Nordic Journal of Surveying and Real Estate Research 5:1 (2008) 42–63
submitted on 23 November 2007
revised on 15 February 2008
accepted on 23 May 2008

The Effect of Three-Rate Property Taxation on Housing Supply

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Abstract. *This paper investigates the effect of a higher real estate tax rate for un-built sites on housing supply in the city of Espoo, Finland. The study finds that there are no increases in the housing construction, since year 2005, in which the additional tax was introduced in the city of Espoo. All hedonic model formulations supported this view. The study shows that the amount of housing construction can be explained by variations in apartment unit prices, unit rents of dwellings and the building cost index. Also unobserved components, which measure the effect of time, indicate that there are trends and cycles embedded with the series that have a significant effect on new housing construction. The paper also briefly investigated Tobin's q-theory and its application to explaining construction activity. The empirical study showed that the q-ratio, which is estimated as a ratio of housing prices to building costs, in conjunction with unobserved components largely explain the variability in actual housing starts.*

1 Introduction

The prices for undeveloped land zoned for housing have been strongly increasing during the last few years in the Greater Helsinki Area[1] with an annual increase from circa 10 up to 30 percent [NLS, 2002–2006]. These price changes can be explained partly by products' quality differences and partly by factors influencing the housing demand such as population growth, low interest rates and increased household income. Whereas the demand for undeveloped land has increased, the number of building land transactions has decreased since year 2002, which can be interpreted as a sign of falling supply [Falkenbach *et al*., 2006].

According to the opinion among decision-makers there is enough land area covered by local detailed plans, but these areas remain undeveloped because private landowners are unwilling to build on them [Falkenbach *et al*., 2006]. As a solution the Finnish municipalities were allowed to impose from year 2001

[1] The Greater Helsinki Area includes 14 municipalities: Helsinki, Espoo, Vantaa, Kauniainen, Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Mäntsälä, Nurmijärvi, Pornainen, Sipoo, Tuusula and Vihti.

onwards a higher real estate tax percent for unbuilt residential building sites. The basic aim of this reform was to encourage housing construction and thus to increase housing supply. In year 2005, the Finnish parliament enacted an amendment to the existing law of real estate taxation, which forces 14 municipalities in the Greater Helsinki Area to use a higher real estate tax for undeveloped land zoned for housing. By 2007, 30% of the municipalities have adopted this new reform. These municipalities have a three-rate real estate taxation system with different tax rates for land value pre and post development and a separate tax rate for buildings. The remaining municipalities have a two-rate real estate taxation system with a uniform residential land tax and a building tax. [Lyytikäinen, 2007]

2 Finnish Real Estate Taxation System

In Finland, there has been a real estate tax since 1993. According to the Finnish Real Estate Tax Act, the real estate tax is paid by the owner of the real estate and collected by the municipality in which the real estate is located. All land and buildings are subject to the real estate taxation, except agricultural fields and forests, which are not taxed. The amount of real estate tax is based on the value of the real estate. The target taxable value of both developed and undeveloped zoned land is 73.5% of the annual local market price of the real estate. The target taxable value of buildings is 70% of their replacement cost [Lyytikäinen, 2007].

The municipal council defines the real estate tax percent annually before the taxation year. The general real estate tax percentage is between 0.50% and 1.00%, which concerns items such as zoned land, commercial buildings, etc. The real estate tax percentage for permanent dwellings is between 0.22% and 0.50%. The real estate tax percentage for recreational and secondary homes can be 0.60% higher than for permanent dwellings. From the year 2001, it has been possible for a municipality to impose an additional real estate tax rate on undeveloped residential building sites; The range of this additional real estate tax is 1.00–3.00%.[2]

Applying the higher real estate tax percent for unbuilt residential building sites is optional, except in the Greater Helsinki Area: The Finnish parliament enacted in 2005 an amendment to the Real Estate Tax Act, which obligates 14 municipalities in the Greater Helsinki Area to impose this additional property tax on undeveloped residential building sites[3]. Otherwise municipalities can decide whether or not to apply it. If they choose not to use it, undeveloped residential building sites will be taxed at the general real estate tax percentage. Before the amendment of the law in 2000 all land was taxed at the general real estate tax percentage, but the reform gave municipalities an opportunity to tax undeveloped land at a higher rate.

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[2] In addition, there are separate real estate tax percentages for non-profit organisations and power stations.

[3] According to the estimates, there exist about 4,000 unbuilt residential building sites in the Greater Helsinki Area that that qualify for this additional property tax. This amount corresponds to circa 2 million square meters of vacant zoned land, which suffices for about 2 years' construction of new dwellings. [Mattila, 2005]

According to the renewed legislation, the additional real estate tax percent has to be at least 1.00% higher in the Greater Helsinki Area than the general real estate tax percent applied in the municipality. Also the tax rate cannot be more than 3.00% of the value of the building site. The higher tax percentage should be used if [the Real Estate Tax Act, Section 12a; Falkenbach et al., 2006]:

1. the local detailed plan of the area has been effective for at least a year;
2. more than 50% of the permitted building volume is planned for residential purposes;
3. there are no buildings used for residential purposes on the building site or the construction work for the building has not been started;
4. there is a feasible road access to the building site or a possibility to arrange one;
5. the building site can be connected to a municipal water pipe and sewer;
6. there is no building prohibition enacted according to the sections 53 or 58.4 of the Land Use and Building Act;
7. the building site is owned by one owner, i.e. the building site is owned by one natural or legal person or more than one natural or legal persons own a quotient of such building site in a joint ownership.

Table 1 shows the evolution of the proportion of the municipalities that have adopted the new higher real estate tax percentage for undeveloped residential building sites. In year 2001, roughly 11% of the municipalities adopted the new system and this proportion has increased ever since: In 2007 almost 30% of the municipalities have adopted the new additional real estate tax rate. It should be noted that in 2006, the share of municipalities with this additional real estate tax rose from circa 20% to over 27%, largely because the government forced 14 municipalities in the Greater Helsinki Area to adopt this new amendment. [Lyytikäinen, 2007]

Table 1. *The proportion of municipalities with three-rate real estate tax system.*

Year	2000	2001	2002	2003	2004	2005	2006	2007
Three-rate real estate tax system (%)	0	10.6	12.8	14.5	18.1	19.8	27.3	29.4

Local income tax and corporate tax revenues are the main sources of revenue for the Finnish municipalities. When compared to these sources, the amount of real estate tax is minimal. In 2005, the total municipality tax revenue was 2,700 € per person, while the building tax revenue was only 41 € per person and the general real estate tax revenue was 84 € per person. Although the pre-development land tax rates are much higher than other real estate taxes, the tax base of the pre-development tax is so narrow that these revenues are negligible compared to other real estate taxes. [Lyytikäinen, 2007]

3 Overview of the Finnish Housing Markets

According to the Central Statistical Office of Finland, there were 2.38 million dwellings in Finland in 2003. From these 1.50 million (63.1%) were owneroccupied and 0.793 million (33.4%) were rental dwellings. About half of the rental dwellings are privately financed and the other half are government-subsidized. The relative amount of rental dwellings increased significantly from year 1985, when their corresponding relative amount was 26.0%.

The stock of dwellings increased steadily by about one percent from 1985 to 2003. Our dwelling stock is relatively speaking young: 61% of the current dwelling stock were constructed in the 1970's or after that. There were 1.36 million buildings in 2004 in Finland. 86% of them were residential buildings and the majority of them were detached and semi-detached houses. The total floor area of these buildings was 395.80 million square meters. In 2003, 45% of the housing production were concerned with apartment houses, 30% detached and semi-detached houses and 15% terraced houses. The relative amount of apartment houses in the housing production has significantly increased (over 15%) from 1990. [the Central Statistical Office of Finland]

There was a strong overheating of the whole Finnish economy in the late 1980's, which was followed by a deep depression in the beginning of 1990's. This has influenced heavily on housing markets also. In 1987 the real average unit price of a dwelling in Finland was circa 1,100 €, in 1989 already over 1,500 € and when the depression hit the economy in the beginning of the 1990's, the real average unit price of a dwelling sunk finally under 900 € during the years 1993–1996. After 1997 the house prices began to rise again and in 2003 the real average unit price of a dwelling was 1,370 €. This increase has continued during recent years. Rents in housing markets have also experienced changes in last 20 years. Real average unit rent of a dwelling was 4.60 € in 1987 and after that the real average unit price has rised quite steadily reaching 7.60 € in 2003. During the last couple of years this increase has continued. In the turn of the 80's and 90's about 60,000 new dwellings were constructed each year whereas in the 2000's the amount of new dwellings has been under 30,000 each year. [the Central Statistical Office of Finland]

In 2004, the number of households who lived confined was 0.25 million and the number of persons who lived confined was 1.04 million, which is 20% of the total population in Finland. On average the households had a living area of 79 square meters, which is 37 square meters for a single person. [the Central Statistical Office of Finland]

The estimated demand for new dwellings is circa 12,000 dwellings each year in the province of Uusimaa (which consists of 24 municipalities), mainly in the Greater Helsinki Area. The amount of constructed new dwellings has been varying in the province of Uusimaa from 8,500 to 10,500 per year [Vanhanen, 2005]. Mainly because the supply of dwellings has been too low in relation to existing demand in the Greater Helsinki Area and especially in the Helsinki Metropolitan Area, the prices of houses have been rising there faster than in the other parts of the Finland. In the 1st quarter of 2005 the average unit price of a used apartment house was about 2,400 € in the Helsinki Metropolitan area, whereas outside this area it was only 1,200 €. [the Central Statistical Office of Finland]

In the City of Espoo, the study area of this paper, the change in the prices and rents of dwellings has been even more dramatic. In the 1st quarter of year

1985, the average nominal unit price of apartmets was 921 € and the quality-adjusted apartment price index was 118.1 in Espoo. In the 3rd quarter of 2007, the corresponding average nominal unit price was 2,747 € and corresponding index value was 349.2. The average nominal unit price of apartments has increased by 198% in circa 23 years in the city of Espoo, and the apartments' price index has risen by 196% in the same time period and in the same market area. The average nominal unit rent of dwellings in the city of Espoo in year 1985 was 3.35 € and in year 2006 9.81 €. This means that the nominal rents of dwellings have increased by 193% in 22 years. [the Central Statistical Office of Finland]

4 Research Problem

This paper investigates empirically whether the new additional real estate tax for unbuilt residential building sites has led to an increased housing supply. The study uses observations from the local markets of the city of Espoo, where the use of a higher tax rate for undeveloped residential land become obligatory in year 2006. The amendment of year 2006 is a part of the Finnish government's six degree measures program, which aims to increase housing supply and moderate house prices. To reach this goal, the following measures were suggested [Government Proposition for the State Budget, 2006]:

1. amendments of the taxation of unbuilt building sites;
2. some kind of compulsion for municipalities to draft local plans;
3. a reduction of the possibilities to appeal against a plan;
4. speeding up of the appeal process by increasing the monetary resources of the appellate authority;
5. supporting of the building of municipal infrastructure in areas where it would lead to increasing supply of building land; and
6. planning of residential areas on state-owned land.

The city of Espoo is a part of the Helsinki Metropolitan Area, which on the other hand is a part of the Greater Helsinki Area[4]. The total population of Espoo is 232,000, which makes it the second largest city in Finland.

5 Previous Research

According to the theoretical literature about land owners' development decisions, a real estate tax system with different tax rates on undeveloped and developed land, a higher tax rate on undeveloped land should hasten the development [see e.g. Turnbull, 1988; Capozza & Li, 1994].

There have been some empirical studies on the effect of the two-rate property taxes on construction activity. Most of the studies are done in the US markets and use the number of the building permits as a dependent variable, as a proxy for housing construction activity. Mathis & Zech [1982; 1983] undertook a cross-sectional analysis of the influence of the ratio of the taxes of land and structures among 27 cities in Pennsylvania, US, in the 1970's. They were unable to detect

[4] The Helsinki Metropolitan Area includes four municipalities: Helsinki, Espoo, Vantaa and Kauniainen.

a statistically significant relationship on the effect of the two-rate property taxes on construction activity. The empirical study due to [Tideman & Johnson, 1995] that used panel data between 1980 and 1994 for all 53 Pennsylvania cities also did not show a statistically significant effect of the two-rate property taxes. Bourassa [1987; 1990] performed separate time series analyses for three Pennsylvania cities that had adopted two-rate property taxes; As a result he was unable to provide definitive results that a higher tax rate on land led to more construction activity. Pollakowski [1982], Batt [1995] and Oates & Schwab [1997] analysed the situation in Pittsburg, US, and found no clear evidence that the two-rate property tax increased construction in the study periods. Contrary to the previous research Plasmann et al. [2000] found that a difference between tax on land and on buildings had a positive effect on the number of building permits.

In Finland, the recent study due to the [Lyytikäinen, 2007], is the first one which empirically investigates the effect of the three-rate property taxation on the number of housing starts, a used proxy for new housing construction. He found evidence that the three-rate property taxation system increased single-family housing starts annually by roughly 10% on average. However, the Greater Helsinki Area was not included in the study because of the differences compared to the voluntary of the three-rate taxation system. Falkenbach et al. [2006] conduct-ed a survey in the city of Espoo among the owners of unbuilt building sites and concluded that the "as people are expecting land prices to keep increasing, at least at a moderate rate, the effectiveness of the additional real estate tax is also doubtful".

6 Research Methodology

Time is an important attribute that causes variability in the observed series of a dependent variable in property markets. Time itself is directly an unobserved quantity, i.e. time is a latent variable. What we can observe are different states that occur in a predefined submarket and changes that they cause in a dependent variable in that market area. Temporal variation is a result of changing market conditions, which are driven by, among others, changes in consumers' preferences, investors' expectations, technological advantages, income changes and interest rate changes. The temporal variation can be understood as representing that part of variation that is more or less common to all variables in the same submarket.

In modelling the time series or temporal variation of series it is important to understand that the behaviour of series over time, which is also typical of wider range of economic time series, is generally nonstationary or transient, meaning that the data-generating process itself evolves over time. More specifically, nonstationarity denotes the general sense of processes whose first two moments (conditional expectation and the variance of its error distribution) are not constant over time[5]. This dynamic nature of data-generating processes is attributable to

[5] There are in fact two common definitions of stationarity. Weak or covariance stationarity refers to the situation where the first two moments (mean and variance) of the series are time-independent, whereas strict stationarity refers to the situation where all moments

changes in economic environments, technological progress, political shifts, cultural movements, etc.

The effect of temporal variation is also multidimensional: Often one can legitimately separate the trend, the cycle, the seasonal variability and the irregular variability from each other. The trend can be understood as that part of the series that when extrapolated gives the clearest indication of the future long-term movements; it can be linear or nonlinear. The simplest choice of a trend would be a deterministic linear time trend, but this usually is too restrictive, unless the time period is very short [Harvey, 1997]. Cycles are characteristic to many economic time series as the economy goes from boom to recession and back again. More specifically, the cycle refers to the ups and downs seen somewhat simultaneously in most parts of a local market; it involves shifts over time between periods of relatively rapid growth of a dependent variable alternating with periods of relative decline. Seasonals represent patterns of change in a time series within a year; they tend to repeat themselves each year. Irregular variability is the unexplainable or random variability of the series.

In this study structural time series (or unobserved component) models are used to determine whether the housing construction really increased in the city of Espoo since 2005. The structural time series approach is a viable tool, which can separate long-term price movements (trends and cycles) from seasonal and irregular variability. They are suitable for the analysis of nonstationary features of series, in which the time interval need not be equispaced (i.e. a time series is simply a set of observations ordered in time). In essence, structural time series models can be thought of as a certain type of generalized regression models in which explanatory variables are functions of time and the parameters are time-varying [Harvey 1989, p. 10; Harvey & Shephard, 1993; Harvey, 1997]. More precisely, structural time series models can be understood as semiparametric estimators that combine many of the benefits of parametric and nonparametric estimators; temporal variability of series is estimated in a nonparametric fashion, which permits the effect of time to be linear, convex and concave in different regions, whereas the hedonic prices of attribute variables are estimated in a parametric manner. In a structural model an explicit stochastic trend is assumed in which the level and slope coefficient are allowed to evolve over time. When using structural time series models, cycles are modelled effectively by means of a mixture of sine and cosine waves.

When considering the determination of the temporal dimension, there are several benefits in using the structural time series approach and the associated state space form as compared to the Box-Jenkins ARIMA methodology. These include [Harvey & Shephard, 1993; Harvey, 1997; Durbin & Koopman, 2002, p. 51–53]:

– *Structural analysis of the problem*. Different components that make up the series, including the regression elements, are modelled explicitly when, in contrast, the Box-Jenkins approach is a sort of "black box". A structural

(not just the mean and variance) are constant. In this study stationarity refers to the weak stationarity and thus nonstationarity is the situation where the first two moments of the series are not constant in time.

model provides not only the forecasts of the series but also presents a set of stylised facts. Also a structural model can be handled within a unified statistical framework that produces optimal estimates with well-defined properties.

– *Management of nonstationarity*. In a structural model nonstationarity (transitory parts of the model specification) can be handled conveniently by unobserved components without the need of differencing any variables. By comparison, in the Box-Jenkins approach stationary is assumed, and nonstationary components of the series are usually eliminated by differencing the variables, which results to a potential loss of valuable long-term information. Furthermore, the standard unobserved component models are simple, yet effective, leading to parsimonious representations for the systems.
– *Generality*. Multivariate observations can easily be handled with structural models, which cover as special cases a wide range of econometric models (including all ARIMA models). Explanatory variables can be introduced into the model structure and the associated regression coefficients (hedonic prices) can be permitted to vary stochastically over time if needed. Different kinds of intervention variables, e.g. impulse and level interventions, can be specified and lagged values of dependent as well as explanatory variables can be incorporated to a model. Missing observations and varying dimensionality of observations are issues that are straightforward to deal with in structural models.

7 Empirical Study

In this section are described in detail the data set, variables, estimation models and obtained results. The empirical analysis is based on two common hedonic models, the double-log model and the error correction model, which give the specification of regression effects. In addition, these basic model specifications contain unobserved components in order to encapsulate the intrinsic temporal movement in the series as precisely as possible.

7.1 Research Data

The data set of the empirical study was mainly obtained from the Central Statistical Office of Finland. Some additional information was provided by the Bank of Finland. The data set represents a time series, in which the time period is spanning from the 1st quarter of 1991 to the 2nd quarter of 2007. The data about different dependent variables is quartely and the total number of observations is 66 (which is sufficiently large for a hedonic analysis). Some information about the explanatory variables is available only annually. The observations are collected from the city of Espoo, a highly polycentric city, which lies inside the Helsinki Metropolitan Area and has circa 232,000 habitants; its population is the second largest of the cities in Finland, which has experienced a rapid growth in its late history.

In table 2 are documented some standard sample statistics (arithmetic mean, minimum, maximum and standard deviation) for the study variables in the submarket of Espoo. The 8 different dependent variables (the number of building permits as measured by the number of buildings in a quarter, the number of building permits as measured by the volume of buildings in a quarter, the number of building permits as measured by the floor area of buildings in a quarter, the number of building permits as measured by the number of dwellings in a quarter, the number of housing starts as measured by the number of buildings in a quarter, the number of housing starts as measured by the volume of buildings in a quarter, the number of housing starts as measured by the floor area of buildings in a quarter and the number of housing starts as measured by the number of dwellings in a quarter) measure somewhat different aspects of the new housing construction activity in the Espoo.

New building permits are often used as a proxy for new housing production. Using this information includes a problem because a new admitted building permit does not necessarily mean that the actual construction starts. Therefore, it has been suggested in the literature that housing starts are better proxies for the new construction. However, the main problem with this variable is that the

Table 2. *Descriptive statistics for the study variables of the paper.*

Variable (unit)	**Arith-metic mean**	**Minimum**	**Maximum**	**Std. Deviation**
Number of building permits (number of buildings in a quarter)	346	146	632	119
Number of building permits (volume of buildings in a quarter)	466,730	137,869	1,301,055	250,954
Number of building permits (floor area of buildings in a quarter)	101,308	33941	222,626	42,507
Number of building permits (number of dwellings in a quarter)	574	211	1,091	215
Number of housing starts (number of buildings in a quarter)	290	69	594	115
Number of housing starts (volume of buildings in a quarter)	403,471	114,453	1,124,269	211,097
Number of housing starts (floor area of buildings in a quarter)	89,189	28,660	199,232	38,280
Number of housing starts (number of dwellings in a quarter)	528	120	975	218
Average quarterly unit price of apart-ments (€/m^2)	1,537	907	2,691	496
Quarterly price index of apartments	200	116	340	62
Average annual unit rent of dwellings (€/m^2)	7.9	5.2	9.8	1.5
Annual building cost index	218	195	268	22
Basic rate of interest (%)	4.6	2.3	9.5	2.0
Time dummy (= 0, before year 2006, 1 otherwise)	–	0	1	–

practice underlying registering a construction as started is mixed in the city of Espoo: There exists no uniform policy that is applied in the registration. The average quarterly unit price of apartments and the average annual unit rent of dwellings are calculated as geometric mean values and relate to the submarket of Espoo. The quarterly price index of apartments is quality-adjusted average price in submarket of Espoo. No local rent index of dwellings was obtainable for this study. The annual building cost index measures building costs (e.g., materials, work) in the whole of Finland, no local measure was available. The basic rate of index is calculated based on the 12-month market interest rate. The time dummy variable is used in measuring the effect of the three-rate real estate tax in Espoo on construction activity.

7.2 Hedonic Models

In the estimation of regression effects two different hedonic models are used. The first model is the conventional multiplicative form of double-log model:

$$y_i = e^{\beta_0} \prod_{j=1}^{k} x_{ij}^{\beta_j} \prod_{j=1}^{s} e^{\gamma_j d_{ij}} e^{\varepsilon_i} = e^{\beta_0} x_{i1}^{\beta_1} x_{i2}^{\beta_2} \cdot \ldots \cdot x_{ik}^{\beta_k} e^{\sum \gamma_j d_{ij}} e^{\varepsilon_i} \; \forall \; i \in n \tag{1}$$

in which y_i is the dependent variable, x_{ik} represents a quantitative explanatory variable, d_{ij} represents an explanatory variable which can receive only values of zero and one. β_k and γ_j represent hedonic prices. The second model is the standard error correction model:

$$\Delta \ln(y_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \Delta \ln(x_{ij}) + \sum_{j=1}^{s} \gamma_j d_{ij} + \theta' z_{i-1} + \varepsilon_i \; \forall \; i \in n \tag{2}$$

where θ denotes an error correction parameter vector; z_{i-1} represents a linear combination of attributes that possess a long-term relation to response vector and Δ is a difference operator.

Furthermore, unobserved components are used in estimating the trend and cycle components embedded in the series. The trend is estimated used using the local linear trend model:

$$\begin{aligned} y_t &= \mu_t + \varepsilon_t, & \{\varepsilon_t\} &\sim NID(0, \sigma_\varepsilon^2) \\ \mu_t &= \mu_{t-1} + v_{t-1} + \eta_t, & \{\eta_t\} &\sim NID(0, \sigma_\eta^2) \\ v_t &= v_{t-1} + \xi_t, & \{\xi_t\} &\sim NID(0, \sigma_\xi^2) \end{aligned} \tag{3}$$

The underlying level μ_t is not directly observable. It is generated by a random walk, i.e. the level term in the current period is equal to the level term in the previous period plus a level disturbance term η_t. The effect of η_t is to allow the level of the trend to shift up and down. $\sigma_\eta^2 / \sigma_\varepsilon^2$ is the signal-to-noise ratio. The stochastic slope v_t (which itself follows a random walk) allows the slope coefficients to change. If $\sigma_\xi^2 = 0$, the trend reduces to a random walk with a drift, whereas for $\sigma_\eta^2 = 0$, the trend reduces to an integrated random walk or a smooth trend model. The local level model is obtained if there are no terms including the stochastic slope.

The different cycle components are estimated using a mixture of sine and cosine waves:

$$\begin{pmatrix} \psi_t \\ \psi_t' \end{pmatrix} = \rho \begin{pmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{pmatrix} \begin{pmatrix} \psi_{t-1} \\ \psi_{t-1}' \end{pmatrix} + \begin{pmatrix} \kappa_t \\ \kappa_t' \end{pmatrix} \tag{4}$$

where κ_t and κ_t' are mutually uncorrelated with a common variance σ_κ^2. $\rho \in [\,0,1\,]$ is a damping factor. Stationary models correspond to situations where ρ is strictly less than one. A first-order autoregressive process, which is also estimated and used in this study, is an important limiting case of a stochastic cycle when a frequency λ_c is equal to 0 or π.

7.3 Estimation results of hedonic models[6]

This subsection presents the estimation results, when the dependent variable is the number of housing starts[7]. There are, in fact, four different regressands depending on what units (buildings, volume, floor area or dwellings) are applied. Here is documented only the results relating to the best-fit hedonic model.

Empirical investigation revealed that, when using the conventional double-log model specification for regression effects, the strongest and the most reliable association between the dependent variables and a set of regressors is achieved, when the number of buildings is used as a unit in housing starts. The relationships with other regressands (housing starts as measured by the volume, the floor area and the number of dwellings) are much weaker and inaccurate. Table 3 documents the estimation results when the dependent variable consists of the housing starts measured by the number of buildings.

Table 3. *Estimated unobserved components and hedonic prices (double-log model specification for regression effects, local level model for a trend specification, one cycle term + AR(1) -process).*

Variable	Coefficient	r.m.s.e	t-value	p-value
Level	24.22	2.76	8.77	0.0000
AR(1)	-0.25	0.081	NA	NA
Cycle 1 (comp. #1)	0.30	0.056	NA	NA
Cycle 1 (comp. #2)	0.11	0.058	NA	NA
Unit price index of apartments	1.34	0.20	6.61	0.0000
Average unit rent of dwellings	1.43	0.24	5.90	0.0000
Building cost index	–5.33	0.68	–7.82	0.0000

* The dependent variable is the housing starts measured by the number of buildings.

6 The constructed models are not, strictly speaking, hedonic: the only genuine hedonic element is the hedonic price index, which is used as an independent variable.

7 Housing starts are chosen as the dependent variable after some empirical experimentation. Highly similar results, which are not reported in this paper, are obtained when building permits are used as a dependent variable.

In table 3 the familiar double-log specification is used for describing the relationship between the housing starts as measured by the number of buildings and the unit price index of apartments, the average unit rent of dwellings and the building cost index[8]. These were the only regressors that were statistically significant at the usual significance level (0.05). Statistically insignificant variables (market interest rate and time dummy variable) are not included into the final hedonic model (this would bias the results) and thus their hedonic prices are not reported in the final hedonic model. The hedonic models tell that the change in the housing starts as measured by the number of buildings is over-elastic with respect to the building cost index, the unit price index of apartments and the average unit rent of dwellings. The market interest rate variable was statistically insignificant at the standard risk level (the corresponding p-value was 0.44). The time dummy variable, which measures whether the level of housing production has changed since the year 2005, was also statistically insignificant (p-value was 0.91). The very high p-value of the time dummy variable indicates that there has not been a change in the level of housing production due to the introduction the additional property tax rate in the year 2006.

In table 3, the trend term was best described by the local level model (without any slope coefficient, only a level term). The local level model here uses, in fact, a fixed trend. One cycle term, which is statistically very significant (p-value is 0.0000), with two components was included to the final model. Other cycle terms were statistically insignificant. This cycle term essentially captures the seasonal variability, since the period of the cycle is exactly one year (it shows that the maximum value is obtained in the middle of each year and the minimum value is obtained at the very beginning of each year). A 1st order autoregressive process (AR(1)) was an integral part of the final hedonic model, since it improved significantly congruence statistics.

Table 4. *Goodness-of-fit statistics (double-log model specification for regression effects, local level model for a trend specification, one cycle term + AR(1) -process).*

Goodness-of-fit statistic	**Value**
R^2	0.80
Standard error of regression	0.19
R_d^2	0.87
AIC	–2.98
BIC	–2.65
PEV	0.037
PEMD	0.028

Table 4 presents some fundamental information of the relevant goodness-of-fit statistics. In essence, the hedonic model appears to be adequate. Both coefficients of determinations are above the usual cut-off rate of 0.70 commonly applied in

8 Degrees of freedom are 63 in table 3.

property valuation and investment in Finland[9]. Furthermore, the standard error of regression is clearly below the cut-off rate of 0.30 that is commonly used in Finland. Prediction error variance and prediction error mean deviation measures are minimal. Overall, the hedonic model seems to possess quite good fit.

The normality tests indicate that residuals are slightly non-normally distributed (p-values of test statistics are in the range 0.01–0.04). One large outlier was detected (its standardised residual was –3.70). This was, however, not removed from the final hedonic model because this would significantly lower the congruence statistics. No evident autocorrelation is observed in the correlogram. The CUSUM and CUSUMSQ statistics indicate that there is no significant change in the mean and the variance of the process underlying the generation of housing starts as measured by the number of buildings. There is some evidence about a multicollinearity problem since two VIF-values (which are calculated without the unobserved components) lie around the value of 10. This might distort the final analysis.

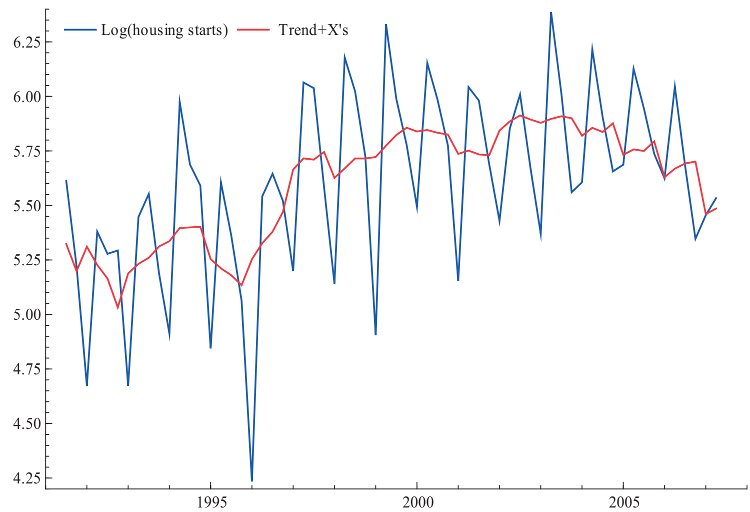

Figure 1. *Hedonic model's approximation to the log of housing starts (double-log model for regression effects, local level model for a trend specification, no cycles and no AR(1) -process).*

Figure 1 depicts the estimated hedonic model (named as "Trend+X's") when a double-log model is used for regression effects and a local level model is used for a trend specification (cycles are not included in this figure to make interpretation easier). It can be detected from figure 1 that there is a downward movement in the series of log(housing starts) from circa year 2004 to the present moment.

9 A very large portion of the variability of the dependent variable is explained by the unobserved components. For example, the standard coefficient of determination is only 0.36 when no unobserved components are present in the hedonic model and R^2 increases to 0.80 when the estimated model includes unobserved components.

In table 5 the standard error correction model is used for describing the relationship between the housing starts as measured by the number of buildings, the unit price index of apartments and the error correction term[10]. These were the only regressors that were statistically significant at the usual significance level (0.05) in the final hedonic model. Statistically insignificant variables (market interest rate and time dummy variable) do not appear in the final hedonic model, not in the error correction term or otherwise (the inclusion would bias the results) and thus their hedonic prices are not reported in the final hedonic model. The building cost index and the unit rent of dwellings only appear in the error correction term and thus do not possess a short-term influence on the level of housing construction. The hedonic model indicates that there is a long run relationship between the variables comprising the error correction term (i.e. the apartment unit price index, the building cost index and the unit rent of dwellings) and the dependent variable. The long term and short run effects of the market interest rate variable were statistically insignificant at the standard risk levels (the long term p-value was 0.43 and the short term p-value was 0.60). The time dummy variable, which measures whether there has been a change in the level of housing production since the year 2005, was also statistically insignificant at the short term (p-value was 0.77) and at the long term (p-value was 0.91). This implies that the introduction of the three-rate property tax in the beginning of the year 2006 has had no effect on the new housing supply.

Table 5. *Estimated unobserved components and hedonic prices (error correction model specification for regression effects, local linear trend model for a trend specification, one cycle term + AR(1) -process).*

Variable	Coefficient	r.m.s.e	t-value	p-value
Level	–0.081	0.038	–2.15	0.0358
Slope	–0.0019	0.00099	–1.86	0.0673
AR(1)	0.052	0.046	NA	NA
Cycle 1 (comp. #1)	0.26	0.060	NA	NA
Cycle 1 (comp. #2)	0.14	0.073	NA	NA
Unit price index of apartments	2.34	0.57	4.11	0.0001
Error correction	–0.88	0.12	–7.42	0.0000

* The dependent variable is the housing starts measured by the number of buildings.

In table 5, the trend term was best described by the local linear trend model (with level and slope terms). The p-value for the slope term is, strictly speaking, statistically insignificant at the standard risk level. However, this is an important part of the overall model here because it improves the congruence statistics significantly. The local linear trend model indicates a decreasing trend. One cycle term, which is statistically very significant (p-value is 0.0000), with two components was included to the final model. Other cycle terms were statistically insignificant. This cycle term essentially captures the seasonal variability, since the period of the cycle is exactly one year (it shows that maximum value is obtained in

[10] Degrees of freedom are 64 in table 5.

the middle of each year and the minimum value is obtained at the very beginning of each year). A 1st order autoregressive process (AR(1)) was an integral part of the final hedonic model, since it improved significantly congruence statistics.

Table 6 presents some fundamental information of the relevant goodness-of-fit statistics. In essence, the hedonic model appears to be adequate. Both coefficients of determinations are above the usual cut-off rate of 0.70 commonly applied in property valuation and investment in Finland. Furthermore, the standard error of regression is clearly below the cut-off rate of 0.30 that is commonly used in Finland. Prediction error variance and prediction error mean deviation measures are minimal. Overall, the hedonic model seems to possess quite good fit that is improved from the hedonic model of table 8.

Table 6. *Goodness-of-fit statistics (double-log model specification for regression effects, local level model for a trend specification, one cycle term + AR(1) -process).*

Goodness-of-fit statistic	**Value**
R^2	0.91
Standard error of regression	0.16
R_d^2	0.97
AIC	–3.41
BIC	–3.08
PEV	0.024
PEMD	0.018

All normality tests indicate that residuals are normally distributed (p-values of test statistics are in the range [0.24, 0.26]. No large outliers are detected (all standardised residuals are below 3). No autocorrelation is observed in the

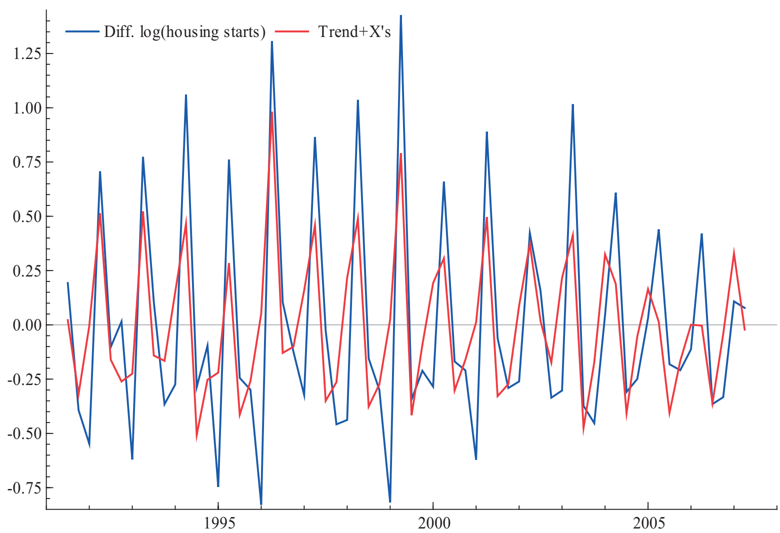

Figure 2. *Hedonic model's approximation to the differenced log of housing starts (error correction model for regression effects, local linear trend model for a trend specification, no cycles and no AR(1) -process).*

correlogram. The CUSUM and CUSUMSQ statistics indicate that there is no change in the mean and the variance of process underlying the generation of housing starts as measured by the number of buildings. Furthermore, there is no evidence about multicollinearity since all VIF-values (which are calculated without the unobserved components) are 1. All in all, these considerations mean that the estimated hedonic model is statistically quite reliable as the basic assumptions underlying the model are mainly fulfilled.

Figure 2 depicts the estimated hedonic model (named as "Trend+X's") when an error correction model is used for regression effects and a local linear trend model is used for a trend specification (cycles are not included in this figure to make interpretation easier). It is a bit difficult to detect from figure 2 whether there is a downward movement in the series of differenced log(housing starts), but it seems that movement is mainly downward from circa year 2003.

7.4 Tobin's q-theory and housing construction

James Tobin [1969] presented about 40 years ago that the investment rate should be related to the ratio of the capital value to the replacement cost, the so-called q-ratio. In housing markets, this ratio can be estimated as a ratio of the housing prices to building costs. This subsection examines whether housing construction can be explained by the q-ratio.

Table 7 summarizes the information about unobserved components and hedonic prices, when a double-log model was used for measuring the regression effect, local linear trend model was used for a trend specification, one cycle term was used and an AR(1) -process was also included. The strongest association was found when housing starts as measured by the number of buildings were used as a dependent variable. Table 11 also shows that are three impulse intervention variables included into the final hedonic model, since they are statistically significant and improve the model's congruence somewhat[11].

Table 7. *Estimated unobserved components and hedonic prices (double-log model specification.*

Variable	Coefficient	r.m.s.e	t-value	p-value
Level	–7.29	2.40	–3.04	0.0034
Slope	–0.069	0.032	–2.15	0.0356
AR(1)	–0.067	0.055	NA	NA
Cycle 1 (comp. #1)	0.21	0.052	NA	NA
Cycle 1 (comp. #2)	0.038	0.055	NA	NA
Tobin's q-ratio	12.16	2.29	5.30	0.0000
Intervention #1	0.42	0.13	3.17	0.0024
Intervention #2	–0.40	0.12	–3.22	0.0021
Intervention #3	–0.41	0.12	–3.45	0.0010

*The dependent variable is the housing starts measured by the number of buildings.

[11] Degrees of freedom are 62 in table 7.

Table 8 presents some fundamental information of the relevant goodness-of-fit statistics of the hedonic model in table 11. In essence, the hedonic model appears to be adequate. Both coefficients of determinations are above the usual cut-off rate of 0.70 commonly applied in property valuation and investment in Finland. Furthermore, the standard error of regression is clearly below the cut-off rate of 0.30 that is commonly used in Finland. Prediction error variance and prediction error mean deviation measures are minimal.[12]

Table 8. *Goodness-of-fit statistics (double-log model specification for regression effects, local linear model for a trend specification, three cycle terms + AR(1) -process).*

Goodness-of-fit statistic	**Value**
R^2	0.85
Standard error of regression	0.17
R_d^2	0.90
AIC	–3.19
BIC	–2.75
PEV	0.028
PEMD	0.022

Diagnostic checking of the model in tables 7–8 reveals that the residuals are approximated by the normal density function (corresponding p-values of different normality tests are high and in the range of [0.45, 0.55]. Three potential outliers were detected and their effect was modelled by using impulse intervention variables. This procedure improved the model's congruence statistics somewhat. No significant autocorrelation was detected by visually inspecting the correlogram. The CUSUM and CUSUMSQ statistics indicate that there is no change in the mean and the variance of process underlying the generation of housing starts as measured by the number of buildings. Furthermore, multicollinearity is no problem because there is only one observable variable in the model.

Figure 3 depicts the estimated hedonic model (named as "Trend+X's") when a double-log model is used for regression effects and a local linear trend model is used for a trend specification (cycles are not included in this figure to make interpretation easier). The figure shows that there is a clear downward movement in the series starting in year 2005.

Table 9 summaries the information about unobserved components and hedonic prices, when the standard error model was used for measuring the regression effect,

[12] Here a very large portion of the total variation in the dependent variable is explained by the unobserved components. The standard coefficient of determination is only 0.37, when the hedonic model does not contain any unobserved components, but rises to 0.85 when unobserved components are included into the final model.

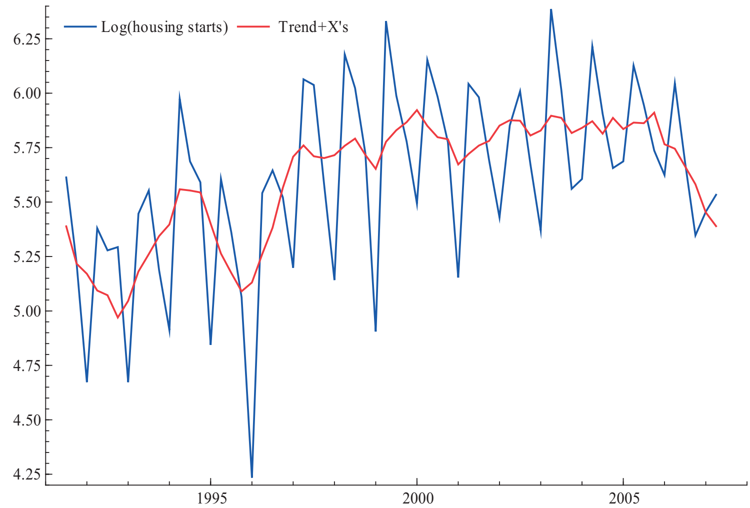

Figure 3. *Hedonic model's approximation to the log of housing starts (double-log model for regression effects, local linear trend model for a trend specification, no cycles and no AR(1) -process).*

a local linear trend model was used for a trend specification and two cycle terms were used. The strongest association was found when housing starts as measured by the number of buildings were used as a dependent variable[13]. In table 9 there is also one significant impulse intervention variable whose estimation improved congruence statistics a bit[14].

Table 10 presents some fundamental information of the relevant goodness-of-fit statistics of the hedonic model in table 9. In essence, the hedonic model appears to be adequate. Both coefficients of determinations are above the usual cut-off rate of 0.70[15]. Furthermore, the standard error of regression is clearly below the cut-off rate of 0.30. Prediction error variance and prediction error mean deviation measures are minimal. As compared to the model in table 8, the coefficients of determination statistics are now improved a bit as are the AIC and BIC measures. However, other goodness-of-fit statistics are slightly worse in the case of table 8.

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13 Degrees of freedom are 64 in table 9.

14 The slope coefficient, strictly speaking, is not statistically significant at the usual risk level. However, this is included into the final hedonic model because its inclusion improves the model's congruence.

15 Here a significant portion of the total variation in the dependent variable is explained by the unobserved components. The standard coefficient of determination is only 0.49, when the hedonic model does not contain any unobserved components, but rises to 0.87 when unobserved components are included into the final model.

Table 9. *Estimated unobserved components and hedonic prices (error correction model specification for regression effects, local linear trend model for a trend specification and three cycle terms).*

Variable	Coefficient	r.m.s.e	t-value	p-value
Level	–0.50	0.15	–3.29	0.0017
Slope	–0.046	0.024	–1.89	0.0631
Cycle 1 (comp. #1)	0.13	0.072	NA	NA
Cycle 1 (comp. #2)	0.27	0.073	NA	NA
Cycle 2 (comp. #1)	–0.37	0.15	NA	NA
Cycle 2 (comp. #2)	–0.057	0.20	NA	NA
Error correction	–1.86	0.061	–30.36	0.0000
Intervention #1	0.36	0.13	2.89	0.0053

* The dependent variable is the housing starts measured by the number of buildings.

Table 10. *Goodness-of-fit statistics (error correction model specification for regression effects, local linear model for a trend specification and two cycle terms).*

Goodness-of-fit statistic	Value
R^2	0.87
Standard error of regression	0.19
R_d^2	0.95
AIC	–2.93
BIC	–2.53
PEV	0.037
PEMD	0.030

Diagnostic checking of the model in tables 9–10 reveals the residuals are approximated by the normal density function (corresponding p-values of different normality tests are high and in the range of [0.55, 0.66]. One potential outlier was detected and its effect was modelled by using an impulse intervention variable. This procedure improved the model's congruence statistics slightly. There is no evidence of autocorrelation. The CUSUM and CUSUMSQ statistics indicate that there is no change in the mean and the variance of process underlying the generation of housing starts as measured by the number of buildings. Furthermore, multicollinearity is no problem because there is only one observable variable in the model.

Figure 4 depicts the estimated hedonic model (named as "Trend+X's") when an error correction model is used for regression effects and a local linear trend model is used for a trend specification (cycles are not included in this figure to make interpretation easier). In this figure there is no visually discernible change occurred in the series, the process seems to fluctuate quite randomly around the null value.

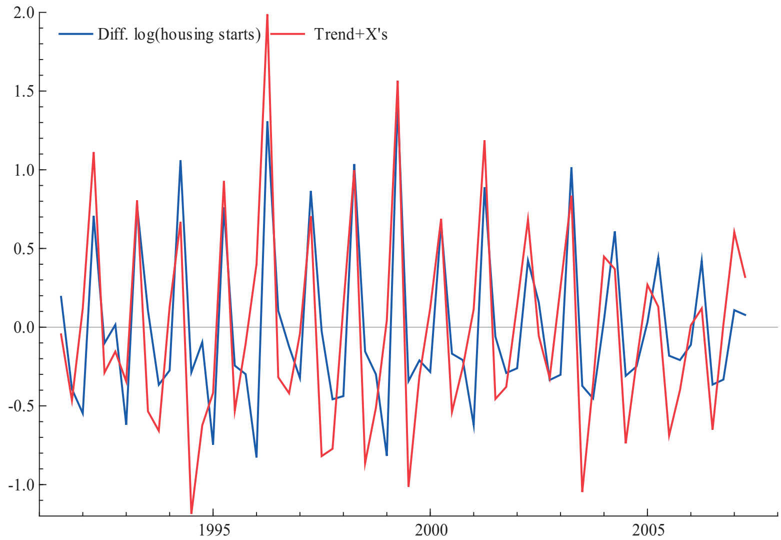

Figure 4. *Hedonic model's approximation to the differenced log of housing starts (error correction model for regression effects, local linear trend model for a trend specification and no cycles)*

8 Conclusions

This paper has empirically investigated the effect of three-rate property taxation on housing construction in the city of Espoo, Finland. After year 2005 a higher real estate tax has been in force for undeveloped residential building sites in the Greater Helsinki Area. The decision makers are hoping that this will lead to increases in the supply of housing.

The empirical investigation witnessed that no statistically discernable change has occurred in the amount of new construction since 2005 in the Espoo submarket area. All hedonic model formulations supported this view. This means that the higher real estate tax has not achieved so far its goals in improving the housing supply and thus moderate house prices in the Espoo case. This is understandable because recent increases in the prices of building sites have been much higher that the cost of the additional real estate tax. It therefore seems that as long as land prices keep rising fast, there is no significant effect of the additional real estate tax on new housing supply.

In this study the most data-congruent hedonic models could be estimated by using housing starts, as measured by the number of buildings, as a dependent variable. Statistically the apartment unit price index, the building cost index and the unit rent of dwellings possessed a significant relationship to the housing starts. The market interest rate, on the other hand, did not have a statistically significant effect on the number of housing starts. Using a standard error correction model in order to capture the regression effects resulted to a slightly more data-congruent hedonic model when compared to the fit of a conventional double-log model. Overall, the fits of chosen hedonic models were good and most of the congruence requirements were satisfied with a given data set. This implies that the results of the study are quite reliable.

The use of unobserved components significantly enhanced the hedonic model's data congruence. Without them the resulting estimated models would possess a fit that in many respects is poor and does not reach the desired modelling goals. The study showed that cycles and trends were an integral part of an overall hedonic model in all cases studied. The effect of time is clearly nonstationary, which means that the analysed market is not in a steady state, but continuously evolving.

The paper also studied Tobin's q-theory and its relevance to modelling housing construction. The empirical investigation showed that the q-ratio, which can be estimated as a ratio of housing prices to building costs, significantly explained the changes in housing construction activity. The q-ratio and unobserved components explained 85–95% (depending on the overall model structure) of the total variability of the actual housing starts.

Finally, it should be noted that the time period in which the three-rate property tax has been in force, is only six quarters in this study. It is possible that the impact mechanism of this tax is so that the necessary adjustment can only be seen in a longer time frame.

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