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A meta-analysis of the impact of rail projects on land and property values

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ABSTRACT

The literature on land and property values demonstrates a great deal of variability in the estimated change in values arising from rail investments. This paper conducts a meta-analysis on empirical estimates from 23 studies (102 observations) that analysed the impact of rail on land/property value changes. Variation in the estimated impacts is calculated and discussed in relation to key dimensions of study-design characteristics. The results show that a number of factors produce significant variations in the estimates. These include the type of land use, the type of rail service, the rail system life cycle maturity, the distance to stations, the geographical location, accessibility to roads, methodological characteristics, as well as whether the impacted area is land or property. On the other hand, we observe that changes in purchase price and rent values due to rail projects are statistically similar to each other, that there is no evidence of change in values over time nor due to the location of land/property within the city, and that including property characteristics and neighbourhood type in the estimation model do not change values significantly. Publication bias tests are also performed and show that although researchers tend to report both positive and negative results, they tend to be biased towards statistically significant estimates.

1. Introduction

Rail investments are thought to bring various benefits to cities such as mobility, economic, environmental and public health benefits. Economic benefits, in particular, can be measured in terms of an increase in accessibility to specific locations, which can eventually lead to trade improvements, employment density increases, a more efficient distribution of land use, and in some cases, enhancement in land and property values. This paper focuses on assessing the main causes of the variation underlying existing empirical evidence on the impacts of rail projects on land/property values around rail stations.

Studies show that the range of rail impact estimates on land/property values is large. The majority of research has identified positive gains in values (e.g. Agostini and Palmucci, 2008; Laakso, 1992; Pan and Zhang, 2008; Voith, 1991), although some studies suggest depreciation in some locations (e.g. Du and Mulley, 2007), and a small number of reports show no significant differences for some properties (e.g. Clower and Weinstein, 2002). Why do estimates vary greatly among studies? How does the design context of a study, including model specification and nature of the data, affect the estimates of land/property value changes? What is the influence of different rail systems on different property types and land uses?

The above are some of the questions this study aims to answer. While there have been previous attempts to analyse the variation in estimates of land/property value change arising from investments in rail, they suffer from limitations related to the analysis techniques used and/or the number of factors considered. The majority of such studies use traditional literature

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review techniques based on a subjective interpretation of results obtained from case studies without conducting any form of systematic analysis (e.g. RICS Policy Unit, 2002; Zhang, 2009). Moreover, some studies consider only a small subset of study-design factors to explain the variation in empirical findings. For example, Ryan (1999) examined the effect of a single factor (time-based and distance-based accessibility) on the estimated change in land/property values arising from rail schemes. Debrezion et al. (2007) considered a larger set of study-design factors in a meta-analysis model; including type of property, type of public transport system, type of empirical model, time period of the analysis, accessibility to roads, and demographic variables. To our best knowledge, this is the only study that conducted a systematic analysis of the empirical literature accounting for the role of a set of study characteristics; however, we believe that the list of factors considered was not exhaustive.

In this paper we contribute to existing research by conducting a more extensive quantitative review of the effects of rail systems on land/property values. Our study provides an up-to-date survey of the literature in the field and considers a wider range of contextual and methodological characteristics of related studies that are expected to influence results. Compared to the previous meta-analysis by Debrezion et al. (2007), we have added or modified 15 contextual factors and introduced 5 additional methodological factors. A number of these added factors were found to be statistically significant. The study by Debrezion et al. (2007) analysed a sample of 57 observations limited to studies using US data. We use a wider geographical coverage, including European and Asian studies, and a larger dataset made of 102 observations obtained from 23 studies for the period between 1980 and 2007. Results indicate that the changes in values of land/property due to rail investments vary substantially across continents. The findings from this meta-analysis can provide a reference point for future research investigating the impacts of new or improved rail schemes on the values of surrounding land/property; especially if no empirical evidence is yet available. The dataset was analysed using meta-analysis techniques to test if the estimates obtained from the various studies vary as a result of differences in their contextual and methodological characteristics. We also conducted the first publication bias tests in the field to examine if researchers tend to report positive and statistically significant values.

The main results of this study show that a number of factors produce significant variation in the estimates of change in land/property values. These include: type of land use, type of rail service, rail system life cycle maturity, distance to stations, geographical location, accessibility to roads, data specification, methodological characteristics, as well as whether the impacted area is land or property. Additionally, the publication bias tests show that researchers report both positive and negative estimates but tend to be biased towards statistically significant results.

This paper is structured as follows. Section 2 explains the main features of meta-analysis and outlines its strengths and some of its difficulties. Section 3 discusses the key elements of the literature on the impacts of rail on land/property values and gives examples on the range of magnitude in empirical results. The factors hypothesised to explain the variation in the reported estimates are classified and discussed in Section 4, as well as the design of the meta-analysis model. Section 5 presents and discusses the results of the meta-analysis. In Section 6, we study the possible presence of reporting bias by conducting publication bias tests. Section 7 concludes with the main research findings.

2. Scope of the meta-analysis

Meta-analysis is a regression based approach that can be used to distinguish, in a clear and systematic way, the reasons underlying the variation in empirical results (see e.g. Melo et al., 2009; Stanley and Jarrell, 2006). Although meta-analysis can provide an objective review of the differences in results, there are some simple rules that should be followed to ensure that a robust basis for comparison is being made. First, the dependent variable needs to be standardised to allow for comparisons between estimates (DeCoster, 2004). Empirical results may be reported in different units (e.g. a monetary or a percentage value) and in some cases the information provided in a study is not enough to allow the conversation of estimates to the same unit. This issue can limit the number of observations for analysis. Second, researchers' choice on the number of observations per study to be included in the meta-sample may bias or invalidate results. When one estimate is used per study, bias can result from the choice of that particular observation among other observations reported in the study. If several observations within a report are used, results may not be accurate due to correlation between those estimates, which requires tests of within-study variance. Third, researchers may tend to report observations that are statistically significant and fit with the theory, leading to publication bias. To overcome this, both published and unpublished studies have been included in the dataset, allowing us to test for publication bias (see e.g. DeCoster, 2004; Melo et al., 2009). Finally, the choice of study-design factors to be considered in the meta-analysis affects the results, as is the case with the estimation of any econometric model. There are no guidelines that explicitly determine the specific characteristics of studies that can influence the results; these are generally chosen based on researchers' knowledge about the literature.

We collected empirical estimates of the impact of rail on land/property values from 23 studies, generating 102 observations. We use more than one observation per study to increase the sample size. Although more literature was found, not all of the estimates were suitable to be included in the dataset due to lack of reported information (e.g. if the reported value was rent or purchase price).

To analyse the variation underlying existing empirical evidence on the impact of rail on land/property values, the estimates of these effects must be comparable. Most of the studies reported percentage changes in land/property values arising from investments in rail, while a few reported changes in actual monetary values (e.g. in $US). The percentage change is a

Table 1
Summary of the meta-sample. *Source*: authors produced table.

Author(s)	Type	Measure	Rail system	Location	% change	Notes
Voith (1991)	Residential	Purchase of property	Commuter rail	Pennsylvania and New Jersey	3.8–10%	
Laakso (1992)	Residential	Purchase of property	Metro	Helsinki, Finland	3.5–6%	
Al-Mosaind et al. (1993)	Residential	Purchase of property	Light rail	Portland, USA	10.6%	
Chen et al. (1997)	Residential	Purchase of property	Light rail	Portland, USA	10.5%	
Weinstein and Clower (1999)	Residential	Purchase of property	DART light rail	Dallas, USA	−5.2%	
Dueker and Bianco (1999)	Residential	Purchase of property	Light rail	Portland, USA	6.5%	
Chesterton (2000)	Residential	Purchase of property	Underground	London, UK	71.1% and 42%	Report shows the impact of transport, neighbourhood and property characteristics affect values
Bowes and Ihlanfeldt (2001)	Residential	Purchase of property	MARTA	Atlanta, USA	−19% to 2.4%	
Clower and Weinstein (2002)	Residential	Purchase of property	DART light rail	Dallas, USA	7.2% and 18.2%	
Bae et al. (2003)	Residential	Purchase of property	Seoul's rail	Seoul, Korea	0.13–2.6%	
Cervero (2003)	Residential	Purchase of property	Light and commuter rail	San Diego County, USA	−12% to 46%	
Gibbons and Machin (2003)	Residential	Purchase of property	Underground	London, UK	1.5% increase every 1 km reduction	
Yankaya and Celik (2004)	Residential	Purchase of property	Metro	Izmir, Turkey	0.7% and 13.7%	
Debrezion et al. (2006)	Residential	Purchase of property	Dutch national railway	Holland	25%	
Du and Mulley (2007)	Residential	Purchase of property	Tyne and Wear light rail	England, UK	−42% to 50%	Large variations depending on location
Duncan (2008)	Residential	Purchase of property	Light rail	San Diego, USA	5.7% and 16.6%	
Pan and Zhang (2008)	Residential	Purchase of property	Shanghai rail transit system	Shanghai, China	1.1% and 3.3%	
Agostini and Palmucci (2008)	Residential	Purchase of property	Santiago metro	Santiago, USA	From 3.8% to 7.4%	
Benjamin and Sirmans (1996)	Residential	Rent of property	Metro	Washington, DC, USA	Each one-tenth of a mile reduces by 2.5%	
Bollinger et al. (1998)	Office	Rent of property	Light rail	Atlanta, USA	−7%	
Weinberger (2001)	Office	Rent of property	Light rail	Santa Clara County, USA	7–10%	Using semi-log models
Weinstein and Clower (1999)	Retail	Purchase of property	DART light rail	Dallas, USA	4.6%	
	Office		DART light rail	Dallas, USA	22.7%	
FTA (2000)	Commercial	Purchase of property	Metro	Washington, DC, USA	2% increase every 1000 feet	
Cervero (2003)	Commercial		Light and commuter rail	San Diego County, USA	71.9–91%	
Weinstein and Clower (1999)	Residential	Purchase of land	DART light rail	Dallas, USA	7.7%	
	Retail	Purchase of land			29.7%	
	Office	Purchase of land			10.1%	
Cervero and Duncan (2002)	Commercial	Purchase of land	Light rail	Santa Clara County, USA	23%	
	Commercial	Purchase of land	Commuter		120%	

unit free estimate that was used here. In the cases where monetary values were given, a percentage value was obtained by comparing the land/property values in the catchment zone of rail stations to the average land/property values outside the catchment zone.

3. Literature review

Land and property values vary spatially due to certain characteristics of properties, neighbourhood, accessibility, etc. Accessibility impact on land/property values are explained by bid-rent theory, which views the price that a consumer is willing to pay for a particular land/property as a decreasing function of distance to a certain attraction due to certain benefits realised from that attraction (e.g. distance to Central Business District – CBD) (O'Sullivan, 2003; Zhang, 2009). Any good or attraction zone that is perceived to have added benefits to residents, commuters, and users of an area can have an effect on land/property values around that attraction. By comparison, access to transport services such as stations and highways can impact land/property values surrounding them.

Some studies have attempted to analyse the factors determining variation in estimates of change in land/property values due to rail projects. These include: property type, railway type (e.g. Duncan, 2008; Pan and Zhang, 2008; Zhang, 2009), the extent of impact (e.g. RICS Policy Unit, 2002), the methodologies used (e.g. Du and Mulley, 2006), and the measure of accessibility used (Ryan, 1999). The principal study characteristics that may influence empirical values estimated in related studies are discussed below. These include the type of property, type of rail service, reported value (positive, negative or not significant), geographical scope of the study, and data type.

Table 1 provides a summary of estimates and study-design dimensions for the studies reviewed. The majority of work has concentrated on the impacts of rail on housing property markets and few on other properties and land uses. Transactions in residential markets are generally greater than other types of land uses and hence more data are available for analysis (e.g. Diaz, 1999; Duncan, 2008). The table reveals that estimates vary greatly for each land/property type. Commercial properties appear to experience a greater increase in their rental values compared to residential properties (see also Debrezion et al., 2007). Similarly, the value change of land due to rail investments appears to be generally higher than property value changes. The range of magnitude in rent values is narrower than for purchase prices. Estimates also seem to vary across the type of rail service. We find that the impact of light rail and metro on land/property value changes range from negative to positive, whereas commuter rail seems to enhance values at a greater rate. Other sources of difference among studies are the type of empirical model and the geographical location.

Fig. 1 provides a histogram of the estimates of the changes in land and property values due to investments in rail projects. Although the majority of studies report a positive effect, estimates range dramatically from positive to negative values and in some cases very little impact is reported. The empirical results of changes in land and property values in our meta-sample vary between −0.45 and over 1 with a mean of 0.080, a median of 0.054 and a standard deviation of 0.172. This confirms that although on average rail schemes tend to have economic benefit on land and property values, there is a large variation in estimates across case studies.

The literature has estimated positive gains in land/property values in close proximity to stations for most rail systems (e.g. Agostini and Palmucci, 2008; Laakso, 1992; Pan and Zhang, 2008; Voith, 1991). It can be observed that percentage changes in values are higher in East Asian and European cities compared to North American ones. One explanation may be the high dependence on public transport services in most of Europe and East Asia, compared to the more car-oriented culture of most of North American cities. In addition, the literature has shown that values increase more in congested zones (Clower and Weinstein, 2002). Overall, the changes seem to be specific to the study area and no particular pattern may be found in this regard.

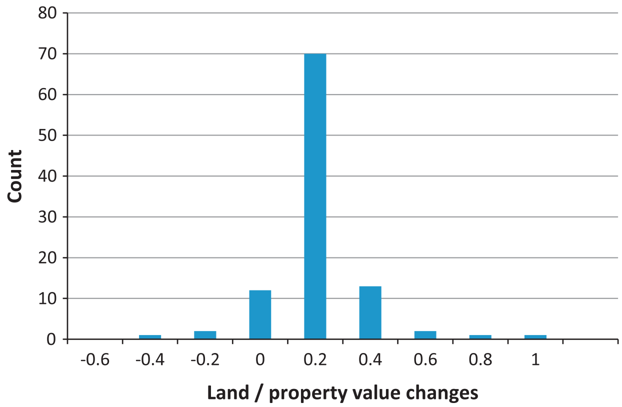

Fig. 1. Histogram of the changes in land and property values. *Source*: authors produced graph.

A small number of studies have found that at locations very close to stations or railway lines (typically within walking distances to stations where noise, pollution and crime levels increase), property and land values have reduced (e.g. Diaz, 1999; Hui and Ho, 2004; PB, 2001). For example, Bollinger et al. (1998) argue in their study of the impacts of Atlanta's Rail (US) on office rent values that rents have reduced within a quarter of a mile from stations due to the perceived risk of safety near stations. The study has also shown a positive relationship between access to highway and office rents. This can imply that accessibility to a competitive mode of transport (e.g. car versus public transport) may be another reason for variation across studies. In this example, the railway might not have provided any perceived benefits to workers in the region to tempt them to use rail service. A study conducted by Du and Mulley (2007) demonstrated that in some non-CBD areas at distances between 200 and 500 m from Tyne and Wear light rail stations (Newcastle, England), there were evidence on statistically significant negative impacts on dwelling values that ranged from −5% to over −40%. The authors did not explain the reason. One interpretation may be that the light rail system did not provide a favourable mode of transport to residents and users of these areas compared to other modes.

Some land/properties are found to experience hardly any impact from rail investments on their values, such as the residential properties in close proximity to the Miami's Metrorail (Gatzlaff and Smith, 1993). In such cases, one may need to analyse the benefit that a rail system brings to the community such as improvements in accessibility of the neighbourhood in question. For example, although a new railway may provide accessibility to the majority of commuters' destinations, it may not improve it; i.e. it may compete with other modes such as private cars which may offer a better alternative. As a result, the rail station can fail to provide any considerable benefits to the neighbourhood. This in turn affects the value that consumers will be willing to pay for land/property surrounding the stations. However, if with time policies are introduced such that the generalised cost of travel by other modes increases compared to the rail service, a number of commuters may switch to using rail transport leading to an increase in land/property values. This implies that the time the data is collected in relation to rail service maturity and attractiveness to users can cause variation in estimated results. An example of this is the Metropolitan Atlanta Rapid Transit rail system, which started operation in 1979. Nelson and McCleskey (1989) studied the impacts of the rail in 1989 and reported little effect. However, a second study of the same railway has shown both positive and negative impacts depending on location (Bowes and Ihlanfeldt, 2001). Another example is San Francisco's BART system, which required some time to attract passengers and hence affect property values (Clower and Weinstein, 2002).

The radius of impact of new or improved rail schemes on land/property values varies in different locations and according to the type of land use. The literature demonstrates that in most cases the extent of influence may go up to 1000 m for residential areas and 400 m for commercial areas, but in rare cases it can rise to 2000 m and 1200 m for each zone respectively (RICS Policy Unit, 2002). It is worth mentioning that the increase is indeed not linear with distance and appears in most cases to follow the assumed decay of bid-rent theory (e.g. Al-Mosaind et al., 1993).

Studies have either used cross-sectional or panel data, and in few cases time-series data. Panel data has many advantages over cross-sectional data that are relevant here. First, using panel data for dynamic systems can better represent the changes over time and distinguish short and long term impacts. This is applicable to our case, as railway projects go through different periods, from project announcement to system stabilization, and the impact on land/property values can differ at each stage. Second, panel data estimators can correct for unobserved heterogeneity, which in most cases is assumed to be time-invariant, and therefore produce more accurate estimates (Hsiao, 2003). For example, the perception of the public to using rail systems may not be directly observed by the researcher but may be correlated with the accessibility benefit factor used as a covariate in the estimation model. Not accounting for this correlation would result in an incorrect estimate of the effect of accessibility on land/property values.

The discussion above suggests that it would be interesting to compare studies according to the type of data used. A large number of studies have used cross-sectional data (e.g. Al-Mosaind et al., 1993; Du and Mulley, 2007; Laakso, 1992; Voith, 1991) and as discussed above the accuracy of such estimates can be challenged. Others have used panel data to identify the effect of rail at different stages and at different distances from rail stations providing potential advantage over cross-sectional data (e.g. Agostini and Palmucci, 2008; Bae et al., 2003). Some researchers, although using panel data, focused on a particular stage of the rail life cycle (e.g. Bowes and Ihlanfeldt, 2001; Duncan, 2008; Weinberger, 2001). The estimates produced by these studies are likely to be more reliable than those estimates obtained from using cross-sectional data. Considering the sample of studies used in this meta-analysis, around 80% of the studies using panel data reported significant results compared to 73% for studies using cross-sectional data.

Based on the review of the empirical literature conducted in this section, a number of study-design factors can be identified as sources of variation both across and within studies. In the next section, we provide a description of these factors and the design of the meta-regression model.

4. Design of the meta-analysis

Two sets of factors related to study characteristics – namely contextual and methodological factors – can cause variations in the estimated change in land/property values that arises from rail investments. Contextual factors include variables that are expected to affect the value of land/property in real life. Methodological factors are related to the empirical models and data used in the studies. Fig. 2 (top panel) classifies contextual factors according to three categories – economic, internal and external factors – and lists the methodological factors (lower panel). The covariates included in the meta-analysis are shown

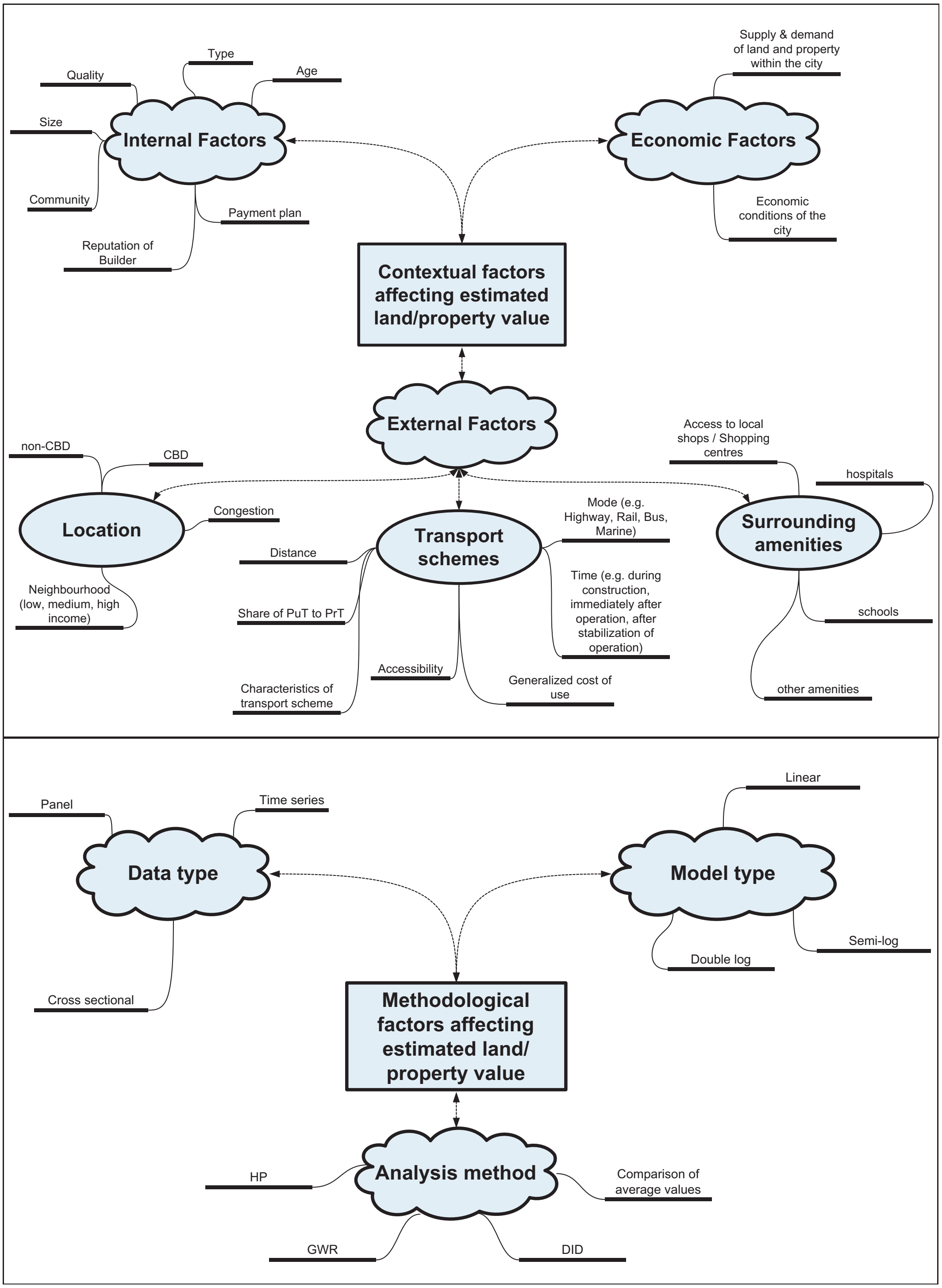

Fig. 2. Top panel: Contextual factors affecting estimated land/property values; lower panel: Methodological factors affecting estimated land/property values. *Source*: authors own classification.

in Table 2. They include most of contextual factors (expect economic factors which are difficult to obtain for case studies) and all the methodological factors. Out of the 21 contextual factors considered in our study, 15 are either new or modified from Debrezion et al. (2007). Only 2 out of the 7 methodological factors used in this meta-analysis were also used by Debrezion et al. (2007).

Table 2
Covariates used in the meta-analysis. *Source*: authors own classification.

Dimension	Variable	Definition	Reference case
Contextual factors			
Property or land	D_{PP}[a]	1 if the outcome is a measure of property value, 0 otherwise	Study reports on land values
Reported value	D_{P}[a]	1 if purchase or sales price, 0 otherwise	Study reports rent values
Type of land/property	D_{comm}	1 if land/property type is commercial, 0 otherwise	Land/property type is residential
	D_{off}[a]	1 if land/property type is office, 0 otherwise	
Property characteristics	D_{pc}	1 if property characteristics are used in study analysis, 0 otherwise	Study does not report on property characteristics
Time of case study data collection	D_{90-99}[b]	1 if the data time is between 1990 and 1999, 0 otherwise	Data is for the time period from 1980 to 1989
	D_{00-10}[b]	1 if the data time is between 2000 and 2010, 0 otherwise	
Type of rail service	D_{HV}	1 if heavy rail or metro, 0 otherwise	Rail service is light rail (LRT)
	D_{commu}	1 if commuter rail, 0 otherwise	
Rail system maturity	D_{cons}[a]	1 if the data are obtained during construction of rail service, 0 otherwise	Data obtained within a few months after project announcement
	D_{imm}[a]	1 if the data are obtained immediately after operation of service, 0 otherwise	
	D_{stab}[a]	1 if the data are obtained after system stabilization, 0 otherwise	
Distance to rail station	D_{0-200}[b]	1 if distance to rail station is between 0 and 200 m, 0 otherwise	Distance to rail station is more than 806 m (i.e. half a mile)
	$D_{201-500}$[b]	1 if distance to rail station is between 201 and 500 m, 0 otherwise	
	$D_{501-805}$[b]	1 if distance to rail station is between 501 and 805 m, 0 otherwise	
Geographical location	D_{EU}[a]	1 if the study is in Europe, 0 otherwise	Study is in the North American cities
	D_{EA}[a]	1 if the study is in East Asia, 0 otherwise	
	D_{A}[a]	1 if the study is in other Asian cities, 0 otherwise	
Accessibility	D_{acc}	1 if the study uses accessibility roads in the analysis, 0 otherwise	Study uses accessibility to rail station only
Land/property location	$D_{non\text{-}CBD}$[a]	1 if land/property is either not in CBD or in both CBD and non-CBD, 0 otherwise	Land/property is in CBD area
Neighbourhood type	D_{nc}	1 if neighbourhood characteristics are used in study analysis, 0 otherwise	Study does not report on neighbourhood characteristics
Methodological factors			
Data type	D_{cs}[a]	1 if the study uses cross sectional data, 0 otherwise	Study uses panel or time series data
Analysis method	D_{GWR}[a]	1 if the study uses Geographically Weighted Regression, 0 otherwise	Study uses Hedonic Price model
	D_{DID}[a]	1 if the study uses Difference-in-Difference model, 0 otherwise	
	D_{comp}[a]	1 if the study compares average value changes over time, 0 otherwise	
Model type	D_{SL}	1 if the model type is semi-log, 0 otherwise	Model type is linear regression
	D_{DL}	1 if the model type is double-log, 0 otherwise	
Results type	$D_{non\text{-}sig}$[a]	1 if result type is not-significant, 0 otherwise	Result type is significant

[a] These variables were not used in previous meta-analysis papers.
[b] These variables were used in previous meta-analysis papers however not to the level of detail as those here.

To distinguish between the impact of rail on land and property values, we use a dummy variable that equals 1 if the estimate reports property value and zero otherwise. As discussed in the literature review (Section 3), changes in purchase prices and rent values of land/property vary case by case. We aim to test if the influence of rail schemes on sales is statistically different from the impact on rent values. The reference case includes observations that estimate the change on rent values. As was noted in the literature review (Section 3), residential, commercial and office land/properties are affected differently. A set of control variables for each type is included and residential land/property value is selected as the reference case. An empirical dimension has also been included to test whether the study has considered property characteristics in the estimation model. Additionally, a set of control variables has been used to examine if estimates vary over time. The reference period consists of the estimates collected for the 1980s.

Many studies have summarised the variation in land/property values for different types of transport investment. Dummy variables for the type of rail service have been included (light, heavy or metro and commuter rail) and the reference case is for studies that have reported on the impact of light rail. To distinguish between the impact of rail at different phases of the system, we include dummy variables that distinguish estimates at time of announcement, during construction, immediately after operation (i.e. within a year of operation), and after the stabilization of the system. To control for differences in land/property value changes at different distances from rail stations, we specify a set of control variables for different catchment zones compared to a threshold of half a mile or 806 m away from a station. The motivation to investigate the effect at different distances is to assess whether the impact of rail follows the bid-rent theory described earlier.

The impact of rail services can vary in different parts of the world due to factors like rail patronage share and the perception of travellers to using rail services. This meta-analysis differentiates cases according to their geographical zone (North America, Europe, East Asia, and other parts of Asia). The reason for such a classification is that the majority of cities considered within each sub category exhibit similar characteristics in terms of mode share (i.e. car or public transport orientation). Accessibility to roads is taken as another dimension in the meta-analysis model. The literature suggests that having a competitive mode of transport can affect the extent of land/property value change around rail stations.

Values may also differ at different locations (e.g. CBD or non-CBD). Some studies have distinguished values in CBD and non-CBD zones, however the majority reported an average value for all locations. A dummy variable is used to distinguish studies that report results for both CBD and non-CBD zones, from those reporting results only for the CBD area. Another empirical dimension that was included was whether neighbourhood type had been considered in the model specification.

As discussed in the literature (Section 3), data type may affect the estimates obtained in regression models. In this meta-analysis we test for the effect of using cross-sectional data on the reported estimates, as opposed to panel or time series data. We also account for the role of the empirical methods used, namely, Hedonic Price (HP) models, Geographically Weighted Regression (GWR), Differences-in-Differences (DID), and direct comparison in average value changes. Dummy variables are set for each and the reference case refers to the studies using HP models. We also specify dummy variables for different model types – linear (reference case), semi-log and double log. Finally, the statistical significance of the results is used as another dimension in the meta-analysis.

A typical meta-analysis regression model is shown in Eq. (1) (see also Melo et al., 2009; Stanley and Jarrell, 2006; Weichselbaumer and Winter-Ebmer, 2005).

$$P_{ij} = \alpha_0 + \sum_k \alpha_k D_{ij,k} + \mu_j + \varepsilon_{ij} \tag{1}$$

where i refers to the individual estimate(s) obtained from a given study j. P_{ij} is the dependent variable (i.e. estimate of land/property value change), $D_{ij,k}$ is the meta-regressor k, and α_k is the model parameter associated with meta-regressor k and measures its impact on the estimate of the land/property value change. Finally, α_0 is the constant of the model, μ_j is a study-specific effect, and ε_{ij} is the model disturbance term.

Meta-analysis can be conducted using a fixed-effects model (FE) or a random-effects model (RE). In order to identify which model fits our data best, we first perform a test of heterogeneity (Q)[1] on the reported estimates to examine if the real change in land/property values in different studies is not unique. This means that the variation in the empirical results is partly because each result is an estimate of an actual change in land/property value that may be different in each case study. A statistically significant value of Q is obtained which justifies the need for a RE model. There are other reasons that support the RE model. The sample used in the study, although intended to be as comprehensive as possible, does not include all available studies. Both published and working papers were obtained for a period of almost three decades and from various sources including journals articles, conferences papers, research working papers and online published reports. The studies report estimations for the effect of rail on land/property values in three continents and for over 80 cities. Based on the above, we can therefore view the estimates as a random sample taken from a larger population. In addition, since we have gathered more than one observation per study, we expect the estimates from the same study to be correlated. The RE model allows for both *within* and *between* study variations while the FE model relies solely on the former.

5. Results

The results obtained from the meta-regression models are reported in Table 3. We consider two different model specifications. Model 1 tests the relationship between the change in land/property values due to rail investments in relation to all contextual and methodological factors considered in Table 2. The dependent variable is the 'percentage change in land/property values due to rail investments'. Model 2 reports on the same dependent variable but focuses on a subset of covariates to identify the impact of internal factors of land/property and transport related covariates (like accessibility) on the estimated change in land/property values.

Observing Table 3, models 1 and 2 have similar results indicating the large influence of internal and transport factors on land/property values. The measure of the goodness-of-fit (R-squared) indicates that model 1 and model 2 can explain about 60% and 46% of the variation in the data, respectively. Model 1 has a larger goodness-of-fit value because it has more covariates that are also statistically significant and explain part of the variation in the estimates of land/property value changes due to rail investments. The results of the two models are explained simultaneously in accordance to the contextual and methodological factors classified in Fig. 2.

We start by examining the variations in land/property values due to contextual internal factors. The percentage change in property values is found to be significantly lower (22% and 16% points for models 1 and 2, respectively) compared to changes in land values. An explanation for this result could be that the capitalised value of land has potential for more varied

[1] The result of the Q value equals 4.2×10^9 and it is significant at 1%.

Table 3
Results of the meta-analysis. *Source*: authors own calculation.

Factor type	Dimension	Variable	Model 1	Model 2
Contextual – internal factors	Constant	α_0	0.5759 (0.2652)**	0.3652 (0.2246)*
	Property or land	D_{PP}	−0.2230 (0.0862)***	−0.1626 (0.0813)**
	Reported value	D_P	0.1167 (0.1045)	−0.0329 (0.0920)
	Type of land/property	D_{comm}	0.3156 (0.0581)***	0.2431 (0.0530)***
		D_{off}	0.1342 (0.0909)	0.0211 (0.0886)
	Property characteristics	D_{pc}	−0.0918 (0.1823)	−0.0172 (0.1727)
Contextual – time	Time of case study data collection	$D_{90–99}$	0.0311 (0.0731)	
		$D_{00–10}$	0.0855 (0.0625)	
Contextual – external – transport scheme	Type of rail service	D_{HV}	−0.0488 (0.0693)	−0.1165 (0.0513)**
		D_{commu}	0.2531 (0.0600)***	0.2431 (0.0586)***
	Rail system maturity	D_{cons}	−0.0175 (0.0827)	0.0309 (0.0796)
		D_{imm}	−0.0369 (0.0859)	−0.0949 (0.0874)
		D_{stab}	−0.1452 (0.0879)*	−0.1843 (0.0741)**
	Distance to rail station	$D_{0–200}$	0.0749 (0.0613)	0.0797 (0.0654)
		$D_{201–500}$	0.0706 (0.0441)	0.0627 (0.0458)
		$D_{501–805}$	0.0872 (0.0525)***	0.0946 (0.0515)*
	Geographical location	D_{EU}	0.1486 (0.0591)**	0.0935 (0.0487)*
		D_{EA}	0.1575 (0.0754)**	0.0230 (0.0637)
		D_A	0.1231 (0.1210)	0.0606 (0.1198)
	Accessibility	D_{acc}	−0.1491 (0.0666)**	−0.0279 (0.0487)
Contextual – external-location	Land/property location	$D_{non-CBD}$	−0.0141 (0.0885)	
	Neighbourhood type	D_{nc}	−0.0441 (0.1042)	
Methodological – data type, analysis method and model type	Data type	D_{cs}	−0.1598 (0.0551)***	
	Analysis method	D_{GWR}	−0.0828 (0.0818)	
		D_{DID}	−0.0156 (0.0964)	
		D_{comp}	−0.3202 (0.1410)**	
	Model type	D_{SL}	−0.1498 (0.0661)**	
		D_{DL}	−0.1830 (0.1103)*	
	Results type	$D_{non-sig}$	−0.0102 (0.0503)	
	Observations		102	102
	R^2 (total)		0.6028	0.4647
	R^2 (within)		0.4322	0.2752
	R^2 (between)		0.8024	0.7426

* Significance at 10%. Values in parentheses are standard errors.
** Significance at 5%. Values in parentheses are standard errors.
*** Significance at 1%. Values in parentheses are standard errors.

development schemes compared to already built properties. The literature has also demonstrated that land value changes tend to be positive, whereas property values range from negative to positive estimates. Nonetheless, the coefficient on the reported value in both models shows that there is no significant difference between the impact of rail investments on purchase price changes and rent value changes for properties.

The results also imply that commercial land/properties tend to exhibit significantly higher value changes compared to residential land/properties: by over 31% points for model 1 and 24% points for model 2. The higher impact of rail on commercial land-use is apparent in the literature as discussed previously. On the other hand, no noticeable difference is found on the changes in office values compared to residential land/property value changes. As home-to-work trips are regular trips, commuters may place the same accessibility benefit to both residential and office land uses. The results also suggest that including property characteristics in the model specification does not affect results significantly. This is possibly due to the independence between property characteristics and proximity to rail stations. In addition, model 1 suggests that the reported variations in land/property value changes in each decade are roughly similar.

The type of transport scheme is one of the external factors that affect land/property values. In model 1, the coefficients on the type of rail service dummy variables imply that metro and heavy rail have an impact on land/property value changes similar to that of light rail schemes. Model 2, on the other hand, suggests that heavy rail has a reduced effect on land/property value changes compared to light rail by around 12% points. A possible explanation may be that heavy rail has a higher environmental impact than light rail and hence may add less economic value to the environment around rail stations. In both models, commuter rail exhibits higher impacts, by about 24–25% points. Some cases have indeed proved this finding (e.g. Cervero and Duncan, 2002; Weinstein and Clower, 1999). One reason may be that commuter rail can provide a more beneficial access to travellers at longer distances and hence be valued more than light rail, which is more relevant for shorter distances.

The coefficients of the rail system maturity dummy variables suggest that there are no significant differences in land/property value changes at time of announcement, during construction, and immediately after operation. However, we observe that the change in land/property values after the rail system stabilizes is on average lower (around 15% and 18% points for models 1 and 2, respectively) than at time of announcement. This indicates that the perceived benefit of the rail system at time of announcement is often higher compared to the actual realised benefit after the system stabilizes (e.g. Bae et al., 2003).

The controls for the distance of land/properties to rail stations reveal interesting results. We observe that land/property value changes within 200 m of a station are not significantly different to those observed for land/properties at more than 805 m away. As discussed in the literature review (Section 3), the perceived reduction in environmental and safety standards in close proximity to stations can have negative impacts on land/property values. Therefore, changes in values within a 200 m catchment zone can be at similar levels to those more than half a mile away from stations. Results also suggest no significant difference in value changes between 201 and 500 m compared to land/property more than a half a mile away from stations. This result is quite surprising. However, the coefficient for the dummy variable of catchment areas within 500–805 m from a station indicate that the change in land/property values are significantly higher – by around 9% points in comparison to the reference distance of more than half a mile away. This is expected since most users commute to stations by walking and a catchment area up to half a mile is an acceptable walking distance in many cities.

Comparing changes in land/property values across continents, the results imply that land/property values in European cities (models 1 and 2) and East Asian cities (model 1) experience significantly higher impacts compared to North American cities. Given the mode-share characteristics in these case studies, this is expected. The majority of European and East Asian cities in our meta-analysis are public transport oriented, compared to the car-oriented cities in North America. The coefficient of the dummy variable representing other Asian cases shows no noticeable difference compared to their North American counterparts. We also observe that having access to roads and highways reduces the impact of rail schemes on land/property values by around 15% points in model 1, although there is no noticeable difference in model 2. In almost all cases, roads provide alternative options for commuters and hence having access to competing modes of transport can result in a lower impact of rail projects on land/property values.

Location and neighbourhood type are other external factors that can affect land/property values. The results in model 1 show that the location of land/property within a city (CBD or as an average value of both CBD and non-CBD zones) does not influence the changes in land/property values. Similarly, the results indicate that the inclusion of neighbourhood characteristics in the model specification does not have a statistically significant effect on the estimate of land/property value change.

Considering the parameters obtained for the methodological factors in model 1, we observe that methodological choices can affect the obtained estimates of land/property value changes. The results indicate that studies using cross-sectional data report estimates that are 16% points lower than studies using panel or time-series data. This result confirms that the use of panel data for dynamic systems, such as the one in question, does impact the estimates significantly. Turning to the effect of using different empirical models, we observe that generally estimates do not differ in size across methods, with the exception for the average comparisons of values, which are found to be lower (32% points) than HP models. This is quite surprising given the fact that HP models account for various factors affecting land/property values and report the impact of each separately. The reported impact of rail schemes is only one part of the overall change in values and hence HP models are expected to report lower estimates of land/property value change. One explanation may be that the limited number of studies that have used overall comparison of values happened to have lower estimates of change in land/property values in the meta-sample.

The results indicate that both semi-log and double log models produce significantly lower estimates of the percentage change in values, by 15% and 18% points respectively, compared to linear models. This can be because of the exponential form of these models which reduces values at a greater rate. For example, Weinberger (2001) found that the impact of light rail on office values in Santa Clara (USA) was higher when using a linear model compared to a semi-log model. It can also be argued that semi-log and double log models produce more representative results for these study cases, as was identified by many of the researchers conducing such analyses (e.g. Bowes and Ihlanfeldt, 2001; Weinberger, 2001).

Finally, the results suggest that we cannot reject the null hypothesis of equality between non-significant and significant estimates. This indicates that the range of variation in land/property value changes for significant estimates is not different to that for non-significant estimates. Linking the reported values to their standard errors, we can test whether studies tend to report statistically significant values and possibly reporting bias. The next section considers the issue of publication bias.

6. Publication bias

Researchers may conduct analyses of the impact of rail schemes on land/property values with the pre-conceived position that there should be positive effects. Hence, positive results, and possibly only significant ones, may be reported more often. We examine whether this hypothesis is true by performing publication bias tests. To do this, we consider the relationship between the estimates of the change in land/property values and their respective standard errors.

Only 19 studies (accounting for 91 observations) out of the 23 studies reported standard errors. We divide studies into published articles and working papers. The coefficient of correlation between the change in land/property values and the standard errors is 0.36 and 0.43 for published articles and working papers, respectively. Both values may suggest some sort of bias in reporting statistically significant results. To further examine this pattern, we consider the relationship between the absolute values of the dependent variable and respective standard errors (Fig. 3). Many of the points lie above or very close to

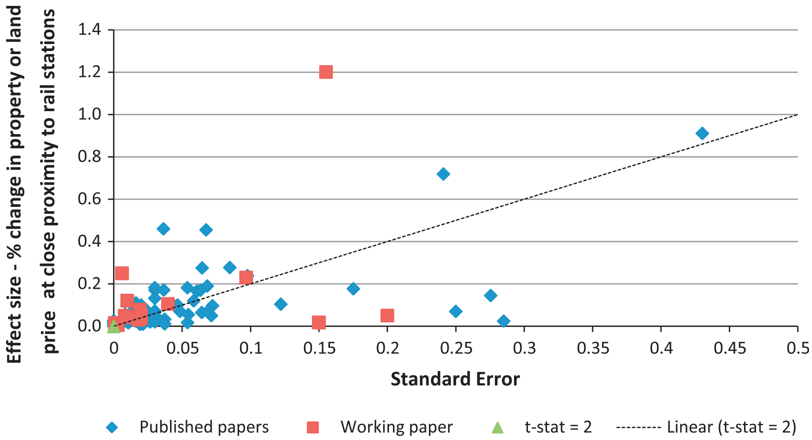

Fig. 3. Relationship between percentage change in land/property values (in absolute values) and the standard errors. *Source*: authors produced graph.

Table 4
Results of publication bias regression models by relating changes in land/property values to the standard error. *Source*: authors own calculation.

Variable	Model 1	Model 2
α_0	0.0239 (0.0395)	0.0317 (0.0290)
α	1.2314 (0.2571)***	
α_p		1.7947 (0.2352)***
α_n		−0.6716 (0.3577)**
Observations	91	91
R^2 (total)	0.1263	0.4508
R^2 (within)	0.2741	0.4703
R^2 (between)	0.0001	0.4470

** Significance at 5%. Values in parentheses are standard errors.
*** Significance at 1%. Values in parentheses are standard errors.

the statistical threshold value of the t-statistic equal to 2. Fig. 3 suggests that working papers and published articles report both positive and negative values and significant and insignificant results. However, there seems to be a slight bias towards significant estimations.

Another test was performed on the same hypothesis using a regression model of the form:

$$y_i = \alpha_0 + \alpha se(y_i) + \varepsilon_i \tag{2}$$

where y_i is the percentage change in land/property values taking both positive and negative estimates and $se(y_i)$ is the standard error.

In order to study publication bias for reporting positive and negative values, a second test can be done introducing dummy variables as shown in the following equation:

$$y_i = \alpha_0 + \alpha_{pi} D_{pi} se(y_i) + \alpha_{ni} D_{ni} se(y_i) + \varepsilon_i \tag{3}$$

where D_{pi} takes the value of one if the study reports positive impacts and zero otherwise. The reverse is for D_{ni}.

Models 1 and 2 in Table 4 show the results obtained from Eqs. (2) and (3), respectively. It can be seen in both models that the coefficients are significant, indicating a publication bias towards reporting statistically significant results. Model 2 suggests that both positive and negative values are reported.

7. Conclusions

This paper has analysed the variation in the estimated impact of rail systems on land/property values reported by a number of studies. Although there have been previous attempts to explain such variation, previous analyses either lacked objectivity and/or did not provide a comprehensive view of study-design factors that explain the range of estimates obtained by the empirical literature. The main contributions of this paper are the following. First, our meta-analysis considers 15 additional or modified contextual factors and 5 additional methodological factors compared to the previous meta-analysis conducted by Debrezion et al. (2007). Each is thought to explain part of the differences in existing evidence on the impact of rail systems on land/property value changes. Second, it covers almost twice as many observations as the previous meta-analysis by Debrezion et al. (2007). Third, it includes data for a wider geographical location, covering European and Asian cities besides North American cities. Finally, the study is the first to test for publication bias of reporting positive and statistically significant results for land/property value changes.

In order to study and understand the variation in estimates of land/property value changes arising from rail investments as reported in different case studies, a sample of 102 estimates was obtained from 23 studies. The factors that may impact land/property values and are expected to give rise to differences in estimations were identified and included in a random-effects meta-analysis regression model. Two model specifications were tested using a different combination of study-design factors. Model 1 uses a comprehensive model specification which includes all contextual and methodological factors affecting land/property value. Model 2 focuses on a subset of factors related to internal characteristics of land/property and factors affecting proximity to rail stations. Both models revealed similar results and indicated that contextual and methodological factors can explain a large portion of the variation in estimates of land/property value changes.

Starting with contextual factors, it was found in both models that land value changes tend to be higher than property value changes. However, no noticeable difference was found for rent values of properties compared to purchase prices. The results indicate that changes for commercial land uses tend to be higher than for residential properties, but dwellings and office values exhibit similar changes. The meta-analysis revealed that including property characteristics in the estimation model does not cause estimates to differ and that changes have been similar over time (from 1980s to 2007).

In both models, commuter rail was found to have higher impacts on land/property value changes in comparison to light rail. Model 2 indicated that heavy rail dampened the effect on land/property values compared to light rail. Results also revealed that the estimated change in land/property values after rail service stabilized were lower compared to announcement time but similar for other stages of the rail system life cycle. This study also showed that average across studies land/property value changes tend to be higher at distances from 500 to 805 m of a rail station, compared to distances longer than half a mile away.

An interesting finding of this study is that the impact of rail on land/property values was found to be higher in European and East Asian cities compared to cities in North America. In addition, model 1 found that accessibility to roads dampened the effect of rail on value changes. The results also indicated that land/property location within the city (i.e. CBD or as an average value in both CBD and non-CBD) and considering neighbourhood type in the model specification did not affect reported values significantly.

Considering the effects of the methodological factors on the reported estimates, this meta-analysis showed that panel or time-series data produced higher value changes compared to cross-sectional data. We also found that there is no noticeable difference in the reported estimates based on the analysis method, but there is some evidence that average comparison methods can produce lower estimates compared to hedonic price models. The results also suggest that semi-log and double-log models tend to produce lower estimates compared to linear models.

We also conducted several publication bias tests. It was found that both published articles and working papers tend to report positive and negative values although biased towards statistically significant results.

The findings from this meta-analysis can be of interest to researchers, industry professionals, and policy makers especially in cases where no empirical evidence is available for the effect of a particular rail on land/property values. For example, the significant results in this meta-analysis may guide researchers interested in analysing the impact of rail services on land/property values on the choice of relevant covariates for their analyses. This study has also suggested that the choice of data structure and estimation model can affect estimations significantly. For example, results indicate that using cross-sectional data versus panel or time-series data produce lower estimates. Similarly, this paper can guide researchers on the effect of model functional form as we have found that semi-log and double-log models tend to provide lower results of the effect of rail on land and property values compared to linear models. In addition, researchers may refer to this paper as a benchmark while comparing their estimations with the empirical results of this meta-analysis to identify how one's findings fit with the average results across studies. Finally, the results may also be used to compare and explain estimates obtained from different case studies.

Additionally, our findings can be of interest to policy makers in cities. Some cities charge a one-time contribution fee and/or annual tax on land/properties at close distances to rail stations to capture part of the benefits of accessibility to rail. In this context, transport decision makers may refer to the results, such as property type and distance to rail station, to identify the contribution share or the annual tax appropriate for each scheme; this is especially relevant if the rail is the first of its kind in the considered region and no empirical values are yet estimated. For example, results show that property values are affected less than land values and hence a higher tax rate may be charged to land owners within the catchment area of a rail station. We have also found that commuter rail enhances prices at a larger rate than light rail and that rail investments increase the value of commercial land/property more than residential land/property. These results may guide policy makers on the choice of the contribution rate to finance rail schemes.

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