EFFICIENCY OF THE REAL ESTATE MARKET: A META-ANALYSIS

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Informational efficiency of the real estate market: A meta-analysis

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Abstract

The growing empirical literature testing informational efficiency of real estate markets uses data from various contexts and at different levels of aggregation. The results of these studies are mixed. We use a distinctive meta-analysis to examine whether some of these study characteristics and contexts lead to a significantly higher chance for identification of an efficient real estate market. The results generated through meta-regression suggest that use of stock market data and individual level data, rather than aggregate data, significantly improves the probability of a study concluding efficiency. Additionally, the findings neither provide support for the suspicion that the view of market efficiency has significantly changed over the years nor do they indicate a publication bias resulting from such a view. The statistical insignificance of other study characteristics suggests that the outcome concerning efficiency is a context-specific random manifestation for the most part.

Keywords: real estate; market efficiency; meta-analysis; logistic model; mixed-effects

JEL Classification: G14, G12, R21, R31

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1 Introduction

Real estate assets demarcate a substantial part of the accumulated wealth of modern economies and of individual households. The real estate market is also an essential element within the overall market system. It relates closely to financial markets where on the one hand loans for real estate investments are a major product and, on the other hand, real estate is an important form of security. The land market guides location decisions and land use patterns and thus substantially influences the responses to infrastructure needs and environmental hazards, and energy consumption. Structural inefficiencies of the real estate market therefore can have far reaching consequences for wide areas of the economy. The recent economic crisis serves as an illustration of this point.

In the economic literature, there is a prolonged discussion as to whether or not asset markets, including the real estate market, are efficient. As generally acknowledged, an efficient market is one in which an allocation of resources is 'pareto efficient' such that no reallocation of resources is possible to make someone better off without making another worse off. The financial economics literature additionally defines three distinct, albeit inter-related, conceptions of efficiency — 'allocative efficiency', 'informational efficiency' and 'operational efficiency'. All these notions of efficiency have implications for the optimal distribution of resources in an economy:

- allocative efficiency indicates that price is a good estimate of the fundamental value of an asset;
- informational efficiency states that market prices fully reflect all relevant information; and
- operational efficiency states that market participants are provided with the least possible cost to perform transactions in the market.

The focus of the present paper is on informational efficiency although allocative efficiency and operational efficiency have important implications for our understanding of informational efficiency (see the detailed discussion in Section 2). Thus the term 'efficiency' hereafter refers to informational efficiency.

Informational efficiency of real estate markets has been widely discussed over the past few decades, particularly since the inception of ideas surrounding the Efficient Market Hypothesis (EMH). These deliberations can generally be split into two broad categories: one branch of studies presents numerous theoretical arguments scrutinizing informational efficiency while the other branch presents empirical investigations of this phenomenon using data and statistical techniques. Studies within this empirical strand analyses diverse real estate market segments in different countries, cities and regions. They not only use data of different levels of aggregation but also cover a time span of more than twenty-five years[3].

Despite the tendency of theoretical literature to indicate informational inefficiency, findings within the empirical literature on informational efficiency of the real estate market are by no means conclusive. Therefore, the present paper performs a meta-analysis to find out whether some of the parameters (study characteristics) of these analyses make the conclusion of an efficient real estate market more (or less) likely. The parameters distinguished include time since publication, type of property, scale of analysis, geography, type of market, aggregation level of data and the type of investigation—our intention is to include as many dimensions as possible so that all possible study dynamics are represented. By using a meta-analysis, the informational efficiency of real estate markets is statistically scrutinized. To the authors' knowledge, this is the first meta-analysis in the context of real estate market efficiency.

Based on our study parameters, the enquiry allows us to address two broader research questions, and within them several specific research questions:

(a) are there statistically significant determinants of informational (in) efficiency?

i. are studies analysing the market for income generating real estate more likely to find efficiency than studies that examine residential markets?

ii. does the scale of analysis (e.g. local, regional, national or international) influence the study outcome concerning efficiency?

iii. do studies analysing US real estate markets have a higher chance

3 See Gatzlaff and Tirtiroglu (1995), Cho (1996) and Maier and Herath (2009) for more extensive reviews on this topic.

of finding inefficiencies than studies using European or Asian data?

iv. are studies on urban real estate markets more likely to find evidence supporting efficiency?

v. does the use of aggregate and individual data influence the outcome of studies?

vi. does a specific type of investigation favour outcomes confirming 'efficiency'?

(b) has the perception of informational efficiency of real estate markets changed over the years so that more recent studies have a higher or lower chance of reporting efficiency than earlier studies?

Findings of this research bear practical implications for both the individual investor as well as the economy in general. Firstly, if a particular real estate market is informationally inefficient, then an informed individual investor can outperform the market in terms of information that is not capitalised into prices using active strategies that identify mispriced assets. In other words, this suggests that one cannot succeed systematically and the trade strategies cannot earn abnormal profits within efficient markets. Second, from an investor's perspective, there are numerous investment vehicles to choose from within the broader real estate asset markets, and the knowledge of relative informational efficiency and the price volatility of particular sub-markets are useful in making informed decisions about optimal investment choices. Therefore, if markets are efficient, the buyers—either investors or prospective home-owners—are less likely to incur costs and efforts to assess the optimal time to enter a specific market. In contrast, a buyer may benefit from weighing the optimal entry point if markets are inefficient.

With respect to the aggregate economy, if prices reflect all the information and send accurate signals to the market, then the limited resources will be effectively allocated to their best use. As a result, most productive investments yielding the highest risk-adjusted return will attract funds. The study of market efficiency is therefore important in order to evaluate the distribution of resources and general economic welfare within an economy. Additionally, it enhances our understanding of how different market segments operate, and this can shed light on how to improve the institutional facets of particular market segments. This kind of enquiry is also fundamental in developing economic theory including investment

theory, the valuation theory and urban and spatial economics through the knowledge it generates about the role of information within these market processes.

The paper is structured as follows: Section 2 briefly discusses the concept of informational efficiency and different forms of market efficiency as defined by the Efficient Market Hypothesis (EMH). Section 3 discusses meta-analysis, the approach used in order to shed light on the issue of informational efficiency. Section 4 and section 5 present the dataset used and the results of the analysis. Section 6 concludes the paper.

2 The efficient market hypothesis and the real estate market

The issue of what characterizes an efficient market was first systematically discussed in the late 1960s and early 1970s (see Samuelson 1965; Fama et al. 1969; Fama 1970). These ideas—formerly known as the Efficient Market Hypotheses (EMH)—stated that a market is efficient when prices adjust rapidly to new information (Fama et al. 1969). This indicates that changes in asset prices follow a random pattern and that future prices cannot be predicted based on past prices and/or other public and non-public information. If one follows this hypothesis, there will be no incentives for speculation.

As emphasized within the EMH, an efficient market is one where prices "fully reflect all available information" (Fama 1991, pp. 1575). This "implies that the market processes information rationally, in the sense that relevant information is not ignored, and systematic errors are not made" (Beechey et al. 2000, pp. 2). The frequently quoted definition of Malkiel (1996) also summarises the specific role of information:

> A capital market is said to be efficient if it fully and correctly reflects all relevant information in determining security prices. Formally, the market is said to be efficient with respect to some information set (...) if security prices would be unaffected by revealing that information to all participants. Moreover, efficiency with respect to an information set (...) implies that it is impossible to make

economic profits by trading on the basis of "that information set".

This definition of Malkiel highlights that market efficiency depends on a specific information set, referring to efficiency not as an absolute characteristic of a market, but rather a relative conception based on a certain information set.

Fama (1970) defined three forms of efficiency based on what type of information is contained in the relevant information set. These three forms—weak, semi-strong and strong—indicate that this information set can vary from just past prices to all publicly available information to non-public information such as insider information. For instance, in the weak form, the relevant information set consists of only past prices. The weak form of the EMH therefore states that it is not possible to predict future prices based on previous price movements. The semi-strong form takes into account all publicly available information including past prices and contends that a market is efficient when prices fully reflect all this information. The strong form of the EMH states that even non-public information is fully incorporated into prices. Therefore, in a strongly efficient market, revealing this non-public information will not change the prices. Fama (1965) and Samuelson (1965) referred to financial markets—particularly the stock market and the foreign exchange market—when they used the term 'market'. Over the years, these markets received most attention in terms of efficiency tests investigating mainly the weak and semi-strong form versions of the EMH.

As far as financial markets are concerned, the hypothesis that these markets are efficient (EMH) gained strong support early on. Within a decade, the EMH was so well established that Jensen (1978) was prompted to write that he believed there to be "no other proposition in economics which has more solid empirical evidence supporting it" (Beechey et al. 2000, pp.21). However, after thirty years of research in the context of financial markets, the EMH has received some criticism. Beechey et al. (2000) provide a summary of issues that cast doubts on the efficiency of financial markets.

2.1 Theoretical arguments concerning informational efficiency

In the context of real estate markets, the argument concerning infor-

mational efficiency can be split into two broad categories: theoretical arguments and empirical arguments. The theoretical arguments discuss the characteristics of the real estate market and point to reasons as to why the market is considered to be informationally efficient or not. Typically this literature tends to demonstrate that real estate markets are inefficient compared to financial markets. Several of these theoretical arguments concerning efficiency of the real estate market are briefly discussed below, before turning to available empirical assessments.

- *Heterogeneous product*: as a commercially traded product, real estate is far from homogeneous. Real estate assets differ by many aspects, not the least by their location. This places them in a specific position relative to infrastructure, other properties and various types of economic activities. The real estate market is typically segmented into submarkets by type, location and quality characteristics of properties traded in the market. Due to these reasons, the relevant 'information set' can be very complex and often be incomplete.
- *High transaction costs and infrequent transactions*: transactions in the real estate market are typically subject to substantial transaction costs, both in the form of public fees and of private expenses. Examples on the private side are costs for appraisal, real estate agents, attorneys and notaries. Public fees often come in the form of taxes, fees for the registration in the land register and fees for mandatory administrative procedures. Due to these transaction costs, and given the average size and value of real estate, transactions occur relatively infrequently. Therefore, prices cannot change quickly as required by market efficiency and they cannot react to every new piece of information.
- *Regulations and strong role of policy*: many of the peculiarities of real estate and of the real estate market justify special regulations. These differ substantially between countries and regions. Price control and buyer-protection regulations imply that market prices cannot react quickly to changes in the fundamentals. Also, in some countries public authorities are actively involved in the real estate market as land owners, landlords or developers. These differences in regulations and state involvement indicate that the way real

estate markets operate may differ substantially between countries and this may have implications in terms of availability of information and informational efficiency of the markets.

- *Production lags*: the supply of real estate cannot react quickly to changes in market conditions. Depending on the size of the project, real estate development takes many months and often years from its initiation until the product is available in the market. This leads to sluggish generation of information—particularly the prices.
- *Other information asymmetries*: the arguments above indicate that some market participants may be uninformed compared to others. Individuals and small firms are typically more interested in using the property than in the transaction itself. Therefore, they are likely to be less informed than their counterpart in the transaction. Buying the service of a professional agent or broker does not necessarily resolve the information asymmetry as these actors will pursue their own economic interests. As a consequence, one can hypothesize that prices will rather reflect the interests of the knowledgeable party involved in the transaction than those of the less knowledgeable one.
- *Long term contracts*: in many markets real estate transactions result in long term contracts that substantially limit the options for price adjustments.

On the one hand, all these arguments cast some doubt on the validity of the EMH in the case of the real estate market. On the other hand, they strongly suggest that one needs to distinguish between types of real estate, and the countries and regions where these markets operate when evaluating efficiency of real estate markets. The results from one submarket will most likely not be transferrable to other submarkets due to the abovementioned substantial differences.

2.2 Empirical arguments on informational efficiency

As far as real estate markets are concerned, attempts to empirically determine whether or not they are efficient in terms of information date back to the mid-1980s (e.g., Gau 1984; Gau 1985; Linneman 1986). This

literature has grown substantially over the past few decades. The empirical strand of the literature either uses real estate market data in order to statistically test the above mentioned versions of the EMH, or tests whether house prices were driven by market fundamentals (Gatzlaff and Tirtiroglu 1995). One potential difficulty related to the former is that the EMH is not testable by itself and thus needs to be tested using a market equilibrium model or a forecasting model. Therefore, the tests of the EMH are typically joint hypothesis tests of both the notion of informational efficiency and the correct specification of the market equilibrium model. An intricacy relating to the latter is that those studies reporting as 'tests of market fundamentals' sometimes investigate operational efficiency not informational efficiency. Therefore, it is important in the context of the present study to examine cases where information on market fundamentals is causing the (in) efficiencies. If prices are not driven by market fundamentals themselves, then this should be a matter of operational inefficiencies.

There are numerous studies assessing informational efficiencies of various real estate markets, although these can generally be split into two broad categories based on the methods used. One group of studies assesses property price (or return) predictability while the other analyses the patterns of autocorrelation in prices (or returns). The studies attempting to predict property prices do so by using information on past prices and other macroeconomic variables. The emphasis of the latter method is to explore if there are any time patterns in prices (or returns) although these investigations typically rule out any profit opportunities given the related high transaction costs.

It is generally acknowledged that real estate markets are less efficient than financial markets. However, the results within real estate markets are inconclusive. For instance, short-run returns to land and housing are generally found to be positively autocorrelated whilst long-run returns are mean-reverting. Income generating property markets are perceived to be more efficient than housing markets but less efficient than real estate security markets. Although there is strong evidence of inefficiencies arising from transaction costs, infrequent transactions, production time lags, regulations, and other information asymmetries, there are also claims that the real estate market is generally efficient. To what extent this is a result of data aggregation, where the effects of well-known sources of distortion at the micro level are levelled out, or other causes, is explored later in this

study.

3 Methodology and empirical models

3.1 The meta-analysis

Informational efficiency of the real estate market is examined using a meta-analysis, which is an established quantitative tool for synthesising available research outcomes. The meta-analysis is superior to a simple narrative review given its capability to econometrically assess the impact of various influences on an outcome. In other words, it has the advantage of being able to examine whether heterogeneity in the estimates across studies is related to specific study characteristics. Rather than using original data, meta-analysis uses previous studies that analysed a particular phenomenon. Therefore, the unit of analysis of meta-analysis is prior studies on a given topic, and it attempts to draw conclusions about the respective subject matter from and across previous studies. Many studies are included to uncover general relationships, offering a robust 'big' picture of the state of the literature on the topic.

Although meta-analysis has been widely used in medical research (recent examples are McClaine et al. 2010; Milne et al. 2010; Visser et al. 2010), it has also been used recently in social sciences (e.g., Yang and Lester 2008; Melo et al. 2009). Melo et al. (2009), for instance, used elasticities that measure the effect of urban agglomeration on productivity, and tried to explain their variations by a set of study characteristics. In conclusion they stated "that study characteristics do matter" (Melo et al. 2009, p.341). They reported "that country specific effects, industrial coverage, the specification of agglomeration economies, and accounting for both the endogeneity of labour force quality and unobserved cross-sectional heterogeneity in time-variant labour quality can give rise to large differences in the results reported in the literature" (Melo et al. 2009, p.341). This example demonstrates how meta-analysis can detect some dependence of empirical results on the context of analyses and identifies the risk of taking the empirical results of one study at its apparent value.

The main challenge of meta-analysis lies in the proper construction of

the dataset. In cases where a large number of primary studies are available, carefully defined inclusion rules need to be adopted in order to select the most relevant case studies. If relevant cases are omitted, then that may lead to biased results. Other related challenges are the differences in the quality of previous studies and how to take that into account within the meta-analysis, and that previous studies often do not describe all the characteristics of analyses in sufficient detail.

A significant limitation of meta-analysis is that publication bias can distort its findings. Publication bias occurs when the publication of research depends on the nature and direction of their findings (Dickersin 1990). It may result from various factors during the process of scientific publication. One of them is the potential selectivity of the peer-review and publication process that yields a higher probability of being published for some results than for others. Since meta-analysis is typically based on published results, the publication bias translates into a problem of endogeneity. The subject under investigation influences the chances for an observation (an individual study in this case) to be included in the meta-analysis.

Publication bias may also occur without the involvement of publishers and peer reviewers. When—in anticipation of negative reviews and rejection or because the results are not in line with a sponsor's interests—studies with one type of results are more often filed and never submitted for publication than those with contrary results, the picture appearing in publications may well be biased. This is sometimes referred to as the file-drawer problem (Rosenthal 1979). Since it is practically impossible to get access to those papers that were rejected during the publication process or filed by researchers or sponsors, a potential publication bias is particularly difficult to detect and correct for in a meta-analysis. Simulation studies have shown that the problem may be serious even for a small number of filed or rejected studies (Scargle 2000).

Publication bias is of particular relevance for our study. We have mentioned above the statement by Jensen (1978) about the EMH that there is "no other proposition in economics which has more solid empirical evidence supporting it" (Beechey et al. 2000, pp. 21). At that time, an article that rejects the EMH would have been looked at more sceptically by reviewers and publishers, and would have had a higher chance of rejection than acceptance. This rejected piece of evidence would not appear in

a meta-analysis based on papers accepted for publication. In this way, a widely shared view in a scientific community can lead to a self-fulfilling prophecy. In later years, when the EMH was viewed more critically, it might have been much easier to publish such a paper. As a matter of fact, the publication bias may even have changed in the other direction, limiting the chance of publication for work that supports the EMH. These possibilities will be examined in the empirical analysis.

3.2 The mixed logistic model as an approach to meta-analysis

There are different approaches available to undertake a meta-analysis. One common approach among them is meta-regression. The way meta-regression is used in this context is similar to the primary studies that use regression methods to examine the relationship between an outcome variable and one or more predictor variables. The point of departure is that the outcome variable and the predictor variables in the meta-regression are at the level of the study rather than subject level. Common challenges such as the need to select the appropriate model and the need to have a sufficiently large ratio of studies to covariates[4] are applicable with regard to the meta-regression as well.

In situations where a dichotomous outcome variable is modelled, and the predictor variables are numerical, logistic (logit) regression is the basic meta-regression technique used[5]. It models the log odds of an outcome variable as a linear combination of predictor variables, thus fitting a logistic curve to the relationship between the outcome and the predictor variables. However, a fixed-effects logit model assumes that the effects of different predictors on the outcome are exactly the same in each observation. On the contrary, the alternative mixed logistic model does not make this unjustified assumption of variance homogeneity, instead the relationship between an outcome and predictor characteristics is examined while accounting for variation among observations.

Mixed logit models are a type of Generalized Linear Mixed Model (Agresti 2002; Breslow and Clayton 1993; Lindstrom and Bates 1990). As presented below, they explain an outcome as the linear combination of

4 This ensures a satisfactory level of degrees of freedom.

5 The ordinary least squares regression is not applicable as the normality and homoscedasticity assumptions are not met.

fixed effects (denoted by $x'\beta$) and conditional random effects (denoted by $z'b$). In the below expression, x' contains the values of the predictor variables for the fixed effects and z' contains the values of the predictor variables for the random effects. The random effect vector b can be thought of as the coefficients for the random effects. It is characterized by a multivariate normal distribution, centred around 0 and with the variance-covariance matrix Σ (Agresti 2002, p.492):

$$\text{logit}(p) = x'\beta + z'b,\ b \sim N(0,\ \Sigma)$$

The parameters of mixed logit models are fit to the data in such a way that the resulting model describes the data optimally. However, unlike for mixed linear models, there are no known systematic solutions for the exact optimization of data likelihood of mixed logit models. As a result, numerical simulations (e.g., Monte Carlo) or analytic optimization of approximations of the true log likelihood (i.e., quasi-log-likelihoods) are used to find optimal parameters of such models. In terms of computational efficiency and feasibility, quasi-log-likelihood is the better alternative (Agresti 2002, p.523-524). In cases where quasi-log-likelihood is maximised, Laplace approximation, which "performs extremely well, both in terms of numerical accuracy and computational time" (Harding and Hausman 2007, p.1325), could be used. All these technical aspects were taken into consideration when estimating the logit model and the mixed-effects model in Section 5.

4 Sample of efficiency studies

An extensive literature search provides the basis for this meta-analysis. There have been numerous studies on real estate markets over the last few decades that have a bearing on the question of efficiency. However, as mentioned in Section 2, a collection of papers reporting on empirical analyses directly testing either the EMH or the notion of 'informational efficiency' were identified from this large pool of literature to construct our dataset. Thus, included empirical studies primarily contain those testing two of the three versions of the EMH presented in Section 2. Additionally included are those directly addressing the issue of 'informational efficiency'

as this notion similarly iterates 'prices reflect relevant information about an asset'. The emphasis of such studies is mainly on predicting/forecasting prices based on relevant information.

In order to retain the most relevant studies for our analysis, the following specific inclusion criteria were adopted:

(1) Given the focus of this study (a) only studies dealing with real estate markets (not financial markets) and (b) those undertaking empirical studies (not theoretical or conceptual studies).

(2) Studies based on or directly addressing the 'efficient market hypothesis' or 'informational efficiency'

This inclusion criterion meant that our search was restricted to studies on informational efficiency (not operational efficiency). One remarkable inconsistency within the literature on EMH is that, although for the most part it discusses informational efficiency, there are a number of studies assuming informational efficiency to imply allocative efficiency. This practise has led many researchers to speciously interpret EMH as inferring allocative efficiency. As an example, consider the following from Fama's early work — "We saw earlier that independence of successive price changes is consistent with an "efficient" market, that is, a market where prices at every point in time represent best estimates of intrinsic values (Fama 1965, p. 94)." Therefore, an important distinction is made between 'informational efficiency' and 'allocative efficiency' within the present study.

(3) Studies published between the first rigorous tests of EMH on real estate (1984) and 2011 in refereed journals.

Gau (1984, 1985), Hamilton and Schwab (1985) and, Linneman (1986) are considered to be the first real estate studies on informational efficiency (Cho 1996; Gatzlaff and Tirtiroglu 1995). Therefore, our sample of studies essentially covers the published literature during the twenty eight years from 1984 to 2011. A careful check of the literature cited in these papers did not identify any additional publications. However, a word of caution is in order — considering publication and citation lags, this cross-checking strategy works only imperfectly for more recent publications.

(4) In cases where a study examines a specific version of the EMH, it is restricted either to the weak form or semi-strong form of efficiency. There are no empirical studies on the strong form of market efficiency as it is not possible to measure/quantify non-public information within these tests.

The above search strategy yielded a total of 101 peer-reviewed academic papers (see Appendix 1). There were situations where a single study examined two or more separate market segments, different types of real estate or different versions of market efficiency (i.e. weak and semi-strong form efficiencies) within its scope. In addition, although the outcome variable of our meta-analysis is a binary indicator that identifies whether or not a previous study concluded that a certain real estate market is efficient, some studies demonstrated specific efficiencies and inefficiencies within them. Due to these reasons, our 101 original papers rendered 172 distinct observations for the dataset.

The conclusion of each individual study was recorded as 'efficiency' or 'inefficiency', to be used as the outcome variable. Then, seven dimensions were used to characterize the publications based on their analyses. Each of these study characteristics provides the basis for one or more predictor variables to be used in our model specification:

(1) *Age*: This variable indicates number of years since publication of the respective study. It was included to examine any potential change in attitude towards market efficiency that we have mentioned in Section 2. Thus, the variable 'age' also serves as an indicator showing whether our analysis may suffer from publication bias.

(2) *Type of property*: This dimension denotes the type(s) of real estate transacted. We distinguished between two types—residential and income generating—and classified each analysis to one or both of these groups. The motivation for including this variable is to investigate whether differences exist within these sub markets in terms of informational efficiency. Residential property is more regulated than other types of real estate in many countries because

they are closely related to basic welfare of individuals. Also, better and more symmetric information as well as less emotional decision making are expected in relation to income generating property. Therefore, a higher chance of support for the EMH is anticipated when income generating property are analysed.

(3) *Scale of analysis*: This dimension distinguishes between the scale of chosen studies — local, regional, national or international. This 'scale' variable thus recognizes the extent of an area in which the data were collected and analysed. We identified the scale of analysis as 'local' when a study covered one city or a local real estate market area. A study was identified as regional, when it combined data from a number of spatially related local markets, but not covering an entire country. In cases where collected data demonstrated national coverage, we identified those studies as 'national'. When data represented more than one country, such studies were categorized as 'international'.

(4) *Geography*: The geographical coverage of analyses is identified through this dimension. We identified six countries (or world regions): the US, Europe, Canada, Asia, OECD countries and other countries. The peculiar market conditions and the prevailing institutional facets differ substantially between the US, Europe and the rest of the world. The motivation for including this variable is to control for the influence of such factors.

(5) *Type of market*: This dimension distinguishes between urban and rural real estate markets. It contains within this variable three categories — urban, rural and 'not known'. The motivation for this variable lies in the expectation that transactions take place frequently and that more information is increasingly being made available through media and technology in urban areas. Some studies are categorised as 'not known' given they only indicate that data comes from large metropolitan markets without specifying whether the concerned market segments are urban or rural in nature.

(6) *Aggregation level of data*: This dimension identifies the level of data aggregation in the underlying studies. There are three possible categories within this variable—'individual', 'aggregate' and 'stock'. The grouping 'individual' indicates an analysis was based on individual real estate data, and 'aggregate' denotes an analysis was based on aggregate market information such as median house prices, quarterly returns or monthly aggregates. Studies using stock market information were labelled 'stock'—i.e., REIT studies[6]. The motivation for including these categories in the meta-analysis lies in the view that the process of aggregation might impact upon factors that are used to identify efficiency or inefficiency within a study. For instance, the theoretical arguments against efficiency listed in Section 2 mainly apply to individual level data. However, it has been suggested that attributes of individual level data could be 'aggregated out' in more aggregated analyses (Capozza and Seguin 1996). On the contrary, Rayburn et al. (1987) have demonstrated that, in cases where aggregation eliminates noise contained in individual data, the characteristics of the market will become more easily visible. Due to the above reasons, it is difficult to rule out that different data aggregation levels may lead to different study outcomes although we do not have a clear hypothesis on the direction of such an effect at this stage.

(7) *Type of investigation*: This variable indicates the type of investigation undertaken in the analyses. We distinguished between three types of enquiries—'weak form', 'semi-strong form' and 'test of market fundamentals'—and classified each study to one or more of those types. Since conceptually the semi-strong form of market efficiency includes the weak form test (see Section 2), it is possible for a specific real estate market to meet the requirements of the weak form test but not the semi-strong form test (not the other way around). Therefore, we expect studies employing the weak form test to have a higher chance of categorizing a real estate market as efficient, than the semi-strong form tests.

6 Taking into account the large literature on 'do REITs trade like stocks or real estate', stocks have been labelled as a unique asset class here.

5 Empirical results

In this section, we first categorize empirical studies testing efficiency of the real estate market into the above study characteristics. The matrix tabulation of this coded classification provides the dataset required for the analysis. Then, a fixed-effects logistic model is estimated with the outcome and predictor variables mentioned in Section 4 to analyse whether some study characteristics lead to a significantly higher chance for identification of an efficient real estate market. Subsequently, a mixed-effects logistic model is estimated. This section closes with a discussion of the findings.

Table 1. Summary statistics

Variable	Description	Categories (frequency-percentage)
efficiency	Study outcome in terms of efficiency/inefficiency	efficient (47-27.3%) inefficient (125-72.7%)
age	Years since publication	1-10 (52-30.2%) 11-20 (78-45.3%) 21-28 (42-24.4%)
type	Type(s) of property transacted	income generating (81-47.1%) residential (91-52.9%)
scale	Scale of the analysis	international (14-8.1%) local (48-27.9%) national (96-55.8%) regional (14-8.1%)
geography	Geographical coverage of countries/regions	US (112-65.1%) Asia (17-9.9%) Canada (9-5.2%) Europe (24-14.0%) OECD countries (6-3.5%) other (4-2.3%)
urban/rural	Type(s) of market	N/K (35-20.3%) rural (52-30.2%) urban (85-49.4%)
aggregation	Level of data aggregation	aggregate level (126-73.3%) individual level (11-6.4%) stock (35-20.3%)
test	Type of investigation	semi-strong form of ME (89-51.7%) weak form of ME (69-40.1%) test of market fundamentals (14-8.1%)

Source: Authors' calculations

Table 1 presents some summary statistics of the sample of studies. A surge in the publication of efficiency studies in the 1990s implies that most of the currently available studies are 11-20 years old. As shown, only 27% of studies within the sample concluded that the real estate market is efficient. Analysing urban residential real estate markets in the US using aggregate data is the most common phenomenon. Thus, a vast majority of studies within our sample originated from the US (112 studies or 65% of the sample) compared to Europe (24 studies or 14%) and Asia (17 studies or 10%). Only few studies represented Canada, OECD countries and the rest of the world. The semi-strong form of market efficiency is dealt with in 52% of analyses followed by the weak-form (40%). Most often, the analyses were undertaken at national level (56% of the sample), typically by combining information from various metropolitan markets. As far as the scale of analysis is concerned, a considerable number of local level studies were also present (28%).

5.1 Fixed-effects logistic model findings

Given the nature of data used, a number of predictor variables were treated as categorical variables—'type', 'scale', 'geography', 'urban/rural', 'aggregation' and 'test'. Since a dichotomous outcome variable is modelled here, a fixed-effects logistic model was estimated. Therefore, all the predictor variables were assumed to generate fixed effects in this first instance. The results of the fixed-effects logistic model estimation are presented in Table 2.

The *Model 1* employing all the variables shows that few standard errors and odd ratios are too large—this presents doubts on the robustness of the model, and provides a basis for further scrutiny of these findings. As large parameter estimates and standard errors are typically a sign of multicollinearity, a reduced model that excludes some of the potentially collinear variables is estimated (see *Model 2* in Table 2). In the reduced model, the reference category for the variable scale includes both national and international studies. In addition, those studies on OECD countries are reclassified into the geography other, as these two categories constitute very small numbers of observations. The reduced model achieves superior parameter estimates.

This *Model 2* yields two coefficients that are significant—'aggrega-

tion - stock' (at the 5% level) and 'aggregation - individual level' (at the 1% level) — in addition to the intercept, which is significant at the 1% level. First, it indicates that if stock market data are used (rather than aggregate level data), the log odds of finding efficiency increases by 2.76. Interpreted differently, studies that are based on stock market data are 16 times more likely to conclude that a certain real estate market is efficient. As this model predicts whether there is a significant link between the study characteristics and the outcome of studies concerning efficiency, use of the variable 'aggregation - stock' tends to increase the incidence of a finding indicating 'efficiency'. This result aligns with our expectations. Secondly, it suggests if individual level data are used (versus aggregate level data), the log odds of a study concluding efficiency increases by 2.78. In other words, studies employing individual level data are 16 times more

Table 2. Summary of the fixed-effects logistic model

Outcome variable: binary indicator efficiency or inefficiency

	Model 1		Model 2	
Predictor	Coefficient	SE	Coefficient	SE
Intercept	-3.29	(1.221)**	-3.00	(1.206)*
type - income generating	-0.49	(0.586)	-0.51	(0.586)
scale - international	-16.17	(1882.118)		
scale - local	0.40	(0.545)	0.64	(0.555)
scale - regional	0.65	(0.791)	0.79	(0.799)
geography - Asia	0.72	(0.676)	0.87	(0.688)
geography - Canada	-0.78	(1.085)	-0.74	(1.094)
geography - Europe	1.27	(0.653)	1.19	(0.646)
geography - OECD countries	0.48	(2466.127)		
geography - other	34.71	(2725.982)	1.04	(0.795)
urban/rural - rural	0.18	(1.146)	-0.15	(1.155)
urban/rural - urban	0.74	(1.122)	0.43	(1.133)
aggregation - individual level	2.79	(0.894)**	2.78	(0.888)**
aggregation - stock	2.54	(1.109)*	2.76	(1.124)*
test - semi-strong form of ME	0.53	(0.474)	0.21	(0.448)
test - test of market fundamentals	0.53	(0.825)	0.18	(0.800)
age	0.04	(0.031)	0.04	(0.031)
N	172		172	
AIC	188.04		193.71	

Notes: (1) standard errors are in parentheses. (2) * denotes significance at the 5% level, and ** denotes significance at the 1% level. (3) The reference values (omitted category) for the dummy variables: type - 'residential'; scale - 'national'; geography - 'USA'; urban/rural - 'N/K'; aggregation - 'aggregate level'; and test - 'weak form of ME'.

likely to conclude that the real estate market is efficient. However, the interpretation of this significantly positive coefficient for 'aggregation—individual level' is less straight-forward. The above findings are compared and contrasted in detail in the following sub-section on mixed-effects model findings.

5.2 Mixed effects model findings

Though it is common to begin a meta-analysis with a fixed-effects model, which is simpler, a random-effects model and a mixed effects model are generally considered more appropriate (Borenstein et al 2009; Hunter and Schmidt 2004). The assumption when using the fixed-effects model in our context was that the likely impact of a given study characteristic in producing an outcome affirming 'efficiency' was the same in all studies. It needs to be highlighted however that studies in our sample have a high degree of heterogeneity with significant differences regarding the nature of data used, type of investigation carried out, markets interrogated, and the time periods covered. Given this, mixed effects logistic regression can be used to allow for both the fixed effects and random effects within the model specification. The mixed effects model thus allows for some of the impact of predictors to vary from one study to another.

The application of a mixed effects model provides scope for comparison of different versions of the model and affords a basis to either confirm or invalidate the robustness of the fixed-effects model findings. Since the predictor variables used are characteristics of individual studies, the assumption of fixed-effects may not hold particularly for study characteristics such as the type(s) of property transacted, scale of the analysis, geographical coverage of countries/regions and type(s) of market.

Types of property transacted is categorised into two clearly distinguishable categories in this study although there are a number of subcategories within them. For instance, income-generating properties could include business real estate (REITs, builders and investments, and management firms), commercial real estate (industry and office), and land (commercial), while residential properties could comprise single-family, multi-family and condominium properties among others. These different subcategories of property are likely to have different impacts on efficiency. In addition, the scale dimension identifies the sample area for which data were collected.

These real estate market areas vary substantially from large cities to small local areas and a simple four tier classification (i.e., local, regional, national and international) may not be able to capture the full effects of these differences. Similarly, the structure and the operation of submarkets classified under 'geography' differ within and between different regions. For instance, availability of public information and the institutional organization within the real estate industry differ considerably between the US, Asia and Europe. Finally, the type(s) of market is classified into two major groups (urban and rural), despite the level of urbanisation not being explained in most studies. Therefore, it is appropriate to allow this variable to vary across studies as urbanization levels of study areas can be vastly different within the sample. For these reasons, estimating a mixed effects model is more appropriate given data may be clustered or there may be both fixed and random effects.

The candidate variables to generate random effects were included in a series of mixed model estimations, estimated via maximum likelihood. The initial mixed model included 'geography' as a random effect and all

Table 3. Summary of the mixed logistic model

(N=172; AIC=193.7; BIC=231.5)

Outcome variable: binary indicator efficiency or inefficiency

Predictor	Coefficient	SE
Fixed effects		
Intercept	-2.22	(1.055)*
type - income generating	-0.49	(0.578)
scale - local	0.27	(0.548)
scale - regional	0.69	(0.771)
aggregation - individual level	2.61	(0.834)**
aggregation - stock	2.53	(1.059)*
urban/rural - rural	-0.08	(1.074)
urban/rural - urban	0.51	(1.038)
test - semi-strong form of ME	0.06	(0.452)
test - test of market fundamentals	0.09	(0.799)
age	0.02	(0.034)
Random effects	Variance	SD
geography	0.017	0.131

Notes: (1) standard errors are in parentheses. (2) * denotes significance at the 5% level, and ** denotes significance at the 1% level. (3) The reference values (omitted category) for the dummy variables: type - 'residential'; scale - 'national' and 'international'; urban/rural - 'N/K'; aggregation - 'aggregate level'; and test - 'weak form of ME'.

the other variables as fixed effects. The variables 'type', 'urban/rural', and 'scale' were added-on step by step to the subsequent estimations as random effects, holding the remaining variables fixed. The best performing models were then chosen based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC)[7]. Looking at these indicators of model quality, the model that includes random effect 'geography' performs the best (Table 3). The respective AIC and BIC values are the smallest in this preferred model. These results therefore show that allowing geography to vary within the model leads to an optimal outcome in terms of performance of the model.

Random effects included are considered to be normally distributed in log-odds space around a mean of zero. As Baayen et al. (2008) and Bates and Sarkar (2007) have shown, variance is the only parameter the model fits for the random effects. The inclusion of a random coefficient allows the effect of covariates to vary among groups. As an example, when the variable 'geography' is included as a random variable, it captures potential differences between information availability and institutional factors within the US, Europe and Asia. If a fixed effect is significant in a mixed effects model, this means it is significant after controlling for the variance associated both within studies and within study characteristics simultaneously.

Turning to the estimated parameters, the direction and size of the effects in the model explain the impact of predictors on the outcome. Even after controlling for random effects, the same three parameters that were significant in the fixed-effects model—intercept, 'aggregation - individual level' and 'aggregation - stock'—remain significant in the mixed effects model. One of the findings thus suggests that use of real estate stock market data (versus aggregate level data) increases the log odds of finding efficiency by 2.53. In other words, studies using real estate stock data are 13 times more likely to conclude efficiency. This indicates when a study uses stock market data rather than aggregated data, the chances are significantly higher that it will identify the real estate market as efficient. This finding is consistent with previous research showing that level of efficiency goes up when moving from housing markets to income generating real es-

7 The AIC and the BIC are model selection mechanisms that compare the data likelihood given the model (based on the degrees of freedom). The quality or fit of nested models could be compared based on these criteria.

tate (commercial, office, retail, industrial etc.) to business real estate such as REITs (see discussion below).

Previous literature identifies several potential reasons for the informational inefficiency of real property markets compared to real estate stock markets. Inefficiency of the real property market partly derives from the localised nature of real estate (Green et al. 1988; Gau 1984). Housing markets are highly segmented and the locational factors influence real estate values (Barkham and Geltner 1996). This local orientation of the market and the unique characteristics of real property require specialised knowledge to perform in the market. As the real property market is not centralized or standardized, calculation of returns becomes extremely difficult (Guntermann and Smith 1987). Adding to this, demand and supply characteristics differ across markets, causing higher search costs. These factors result in prices that may not fully adjust to new information. For these reasons, Linneman (1986) stated that housing markets have price dispersion compared to corporate capital. In comparison, the real estate stock market is relatively homogenous, information rich[8] and densely traded with numerous traders (Barkham and Geltner 1995). The trading density, market breadth, liquidity and micro structure benefit the real estate securities market in terms of informational efficiency (Barkham and Geltner 1995). Moreover, these markets have become more national and international with the advent of group ownership, and trust and pension funds moving into commercial real estate (Guntermann and Smith 1987).

In addition, the fact that there are limited buyers and sellers in the real property market means properties are traded infrequently resulting in increased costs of assessing information. There is limited learning from experience in terms of gathering and processing of information as most participants transact properties infrequently (Linneman 1986). Also, access to some real estate information such as zoning regulations is also restricted within real property markets. Furthermore, housing attributes are not constant across space (Barkham and Geltner 1996), and due to this heterogeneity of design of real properties, prices in housing markets may not reflect all relevant market information. This translates into an inefficiency creating profit opportunities for specialized (and informed) investors. The indivisibility or lumpiness of real estate assets along with capital con-

8 Real estate stock prices are published in wider media in many countries.

straints faced by purchasers due to the expensive nature of the asset limit information capitalization (Clayton 1998) and results in high information costs (Gau 1984).

As suggested in Section 2, another reason for this result lies in the fact that the real estate stock market is typically less regulated than other real estate sub-markets and that actors in this market tend to be better informed and have an upper hand in the information business. For instance, Wang (2004) discussed zoning policies and approval (and review) procedures that limit transactions taking place within housing markets. Additionally, real property sellers are trading in homes they live in—therefore, carrying costs and tax considerations also influence these inefficiencies (Case and Shiller 1989). There are also other transaction costs such as agent fees, stamp duties etc. making price determination problematic in terms of real estate properties (Case and Shiller 1989; Clapp and Tirtiroglu 1994).

The other significant finding is that the variable 'aggregation—individual level' yields a positive coefficient, which is significant at the 1% level. This suggests use of individual level data (versus aggregate level data) increases the log odds of finding efficiency by 2.61. Said differently, studies using individual level data are 14 times more likely to produce results confirming efficiency. The conventional wisdom seems to be that aggregation of prices to a higher level eliminates the variability: this smoothing process should lead to unpredictability of real estate prices in these analyses. This unpredictability could then be interpreted as indicating informational efficiency. However, as discussed below, there is a strong body of literature suggesting the contrary as well.

One possible interpretation of this result suggests that the implied inefficiency in aggregated studies may be an artefact resulting from the aggregation process. The price indices that are used in aggregate studies are themselves estimates and may be subject to an estimation error (Barkham and Geltner 1995; Case and Shiller 1989; Darrat and Glascock 1989; 1993; Meese and Wallace 1994; Tirtiroglu 1992). When price indices are used in an analysis, these estimation errors may make the indices predictable and thus lead to the interpretation of an inefficient market. On the other hand, as Brown (1985) and Pollakowski and Ray (1997) have shown, the lack of serial correlation at the individual property level, when valuers are doing a good job in adjusting valuations in response to new information, is typi-

cally indicative of efficiency. With these two possibilities, aggregate level data can produce results indicating inefficiency while individual level data generates findings postulating efficiency.

Similarly, Rosenthal (2006) and Barkham and Geltner (1995; 1996) have highlighted that data aggregation process could create misleading patterns of correlation in the context of temporal aggregation into monthly or quarterly series. The smoothing that is implied in the spatial aggregation could generate autocorrelation in the data series, and a significant first lag[9] may result from the smoothing process, which eliminates excessive volatility and brings individual values close to each other. For instance, Barkham and Geltner (1995) corrected for smoothing to eliminate positive autocorrelation in the US property returns and the appraisal-based returns in the UK.

An alternative interpretation, however, is that inefficiencies of a real estate market are less visible when using individual data since these inefficiencies are overshadowed by the volatility of the data. Case and Shiller (1989, p. 134) referred to this when they used the term 'noise in individual prices'. In addition, most of the early studies have used appraisal data and it has been suggested that finding autocorrelation in some of these studies may be the result of an appraisal bias. As an example, Darrat and Glascock (1993) stated that appraisal data may misstate appreciation and price variation for a particular period.

Overall, the two predictor variables noted above show positive and highly statistically significant parameters consistently throughout all the models considered, although the model with random intercepts and coefficients improved the model fit. It should also be noted that the two variables—'aggregation - individual level' and 'aggregation - stock'—generate similar coefficients in the two estimations. In fact, the direction of all the fixed effect coefficients estimated including those not significant has not changed in the mixed effects model, both compared to the fixed-effects model as well as the variant versions of the mixed effects model[10].

The statistically insignificant coefficients are also important in the con-

9 One could interpret this significant first lag as indicating 'predictability' thus suggesting an inefficient market.

10 In any case, parameters can only be estimated up to a positive constant in logit models (Ben-Akiva and Lerman 1985; Maier and Weiss 1990) and the differences in the coefficients between the two model versions bear no meaning.

text of our enquiry. It is notable that the variable 'age' is insignificant in both models. This means our analysis neither provides support for the suspicion that the view of market efficiency has significantly changed over the years, nor does it indicate a publication bias resulting from such a shift in view. Another important result is that neither the scale of the analysis as captured by the variables 'regional', 'local' and 'international' nor the geographical focus of the study (i.e., the US and Europe etc.) lead to significant differences in study outcomes. Therefore, our meta-analysis does not provide any support for the hypothesis of marked differences between the US and European real estate markets in terms of informational efficiency. Moreover, the type of investigation ('weak form' and 'semi-strong form') and the urban/rural classification do not lead to significantly different outcomes. Finally, the type of investigation has no effect on efficiency outcomes of studies.

This lack of significant influence of study characteristics on the outcome suggests that informational efficiency is mostly a context-specific random manifestation. In fact only few study characteristics are likely to influence the outcome of efficiency studies. The most likely candidate variables to have an influence on the outcome are 'aggregation—individual level' and 'aggregation—stock'.

The model quality and the fit of the models were assessed using AIC and BIC criteria above. Additionally, the binned residual test is a useful robustness test as dichotomous outcome variables are modelled. The assumption that the residuals of the logistic regression models are normally distributed was tested by plotting the binned residuals[11] (Gelman and Hill 2007, p.99). If the residual series demonstrate any deterministic trends, that is indicative of the omitted variable problem. The generated binned residual pots for the fixed-effects model and the mixed model show that a large portion of the bins falls inside the 95% confidence intervals affirming that residuals of the models estimated are normally distributed.

11 Bins are categories based on the fitted values, thus making it possible to compare average residual and the average fitted values for each bin.

6 Concluding remarks

This paper reports on a meta-analysis undertaken to assess informational efficiency of real estate markets. Meta-analysis involves pooling numerous research studies together into a single data set and utilizing statistical and analytical methodologies to explain the differences of study outcomes given the study characteristics. The dataset used contained information regarding 101 empirical studies on this topic that provide 172 distinct observations, published between 1984 and 2011 in peer-reviewed academic journals.

First, the dichotomous outcome variable 'efficiency' or 'inefficiency' was regressed on study characteristics using the traditional fixed-effects logistic model. This produced two statistically significant parameters, excluding the intercept. These findings suggested the following:

- Studies using data on real estate stocks, compared to aggregate level real estate data, are more likely to produce findings supporting 'efficiency'.

- Studies employing individual level data, rather than aggregate real estate data, are more likely to produce findings supporting 'efficiency'.

The variable denoting time since publication was statistically insignificant implying there is no publication bias associated with our data. All the other study characteristics tested returned statistically insignificant estimates, indicating that informational efficiency of the real estate market is context-specific and occurs randomly for the most part.

Parameter estimates of fixed-effects models are likely to be biased due to unobserved heterogeneity among studies. Given the vast differences within studies and within study characteristics, the alternative mixed logistic model is also estimated. The advantage of using the mixed logistic model is that it does not make the unjustified assumption of variance homogeneity within the sample. There are several variables with potential random effects—type(s) of property transacted, scale of the analysis,

geographical coverage of countries and type(s) of market. Different combinations of these random effects were included in a series of mixed effects regressions. The statistically superior model in terms of quality and fit was retained—this model includes geography as a potential random effect and other variables as fixed-effects.

The mixed effects model results are similar to those produced by the fixed-effects model. Two variables have a significant influence on the probability of a study to conclude that the respective real estate market is efficient. In both cases the influence is significantly positive. Studies using data on real estate stocks, rather than aggregate real estate data, are more likely to conclude that the market is efficient. This result was expected as real estate stock markets possess information richness, liquidity, market breadth, and are trading assets that are densely traded and relatively homogeneous. Also, real estate stocks are typically traded between businesses, which tend to be better informed about the market than private consumers. Moreover, the market for real estate stocks (such as REITs) are also less regulated than the real property markets. This finding places REITs more within the group of stocks rather than real estate.

Based on this finding, investors are likely to benefit by developing and applying active trading strategies to trade real properties rather than real estate stocks. In contrast, real estate stock markets are relatively informationally efficient, which suggests that information about past prices and market fundamentals are already capitalised into prices. These results are consistent with the theory of efficient markets—i.e. EMH. Provided that real property markets are relatively inefficient, Barkham and Geltner (1996) have advocated encouraging more buying and selling of real properties for investment purposes, publication of transaction prices and development of housing contracts tradable in liquid public markets, to improve informational efficiency of real property markets.

Also, studies using information about individual properties are significantly more likely to find an efficient real estate market than studies using more aggregated data. This result concerning the variable 'individual data' is less straight-forward. Whether this is a definitive conclusion or an effect of data aggregation remains an open question.

Moreover, the variable 'age' is insignificant confirming absence of publication bias. All other variables also yield insignificant coefficients, demonstrating that other included study characteristics are unlikely to predict

the outcome concerning efficiency.

All the estimated models, regardless of fixed-effects or mixed-effects, consistently show that variables 'stock market data' and 'individual level data' have a positive and statistically significant effect on efficiency. Inclusion of a geography variable that seems to have varied across studies as a random effect improved the performance of the model.

The finding on 'individual level data' raises concerns on the use of appraisal data, aggregation procedures such as indexing and, on the use of data with considerable levels of noise. Therefore, further research using different data sets is needed to substantiate these effects of appraisal bias and aggregation on informational efficiency.

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Appendix 1. Papers included in the meta-analysis

Study	Journal	Type of property (residential, income generating)	Obs.	Scale (local, regional, national or international)	Geography (US, Europe or Asia etc.)	Urban or rural	Aggregation (individual level, aggregate level or stock)	Type of test	Market efficiency
Anas and Eum (1984)	Journal of Urban Economics	Residential	2	Local	USA-Chicago	Urban	Individual level/Aggregate level	Semi-strong form of ME	Efficient
Anoruo and Braha (2010)	International Real Estate Review	Income generating	1	National	USA	N/K	Stock	Weak form of ME	Inefficient
Atteberry and Rutherford (1993)	Journal of Real Estate Research	Income generating	4	Local	USA-Dallas/ Fort Worth	Urban/ rural	Aggregate level	Weak form of ME/ Semi-strong form of ME	Inefficient
Bardhan et al (2008)	Real Estate Economics	Income generating	1	International	16 countries	N/K	Stock	Weak form of ME	Efficient
Barkham and Geltner (1995)	Real Estate Economics	Income generating	4	International	USA/Europe-UK	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Barkham and Geltner (1996)	Journal of Housing Economics	Residential	2	National	Europe-UK	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Belaire-Franch et al (2007)	International Real Estate Review	Income generating	1	National	Europe-UK	N/K	Stock	Weak form of ME	Inefficient
Beracha and Skiba (2011)	Journal of Real Estate Finance and Economics	Residential	2	National	USA	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Brown (1985)	Journal of Valuation	Income generating	1	National	Europe-UK	N/K	Individual level	Weak form of ME	Efficient
Capozza and Seguin (1996)	Regional Science and Urban Economics	Residential	2	National	USA (64 MSAs)	Urban	Aggregate level	Semi-strong form of ME/Test of market fundamentals	Inefficient

Case and Shiller (1989)	American Economic Review	Residential	1	Regional	USA (4 MSAs)	Urban	Aggregate level	Weak form of ME	Inefficient
Case and Shiller (1990)	Journal of the American Real Estate and Urban Economics Association	Residential	1	Local	USA (4 MSAs)	Urban	Aggregate level	Semi-strong form of ME	Inefficient
Chau et al (2010)	Journal of Real Estate Finance and Economics	Residential	1	Local	Asia-Hong Kong	Urban	Aggregate level	Semi-strong form of ME	Efficient
Chen et al (doi)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Cheng and Roulac (2007)	International Real Estate Review	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Ching and Fu (2003)	Regional Science and Urban Economics	Income generating	1	Local	Asia-Hong Kong	Urban	Individual level	Semi-strong form of ME	Inefficient
Clapp and Giaccotto (1994)	Journal of Urban Economics	Residential	2	Local	USA-Hartford, Manchester, West Hartford	Rural	Aggregate level	Semi-strong form of ME/Test of market fundamentals	Inefficient
Clapp and Giaccotto (2002)	Journal of Real Estate Research	Residential	2	Local	USA-Miami	Rural	Aggregate level	Weak form of ME/ Semi-strong form of ME	Inefficient
Clapp and Tirtiroglu (1994)	Journal of Economic Behavior and Organization	Residential	1	Local	USA-Hartford	Rural	Aggregate level	Weak form of ME	Inefficient
Clapp et al (1995)	Real Estate Economics	Residential	1	Local	USA-Connecticut, San Francisco	Rural	Aggregate level	Weak form of ME	Inefficient
Clayton (1996)	Journal of Real Estate Research	Income generating	2	National	Canada	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Clayton (1996)	Real Estate Economics	Residential	1	Local	Canada-Vancouver	Urban	Aggregate level	Semi-strong form of ME	Inefficient

Clayton (1997)	Journal of Real Estate Finance and Economics	Residential	1	Local	Canada-Vancouver	Urban	Aggregate level	Semi-strong form of ME	Inefficient
Clayton (1998)	Journal of Real Estate Research	Residential	2	Local	Canada-Vancouver	Urban	Aggregate level	Weak form of ME/ Semi-strong form of ME	Inefficient
Cooper et al (2000)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Weak form of ME	Inefficient
Darrat and Glascock (1989)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME/Test of market fundamentals	Inefficient
Darrat and Glascock (1993)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Efficient
DiPasquale and Wheaton (1994)	Journal of Urban Economics	Residential	2	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Dokko et al (1991)	Journal of the American Real Estate and Urban Economics Association	Income generating	2	Regional	USA	Urban/ rural	Stock	Semi-strong form of ME	Efficient
Dolde and Tirtiroglu (1997)	Real Estate Economics	Residential	1	Local	USA-Connecticut, San Francisco	Rural	Aggregate level	Weak form of ME	Inefficient
Elliott et al (2006)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Efficient
Englund and Ioannides (1997)	Journal of Housing Economics	Residential	6	International	15 OECD countries	Urban/ rural	Aggregate level	Weak form of ME/ Semi-strong form of ME/Test of market fundamentals	Inefficient

Englund et al (1999)	Journal of Housing Economics	Residential	2	National	Europe-Sweden	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Eppli et al (1998)	Journal of Real Estate Finance and Economics	Income generating	2	Regional	USA (11 MSAs)	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Evans (1990)	Journal of Real Estate Research	Residential/ Income generating	4	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Falk (1991)	American Journal of Agricultural Economics	Income generating	2	Local	USA-Iowa	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Falk (1992)	Journal of Housing Economics	Income generating	2	Local	USA-Iowa	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Featherstone and Baker (1987)	American Journal of Agricultural Economics	Income generating	2	National	USA	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Fisher et al (2009)	Real Estate Economics	Income generating	2	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Fu and Ng (2001)	Real Estate Economics	Residential/ Income generating	2	Local	Asia-Hong Kong	Urban	Aggregate level	Semi-strong form of ME	Inefficient
Gatzlaff (1994)	Journal of the American Real Estate and Urban Economics Association	Residential	1	Local	USA (4 MSAs)	Urban	Aggregate level	Weak form of ME	Inefficient
Gau (1984)	The Financial Review	Income generating	1	Local	Canada-Vancouver	Urban	Individual level	Weak form of ME	Efficient
Gau (1985)	Journal of the American Real Estate and Urban Economics Association	Income generating	1	Local	Canada-Vancouver	Urban	Individual level	Semi-strong form of ME	Efficient
Goukasian and Majbouri (2010)	Real Estate Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Efficient
Graff and Webb (1997)	Journal of Real Estate Portfolio Management	Income generating	2	National	USA	Urban/ rural	Aggregate level	Weak form of ME	Inefficient

Graff et al (1999)	Journal of Real Estate Portfolio Management	Income generating	4	National	Asia-Australia	Urban/ rural	Aggregate level	Weak form of ME	Efficient (Industry)/ Inefficient (Office and retail)
Green et al. (1988)	The Real Estate Appraiser and Analyst	Residential	1	Regional	USA (73 MSAs)	Urban	Individual level	Weak form of ME	Efficient
Gu (2002)	Journal of Real Estate Research	Residential	2	National	USA	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Guntermann and Norbin (1991)	Journal of Real Estate Finance and Economics	Residential	2	Local	USA-Lubbock	Urban	Aggregate level	Weak form of ME	Efficient* (Ex-post)/ Inefficient (Ex ante)
Guntermann and Smith (1987)	Land Economics	Residential	1	National	USA (57 MSAs)	Urban	Aggregate level	Weak form of ME	Efficient*
Gyamfi-Yeboah et al (doi)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Gyourko and Keim (1992)	Journal of the American Real Estate and Urban Economics Association	Income generating	2	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Gyourko and Voith (1992)	Journal of Urban Economics	Residential	2	National	USA (56 MSAs)	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Hamilton and Schwab (1985)	Journal of Urban Economics	Residential	1	National	USA (49 MSAs)	Urban	Aggregate level	Weak form of ME	Inefficient
Holland (1991)	Regional Science and Urban Economics	Residential	4	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME/Test of market fundamentals	Efficient
Hosios and Pesando (1991)	Journal of Housing Economics	Residential	1	Local	Canada-Toronto	Urban	Aggregate level	Weak form of ME	Inefficient

Huang et al (2009)	Journal of Real Estate Portfolio Management	Income generating	2	National	USA	N/K	Stock	Semi-strong form of ME	Efficient (2001-2007)/ Inefficient (1994-2007)
Jin and Grissom (2008)	International Real Estate Review	Residential	2	Regional	USA	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Jirasakuldech and Knight (2005)	Journal of Real Estate Portfolio Management	Income generating	2	National	USA	N/K	Stock	Weak form of ME	Efficient (EREITs/ Russell 2000)/ Inefficient* (MREITs and HREITs)
Joel-Carbonell and Rottke (2009)	Journal of Property Investment and Finance	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Efficient*
Kleiman et al (2002)	Journal of Real Estate Research	Income generating	1	International	Asia/Europe/ North America	N/K	Stock	Weak form of ME	Efficient
Kuhle and Alvayay (2000)	Journal of Real Estate Portfolio Management	Income generating	1	National	USA	N/K	Stock	Weak form of ME	Inefficient
Larsen and Weum (2008)	Journal of Urban Economics	Residential	1	Local	Europe-Norway	Urban	Aggregate level	Weak form of ME	Inefficient
Ling and Naranjo (2003)	Real Estate Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Ling et al (2009)	Journal of Real Estate Finance and Economics	Income generating	2	National	Europe-UK	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Linneman (1986)	Journal of Urban Economics	Residential	1	Local	USA-Philadelphia	Urban	Individual level	Semi-strong form of ME	Efficient*
Liow (2001)	Journal of Property Investment and Finance	Income generating	1	National	Asia-Singapore	Urban	Stock	Semi-strong form of ME	Efficient
Liow (2009)	Journal of Real Estate Finance and Economics	Income generating	1	International	20 countries	N/K	Stock	Weak form of ME	Efficient

Liu and Mei (1992)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Locke (1987)	Journal of Valuation	Residential/ Income generating	2	National	Asia-Australia	Urban	Aggregate level	Weak form of ME	Inefficient
Lu and Mei (1999)	Journal of Real Estate Portfolio Management	Income generating	1	International	Emerging markets	N/K	Stock	Weak form of ME	Efficient
MacKinnon and Zaman (2009)	Real Estate Economics	Income generating	2	National	USA	Urban/ rural	Individual level	Weak form of ME	Inefficient
Malpezzi (1999)	Journal of Housing Economics	Residential	2	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient
Mankiw and Weil (1989)	Regional Science and Urban Economics	Residential	4	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME/Test of market fundamentals	Inefficient
Maurer et al (2004)	Journal of Real Estate Portfolio Management	Income generating	2	National	Europe-Germany	N/K	Aggregate level	Weak form of ME/ Semi-strong form of ME	Inefficient
McIntosh and Henderson (1989)	Journal of Real Estate Finance and Economics	Income generating	1	Local	USA-Dallas	Urban	Individual level	Weak form of ME	Efficient
Meese and Wallace (1994)	Journal of Urban Economics	Residential	4	Local	USA-Alameda, San Francisco	Urban	Aggregate level	Semi-strong form of ME/ Test of market fundamentals	Efficient (Long run)/ Inefficient (Short run)
Mei and Liu (1994)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Ohtake and Shintani (1996)	Regional Science and Urban Economics	Residential	4	National	Asia-Japan	Urban/ rural	Aggregate level	Semi-strong form of ME/Test of market fundamentals	Inefficient

Oikarinen (2010)	Journal of Real Estate Finance and Economics	Income generating	2	National	Europe-Finland	Urban/ rural	Aggregate level	Semi-strong form of ME	Efficient
Ong and Maxam (1997)	Journal of Property Finance	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Efficient
Pollakowski and Ray (1997)	Journal of Housing Research	Residential	2	Regional	USA	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Poterba (1991)	Brookings Papers on Economic Activity	Residential	2	National	USA (39 MSAs)	Urban	Aggregate level	Semi-strong form of ME/Test of market fundamentals	Inefficient
Price (2009)	Journal of Real Estate Portfolio Management	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Price et al (doi)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Inefficient
Rayburn et al. (1987)	Journal of the American Real Estate and Urban Economics Association	Residential	2	Local	USA-Memphis	Urban	Aggregate level	Weak form of ME	Efficient* (70-84)/ Inefficient* (70-75)
Riddel (2000)	Journal of Regional Science	Residential	2	Local	USA	Urban	Aggregate level	Semi-strong form of ME	Efficient (Long run)/ Inefficient (Short run)
Ro and Ziobrowski (2011)	Journal of Real Estate Finance and Economics	Income generating	1	National	USA	N/K	Stock	Semi-strong form of ME	Efficient
Rosenthal (2006)	Oxford Bulletin of Economics and Statistics	Residential	2	National	Europe-UK	Urban/ rural	Aggregate level	Weak form of ME	Efficient
Serrano and Hoesli (2007)	Journal of Real Estate Portfolio Management	Income generating	1	National	USA	N/K	Stock	Weak form of ME	Inefficient
Sing and Patel (2001)	Journal of Property Investment and Finance	Income generating	1	National	Europe-UK	N/K	Stock	Semi-strong form of ME	Inefficient

Sing and Sng (2003)	Journal of Property Investment and Finance	Income generating	1	Local	Asia-Singapore	Urban	Stock	Semi-strong form of ME	Efficient
Sing et al (2002)	Journal of Real Estate Portfolio Management	Income generating	1	National	Asia-Malaysia	N/K	Stock	Semi-strong form of ME	Efficient
Skantz and Strickland (1987)	Journal of Real Estate Research	Residential	1	Local	USA-Houston	Urban	Individual level	Semi-strong form of ME	Efficient
Tirtiroglu (1992)	Journal of Housing Economics	Residential	1	Local	USA-Hartford	Rural	Aggregate level	Weak form of ME	Inefficient
Tirtiroglu and Clapp (1996)	Journal of Regional Science	Residential	1	Local	USA-Connecticut	Rural	Aggregate level	Weak form of ME	Inefficient
Tuluca et al (2000)	Journal of Real Estate Finance and Economics	Income generating	2	National	USA	N/K	Aggregate level/stock	Semi-strong form of ME	Efficient
Wang (2004)	Journal of Real Estate Finance and Economics	Residential	1	Local	USA-Manhattan	Urban	Aggregate level	Weak form of ME	Inefficient
Willcocks (2009)	Journal of Real Estate Finance and Economics	Residential	2	National	Europe-UK	Urban/ rural	Aggregate level	Weak form of ME	Inefficient
Worthington and Higgs (2003)	Journal of Property Investment and Finance	Residential	4	Regional	Europe-UK	Urban/ rural	Aggregate level	Weak form of ME	Efficient (Long run)/ Inefficient (Short run)
Zhou (1997)	Journal of Real Estate Research	Residential	2	National	USA	Urban/ rural	Aggregate level	Semi-strong form of ME	Inefficient

Appendix 2. List of studies included in the meta-analysis

Anas, A. and S.J. Eum, "Hedonic analysis of a housing market in disequilibrium," *Journal of Urban Economics* 15, 1984, 87-106.

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