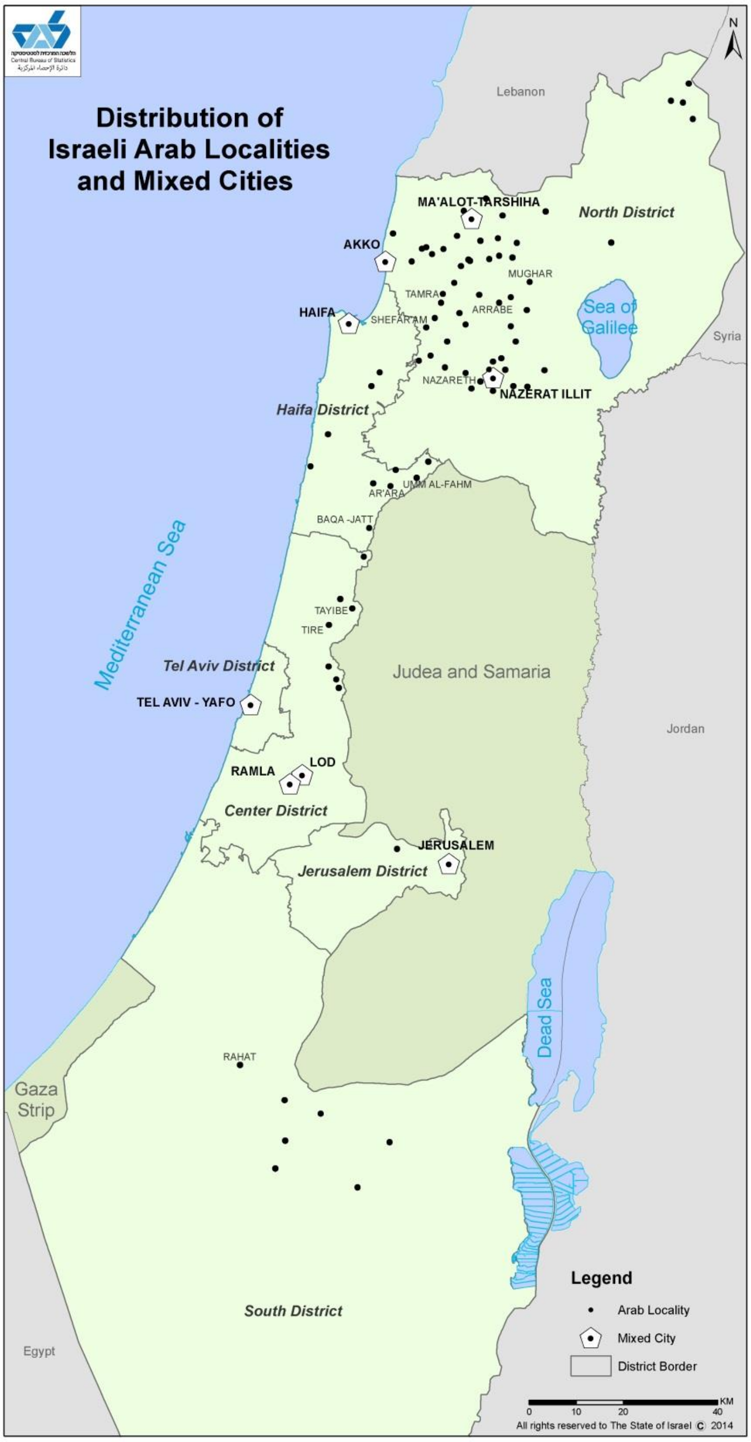
In predictive models, the main criterion for the insertion of a variable relates to predictive ability, as opposed to explanatory power or the statistical significance of the regression coefficient. For estimating dwelling values, Wersing (2011) and Goodman and Thibodeau (2003) propose a classic hedonic model, due to the parsimony of empirical specification accounting for a large number of property characteristics affecting the value of a house.

3. The housing market in the Arab sector

The Arab housing sector constitutes more than one fifth of the total Israeli housing stock and is characterised by its own specific sub market features. The Israeli Arab population stands at 1.6 million today, constituting approximately 20% of the population of Israel (CBS, 2013). The Arab population in Israel is divided into three religious groups: Muslim, 84.1%; Christian, 9.1%; and Druze, 8.1%. The Israeli Arabs live primarily in separate urban-village localities and in discrete neighbourhoods, located in a few mixed cities. Figure 1 shows that a large proportion (approximately 43%) of the Arab population lives in the Galilee region in the north of the country. The remainder live in the central region of Israel and in the southern Negev region (mostly, the Bedouin population).

Figure 1

Distribution of Israeli Arab localities and mixed cities



The physical, environmental, socio-economic and socio-cultural characteristics of the Israeli Arab housing market are major factors which differ it from the Jewish housing market. To a large extent, the residential and housing patterns of Arab communities stem from internal socio-cultural and religious factors that are associated with a strong sense of belonging and attachment to place, family and kinship, known as "*hamula*" (Khamaisi, 2005; 2013; Hassan, 2005; Noach, 2009). Arab residential patterns are typical for traditional rural societies, focusing primarily on family compounds within special localities and neighbourhoods, determined by *hamula* and religious affiliation. These result in limited readiness or willingness to reside in apartment buildings with unfamiliar neighbours, and difficulties promoting the sale of land/home with multiple owners (Almog, 2009; Khamaisi, 2009, 2013). In Arab localities, the statistics reveal a preference for the self-housing method, of building homes mainly on family-owned private land (Despres, 1991). Most Arab families prefer not to take mortgages due to religious and cultural factors (Khamaisi, 2013). Certain financial limitations also play a role in the lack of mortgaged properties in the Arab sector. This is because Islamic mortgages require providers working within the Islamic finances area, where a mortgage must be supplied in accordance with Sharia, (Islamic) law, which forbids the payment or receipt of interest. An Islamic mortgage may be an interest-free loan, but often its arrangement takes the form of more complex transactions. Thus, the Arab sector is characterised by limited rural to urban movements, constrained housing mobility, low availability of housing finance and new housing stock. In addition, specific characteristics associated with Arab residential sector limit homes to three or four floors, reducing scope for promoting public housing projects and the construction of homes/apartments for sale or rent.

Overall, the characteristics listed above that define Arab residential patterns and the Arab housing market place it in sharp contrast with the Jewish housing market. According to data from the 2008 Population Census, 92.6% of the Arab population reside in their own homes, while in the Jewish sector the rate of homeownership is less than 70%. The percentage of multi-storey homes sold in 2011 in the Jewish sector was almost twice that in the Arab sector (83% and 45%, respectively). Regarding home rentals, in 2011 only 9.9% of Arab households resided in rented homes, compared to 28% in the Jewish sector (CBS, 2011). Table 1 presents some background data concerning housing market in Arab sector. It reveals that the Arab housing market in mixed cities is more dynamic than in solely Arab localities.

Table 1. Housing market: background data (%)

Type of locality	*Transactions*	*Residential property*	*Population*	*Transactions – to – housing stock ratio*
Total Arab sector:	100	100	100	0.4
Arab towns	29.2	52.0	68.2	0.2
Arab tracts in the mixed cities	70.8	48.0	32.8	0.6

As a direct result of Arab residential, and the limited scale of free housing available on the market in the Arab sector, the transaction data reported to the Tax Authority are likely to be somewhat downward biased in terms of both numbers and house prices. Therefore, to attain estimation results that may benefit from higher accuracy, various sources of information for estimating market values for each dwelling in the Arab localities needs to be applied.

3. Statistical models

To develop a methodology for estimating the value of each dwelling within the Arab localities with the limited information available on transaction prices data, the following statistical models were applied. In Stage 1, a hedonic model was used to investigate the factors affecting housing values in the Israeli Arab sector, treating economic conditions and the annual number of sales transactions as given. Hedonic models were tailored to sale transaction prices acquired for 2008-2011 from the Israeli Tax Authority's records (ITA data). These models were estimated for a subsample of localities, with a fairly well developed housing market, listing stock of total dwellings, number of transactions, and the advertising of homes for sale by owners.

Due to the rather limited housing market in most Arab localities it was also suitable to utilise the subjective assessments of property value provided by property owners, extracted from the 2008-2011 Household Expenditure Survey (hereinafter: HES data). Thus, in Stage 2 a hedonic model was estimated using the HES data. In this way, the effect of the various characteristics of property and locality on the owner's valuation was examined. In Stage 3, the best models estimated based on both the ITA and HES data were chosen to impute value. This meant that at this stage each dwelling had two imputed values: 1) based on transaction data, and 2) based on the valuation reported by the property owner. In the final stage, and based on the results of the foregoing analysis, the property value for the entire population of dwellings in the Arab sector was calculated as an average being weighted by number of transactions in the locality and by its size. Thus, data limitations on property transactions in Arab localities have been diminished by pulling and weighting data from the ITA and HES respectively.

3.1 Hedonic models

Two hedonic models were estimated for the two subsamples of ITA transactional data: for the Arab census tracts (CT) in mixed cites, and in Arab localities. The third hedonic model was estimated for Arab localities based on the HES data. These models were formulated to account for locality and the effects of segregation, investigating the effect of selected variables on property prices. The hedonic model used for both ITA and HES data is expressed by equation (1).

$$P_i = f(X, \beta, \varepsilon) \tag{1}$$

where (X) represents the set of property's physical and locational characteristics, (β) is a vector of parameters of estimates, (ε) is a stochastic residual term, while (P_i) is the implicit property price.

The semi- logarithmic form of the empirical model includes three sets of independent variables and takes the following form:

$$Ln(P_{ijl}) = \beta_0 + \beta_i Asset_i + \beta_j Building_j + \beta_l Locality_l + \varepsilon_{ijl} \tag{2}$$

where P_{ijl} denotes the price (or valuation in the model based on the HES data) for property i in building j in locality l. $Asset_i$ denotes the characteristics of dwelling *i* (area, number of rooms), $Building_j$ represents the characteristics of building *j* (year of constriction, dwelling purchased from a builder), $Locality_l$ denotes the locality related characteristics (major religion, transactions–to–population ratio, land use, average property price in locality); and ε_{ijl} - random noise with variance as σ. After the log transformation, the explained variable (price in the ITA data and valuation in the HES data) is approximately normally-distributed, justifying the use of the ordinary least squares (OLS) method to estimate the models (1). This transformation also stabilises P_{ijl} variance. Note the model estimated for mixed cities includes additional explanatory variables, which are relevant for mixed cities and available at a census tract level; including details of residents' demographic and economic characteristics, property tax rates and average property price in Jewish CTs in the city.

When reviewing the set of explanatory variables, it should be noted that according to the literature that concentrates on analysis of dwelling value, the property area variable is used after the log transformation because the effect of area on price is nonlinear. Furthermore, the literature offers a lengthy discussion concerning the spatial dependency of property price (an autoregressive spatial effect). This means the value of a specific dwelling affects, and is affected by, the value of those dwellings in its vicinity (Jeanty, Partridge, and Irwin, 2010). This phenomenon creates a strong correlation between the value of a specific dwelling, and the average value of neighbouring dwellings. However, it is extremely difficult to take into account spatial dependency at the individual property level, when estimating property value at the register level. Due to this difficulty, it was decided to include an aggregate variable, '(log) meaning dwelling prices in CT/locality' in the estimation model, as a proxy for dwelling prices in the property's neighbourhood.

The importance of including a variable that reflects the geographic location of the property in the estimation model is emphasised in several studies, such as that by McCluskey et al. (2000) and Bourassa et al. (2003). Following this argument, the estimation models included the variables reflecting property location at the level of both locality and geographical district.

3.2 Estimation models

The literature on the subject of estimation models supports the premise that transaction price is generally the best proxy for property market value (American Institute of Real Estate Appraisers, 1988; Banzhaf & Farooque, 2012; Arguea and Hsiao, 2000). Following the presumption that ITA transactions data relating to the

Arab sector are likely to be downward biased, a further source of information about property value (HES data) was also used when determining the final estimation of dwelling values. Another consideration is that there is an upward bias when respondents report the value of their dwellings, as widely examined and explained in the literature. Considering these preconditions, neither of these two data sources could serve as the sole benchmark; thus, the prediction models were estimated using both data sources. These models were based on equation (1), and served to estimate dwelling valuations for every dwelling belonging to the research population.

Since the 'Logged Dwelling Price/Valuation' variable is approximately normally-distributed, one could infer the value of dwellings is log-normally distributed.

Due to the fact that log-value / log-price distribution is approximately normal, predicted value $\hat{P}_{ijl}$ follows a log-normal distribution. It should be noted that the correction $0.5\sigma^2_{ijl}$ in the predicted value's calculation guarantees an unbiased estimator.

The formulae used to calculate the predicted value (3) and its variance (4) are given as follows (Mcculloch and Neuhaus, 2013):

(3) $$\hat{P}_{ijl} = \exp(\hat{Y}_{ijl} + 0.5\sigma^2_{ijl})$$

(4) $$Var(\hat{P}_{ijl}) = (\exp(\hat{\sigma}^2_{ijl}) - 1)\exp(2\hat{Y}_{ijl} + \hat{\sigma}^2_{ijl})$$

where $\hat{\sigma}^2_{ijl}$ denotes the variance of the residuals estimated in the regression models.

It should be noted that according to the appraisers' assessments, the dwelling value in the Israeli Arab sector mostly ranges between 1,500 NIS (New Israeli Shekels) for a square metre and 50,000 NIS for a square metre[1]. Following these considerations, appropriate restrictions were established as a part of the estimation procedure.

4. Research databases

As stated previously, ITA and HES files from the years 2008–2011 were used in this study to support a comparative analysis of the distribution of valuations by actual transaction prices (ITA) and subjective estimate (HES). The research population

[1] An exchange rate of NIS to US $ was 3.58 in 2011.

comprises privately owned residential properties in census tracts (mixed cities) and localities, in which more than 50 percent of inhabitants are Arabs, where these localities have populations of over 2,000. The 2012 Dwelling and Building Register file yielded 378,653 records for dwellings with relevant populations. The transaction samples registered by the Tax Authority contained more than 6,000 samples for years 2008-2011. For the purpose of this study, relevant transactions were sorted under the following criteria: (1) they must have been made in the free market (excluding records labelled “Estate,” “Gift,” etc.); (2) they must have been concluded between private individuals (excluding corporations and non-profits) for dwellings owned by the seller, including transactions between a building corporation (seller) and a private individual; and (3) they must have taken place in Arab and mixed urban localities, excluding regional council jurisdictions. Transactions in which the reported property area was smaller than 15 square metres were deleted from the file, as were those in which the dwelling value was smaller than 45,000 NIS.

For model estimations on both ITA and HES data, two additional conditions were included: 1) that the number of transactions in a locality should be sufficient in order to represent the price level on the housing market (at least 20 in four years); and 2) at least one media ad should be published on a property sale in a locality. Localities not matching the above criteria were excluded from the regression analysis. The final sample size comprised 4,978 transactions, of which 3,778 transactions were in mixed cities, and 1,200 transactions were in Arab localities, forming a representative sample of the Arab population in Israel.

Regarding the HES data source, the final sample comprised 458 Arab households, answering questions about the valuation of the dwelling that each householder owned: 208 households in 13 Arab towns and 250 households in 57 Arab tracts within 8 mixed cities. Households sampled in different towns and tracts are distributed over the study areas according to areas' size. This form is representative of the Arab population sample size. The relatively small sample size of the households surveyed allegedly signifies a limitation, which is also discussed in the literature. The differences in the sample size for the ITA data and the HES data sources were overcome by defining a threshold of no fewer than 20 transactions annually, while choosing census tracts/localities for estimation property values (Wooldridge, 2002; 2003). Compared to average transaction prices (592,271 NIS, ITA data), average property valuations were much higher (948,340 NIS, HES data) (Table 2). One explanation for this difference was that ITA transaction data is likely to be downward biased. On the other hand, there is upward bias in homeowners' valuations of their dwellings.

Table 2. Distribution of transaction prices vs. property subjective valuations

	Mean	Median	P10	P25	P75	P90	SD
Transaction price (NIS)	597,271	440,000	171,689	265,000	747,330	1,163,539	578,750
Property valuations (NIS)	948,340	676,117	331,560	409,323	1,300,000	1,866,467	705,943

In addition, Population Register and the Income Tax records were used. Data from sources defining population characteristics by locality was obtained for the relevant years. Information concerning the location of the localities relative to the centre of the country was then provided using Geographic Information System (GIS).

5. Results of the hedonic models: ITA data vs. HES data

Analysis of the distribution of the dependent variable in the ITA model (dependent variable being transaction price) and in HES models (dependent variable being subjective valuation), reveals that distribution is nearly log-normal in both cases (i.e., the distribution of the logged price/logged value is almost normal). To perform this estimation, a stepwise selection algorithm was employed, selecting only statistically significant variables. This algorithm, and its associated advantages, are discussed in Seber and Lee (2012). The results for the two estimated models using the ITA data (for the Arab CTs in mixed cities and for the Arab localities) are shown in Tables 3 and 4, respectively, while Table 5 illustrates models estimated based on HES data.

Table 3. Model of ITA data: Mixed cities (Model 1)

Variable	*Parameter Estimates*	*Standard Error*	Pr > |t|
Intercept	3.18	0.34	<.0001
(Log) Area	0.58	0.03	<.0001
(Log) Average property price in CT	0.50	0.02	<.0001
Number of rooms	0.12	0.01	<.0001
Year of construction:			
Before 1947	-0.14	0.02	<.0001
1948 - 1954	-0.16	0.02	<.0001
1955 - 1964	-0.05	0.02	0.009
1995 - 1999	0.16	0.03	<.0001
2000 - 2011	0.33	0.02	<.0001
Year of transactions:			
2008	-0.14	0.02	<.0001
2009	-0.10	0.02	<.0001
2010	-0.09	0.02	<.0001
Difference between the average price in all Jewish CTs in the city and average price in a given Arab CT in the same city (thousands of NIS)	0.04	0.01	0.004
Median age of population in CT	-0.01	0.005	0.052
Number of dwellings in CT (thousands)	0.02	0.006	0.004
Percentage of commerce area in CT	-0.31	0.11	0.004
Percentage of industry area in CT	0.29	0.09	0.003
Percentage of public area in CT	-0.38	0.12	0.002
Population – to – residential area (thousands m^2) ratio in CT	-0.01	0.001	<.0001
Property tax per m^2 in CT	0.003	0.001	0.056
CT with Christian majority	0.24	0.03	<.0001
Cities:			
Akko	0.29	0.05	<.0001
Lod	0.27	0.06	<.0001
Ramla	0.35	0.06	<.0001
Tel Aviv	0.70	0.08	<.0001
Transactions – to – population (thousands) ratio in locality	0.005	0.002	0.014

N=3,778; Adjusted R-Square=0.76; Average Variance Inflation Factor (VIF) is less than 2.0 for all variables and a tolerance is 0.98.

Table 4. Model of ITA data: Arab localities (Model 2)

Variable	*Parameter Estimate*	*Standard Error*	*Pr > |t|*
Intercept	3.28	0.92	<.0001
(Log of) Area	0.80	0.04	<.0001
Number of rooms	0.09	0.01	<.0001
(Log of) Average property price in locality	0.41	0.07	<.0001
Year of construction:			
1948 - 1954	-0.18	0.07	0.013
1955 – 1964	-0.15	0.06	0.009
1995 - 1999	0.09	0.03	0.002
2000 - 2011	0.30	0.03	<.0001
Year of transactions:			
2008	0.21	0.03	<.0001
2009	0.16	0.03	<.0001
2010	0.09	0.03	0.003
Dwelling purchased from a builder	0.17	0.03	<.0001
Percentage of built area in a locality	-0.01	0.003	0.002
Transactions – to – population (thousands) ratio in locality	0.05	0.009	0.010
Central District	0.18	0.07	0.010

N=1,200; Adjusted R-Square=0.69; Average Variance Inflation Factor (VIF) is less than 2.0 for all variables and a tolerance is 0.96.

Table 5. Model of HES data (Model 3)

Variable	*Parameter Estimates*	*Standard Error*	*Pr > |t|*
Intercept	8.81	1.12	<.0001
Number of rooms	0.30	0.02	<.0001
Dwelling purchased from a builder	0.25	0.02	<.0001
Years under construction: 2000 - 2011	0.14	0.07	0.053
Year of survey:			
2008	-0.04	0.06	0.560
2009	0.06	0.08	0.469
2010	-0.35	0.06	<.0001
(Log of) Average property price in a locality	0.27	0.08	0.001
North District	-0.12	0.06	0.074

N=458; Adjusted R-Square=0.49; Average Variance Inflation Factor (VIF) is less than 2.0 for all variables and a tolerance is 0.92.

Generally, we found that both transaction prices and owners' valuations correlate with dwelling and locality features, and with location factors. In addition, certain interactions between Arab and Jewish housing markets were found and considered in a regression model estimated on ITA data on mixed cities (Model 1). The R^2 shows values of 0.76, 0.69, and 0.48 for Models (1), (2), and (3) respectively, thereby validating the models' findings.

Nevertheless, the three models revealed certain differences, both in terms of their explanatory variables and their coefficients. In particular, the findings for Model (1) (ITA data on mixed cities) revealed that marginal contribution of dwelling size variables (in terms of area and number of rooms) to dwelling prices differ from those in Model (2) (Arab localities), while the results for Model (3) (HES data) demonstrate that property owners consider apartment sizes, mainly in terms of number of rooms. Regarding the effect of year of construction of a residential building on property's value, both models estimated the ITA data (1 and 2) shows a clear upward trend in regression coefficients over the period considered, while the corresponding coefficients for the HES data are not statistically significant, with the exception of that pertaining to recently built properties. The positive effect of the property tax rate variable in the model estimated for the mixed cities (1), reflects the correlation between dwelling value and classification of region by the municipal authority for the collection of municipal taxes. The findings from model (1) also demonstrate the effects of type of land use, religious affiliation of the population, CT/locality and population density, on property price. Notably, a positive effect from the variable 'transaction-to-population ratio' reflects the level of housing market development in a locality, on property prices; revealing it is perceptibly greater in Arab localities than in mixed cities; as the housing markets in the majority of these localities are in their infancy.

6. Prediction models: Methodology used

Based on the explanatory models' results described in Section 5, three prediction models were estimated: two models using the ITA data (one for mixed cities and one for Arab localities), and a model using the HES data. Prediction models estimated based on ITA data produced the following results: average estimated value of dwelling was 640,025 NIS, and its median was 526,296 NIS, while the results from the model estimated based on HES were 808,431 NIS and 758,827 NIS, respectively.

During the next step, the weighted average for these two estimated values was used as the final imputed value for each property. The weights for estimating the final predictor of property value were calculated according to the number of transactions in a locality, and calibrated to comply with the ranking of localities in the Arab sector according to average income.

6.1 Weighting procedure justification

As was defined above, the issue in question deviates from the hedonic price modeling technique. To comply with the aims of this study we needed to develop a method for the estimation of property values in locations for which the information derived from real property values is largely lacking, and where the continuous target variable is not observed (Friedman et. al., 2001). According to the recent literature, one possible solution here would be to consider human behavior as a way to heighten the accuracy and feasibility of estimated results (D'Amato and Siniak, 2008). For instance, a number of works suggest allying fuzzy logic sets and numbers for deriving a mathematical solution when availability of data limits usage of alternative modelling techniques (Gonzalez and Formoso, 2003; Lee et al., 2003). To account for human behavioral factors, and to resolve data sample limitations, this study employs data from both sources, subjective valuations from the survey data and market transaction data, obtaining final values by applying weighing procedure. This approach allows us to overcome small data sample issues also disregarding the heterogeneity of the data set[2].

6.2 Description of weighting

Relevant research findings have consistently proven a significant positive correlation between dwelling prices in a locality, and the socio-economic level of inhabitants,

[2] Critically, if sufficient data relating to property values were available, a cross-validation (CV) method could be applied using the learning sample (say, 20% of observations) upon which the prediction values and accuracy indices were calculated. However, in this instance we have no reliable 'ground truth' available. Therefore, this method for testing the accuracy of results for assessment purposes cannot be used here. Instead, we employ an alternative approach to estimate and validate the latent continuous variables applying a weighing procedure.

while income is considered to be the primary factor informing residential areas' socio-economic level (Ozanne and Thibodeau, 1983; Malpezzi et al., 1998; Des Rosiers et al., 2002; Yates, 2002; Yitzhaki et al., 2013). The positive relationships between property values and incomes correspond with the theory of housing demand, suggesting that rank by income could be used as an approximation of rank by dwelling value per square metre in a locality (Brueckner, 1994; Fleishman et al., 2015). This study suggests a weighted average for ITA-based and HES-based estimated values, defining the metrics used for housing value estimation according to the proximity of rank by income in the locality, to the rank by dwelling value per square meter within the same locality (Ngai and and Sheedy, 2018). Considering that the HES and the ITA data can be opposite biased, we propose a combined estimator $\hat{Y}_{li}^{(comb)}$ for defining value of a dwelling *i* in locality *l*. This takes the form:

$$\hat{Y}_{li}^{(comb)} = w_l \hat{Y}_{li}^{(ITA)} + (1 - w_l)\hat{Y}_{li}^{(HES)} \quad (5)$$

where $\hat{Y}_{li}^{(ITA)}$ and $\hat{Y}_{li}^{(HES)}$ denote the estimated values from the model on the ITA and the HES data, respectively, and w_l is the weight for locality *l*. Note, that the range for w is: $0 \le w \le 1$.

It should be stressed that if there were fewer than ten survey respondents in a census track (in mixed cities), or in a locality (Arab towns), but at least 20 transactions, the weighting procedure was not applied, and the estimator obtained from the model on the ITA was defined as the final estimator. If there were fewer than 20 transactions in a locality, the property value was not calculated at all, disregarding the number of survey respondents in that locality. It should also be noted that in those census tracks/localities in which the number of transactions was lower than the defined threshold, the number of survey responses was also less.

A selection of the weights is based on the approximation of the socio-economic level. Then we divide all localities in the Arab sector into ten segments (deciles) to define (a) average work income, (b) average dwelling value per square metre estimated based on the ITA data, (c) average dwelling value per square metre estimated on the HES data, and (d) average dwelling value per square metre using the combined estimator (formula 5). Note that by using value per square metre as an underlying variable when conducting ranking, we neutralised the effect of apartment size, a key variable explaining the differences in dwelling prices (Lozano-Gracia and Anselin, 2012).

Thus, given the assumption of the proximity of rank by income in a locality *l* (R_l^{Income}) to the rank by dwelling value per metre at the same locality, a weights vector, $\boldsymbol{w}$, is given as follows:

$$w_{opt} = argmin\left(\frac{1}{n}\sum_l abs\left(R_l^{Income} - R_l^{comb}(w)\right)\right) \quad (6)$$

where $R_l^{comb}(w)$ is a rank of locality, l, by the combined estimator $\hat{Y}_{li}^{(comb)}$ (5). Given the restriction, $0 \leq w \leq 1$, an expression for weights in (5) and (6) is:

$$w = \frac{\exp(a+bZ)}{1+\exp(a+bZ)} \quad (7)$$

where *Z* is the number of transactions in a locality per 1000 residents. The optimal values for parameters *a* and *b* in (7) were calculated using the numerical optimisation procedure described as formula (5). For localities with no transactions during the research period, the weight is constant and equal to $\frac{\exp(a)}{1+\exp(a)}$. If *a* is negative, this means the HES estimator $\hat{Y}_{li}^{(HES)}$ has a higher weight than the ITA one. Otherwise, the weight for the ITA estimator $\hat{Y}_{li}^{(ITA)}$ is higher.

In localities for which the rank by income was identical to their rank by ITA estimator or by HES estimator, we suggest setting the values for dwelling properties estimated on the ITA or the HES data, respectively, as final. Formally, this means that for locality *l*, (6) should be corrected as follows:

$$w_l = \begin{cases} 1 \quad if\ R_l^{Income} = R_l^{ITA} \\ 0 \quad if\ R_l^{Income} = R_l^{HES} \ \ and\ R_l^{Income} \neq R_l^{ITA} \\ \frac{\exp(a+bZ_l)}{1+\exp(a+bZ_l)} \quad otherwise \end{cases} \quad (7a)$$

The optimisation algorithm was used to determine the values of *a* and *b,* and to minimise the average gap between rank by income and rank by dwelling value per square metre. For this purpose, numerical optimisation was applied to search out a minimum for the target function, as in expression (6).

As a result of the optimisation procedure, we obtained: $a = 0.2, b = -0.3$, meaning that for the localities in which no transactions were registered during the research period, the ITA estimator was weighted by 0.43; while for localities with more than 20 transactions, the weight for the HES estimator was negligible. In the latter case, the ITA estimator required a very small correction to serve as a final estimator for dwelling value. The average weight *w* for the ITA-based estimator was 0.64. In 20% of all cases, $w_I = 1$, the ITA-based estimator, was used to define the final value.

When comparing the income ranking vs. dwelling value rankings before and after the correction, it appears the mean difference (in absolute terms) was 2.81 for the ITA estimator and 4.40 for the HES estimator, as opposed to 2.69 for the final combined estimator. Therefore, we can conclude that the final estimator would be slightly improved by the method described. Table 6 contrasts the distribution of the ITA-based estimator and the HES-based estimator, depicting the distribution of the final combined estimator.

Table 6. Distribution of imputed values based on different data sources

	Mean	*S.D*	*Percentiles*				
			10th	*25th*	*50th*	*75th*	*90th*
Estimator based on the ITA data (NIS):							
Arab CT, value	652,278	699,428	190,967	321,635	533,108	761,053	1,055,186
Arab CT, value per m^2	7,440	3,621	3,817	5,321	6,907	8,054	11,685
Arab towns, value	627,759	463,609	289,486	386,937	521,370	734,441	1,077,115
Arab towns, value per m^2	4,431	1,595	2,920	3,377	4,070	5,004	6,054
Estimator based on the HES data (NIS):							
Arab CT, value	706,149	344,234	390,214	516,751	664,795	821,169	950,281
Arab CT, value per m^2	9,215	2,773	6,220	7,725	8,809	10,512	12,915
Arab towns, value	891,984	311,738	585,359	691,253	833,631	1,036,877	1,259,690
Arab towns, value per m^2	6,885	2,070	4,760	5,418	6,459	8,002	9,528

Combined estimator (NIS):							
Arab CT, value	664,846	631,119	208,893	351,040	579,396	791,427	1,002,748
Arab CT, value per m^2	7,792	3,669	3,831	5,295	7,546	9,235	11,724
Arab towns, value	750,750	360,469	432,503	556,142	695,919	871,478	1,120,811
Arab towns, value per m^2	5,569	1,429	4,077	4,805	5,320	6,229	7,474
Transactions' price (NIS)							
Arab CT, price	571,243	620,858	160,695	237,618	389,911	694,498	1,088,623
Arab CT, price per m^2	7,442	5,523	2,785	3,994	5,909	8,750	14,035
Arab towns, price	679,214	408,967	266,666	386,820	584,867	884,161	1,250,000
Arab towns, price per m^2	5,783	3,283	2,726	3,443	4,811	7,222	10,648

Thus, the table 6 illustrates that the distributions of weighted combined values are closer to the distribution of ITA-based estimators, as anticipated. The mean, median, and percentiles for the distribution of combined values exceed those of the distribution of transaction prices, indicating that the imputation method chosen corrects the slight downward bias in ITA data.

Conclusion

The primary aim of this paper is to address the mass appraisal issues associated with thin markets, based upon the case study of the Arab housing sector in Israel. This paper contributes to the field of study by suggesting a methodological framework which incorporates various available data sets that report a measure of the property market value, assisting in estimation of the dwelling values for the thinly fractioned housing market. This unique statistical modelling technique allows researchers to overcome small data sample size issues when incorporating two input values: one based on transaction data, and the other based on the subjective valuations provided by property owners. Estimating the property value of every dwelling in the Israeli Arab sector posed an immense research challenge, ultimately contributing to a more profound understanding of the distribution of residential properties in this sector. In tackling this challenge, average property values for all dwellings in the Arab sector were weighted by locality factor and by its size, being subsequently calibrated in accordance with the ranking of the localities by average income factors. Empirical estimations on mixed cities and Arab localities employed data on transaction prices and subjective valuations from the Israel Tax Authority (ITA), and the Household Expenditure Survey (HES). The period of the study covers 2008-2011, capturing years of substantial upward dynamics in Israeli housing market. Policy implications that arise may include measures designed to facilitate desegregation within the housing market in Israel by supplying affordable housing units to encourage multicultural neighbourhoods in the mixed localities. Also policy makers may benefit from the better efficiency of the housing tax adjustments, more accurate updates of housing values, housing affordability and housing mobility measures. Housing policies could also gain from a deeper understanding of house price dynamics within thin and local markets, potentially with the ability to monitor changes in dwelling values accounting for segmentation and segregation effects. Value data at the individual-record level appears a productive avenue for future research on estimations and the analysis of the distribution of dwelling value by income level, demographic characteristics and small geographical units. Future research might also examine possibility to construct a novel housing index in Israel, which, alongside the current housing indexes would then provide greater efficiency within the housing market.

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