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Does high-speed rail accessibility influence residential property prices? Hedonic estimates from southern Taiwan

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ABSTRACT

A new high-speed railway line (HSR) connects seven metropolitan areas in Taiwan. From Tainan, it is possible to reach Kaohsiung, Chiayi and Taichung in less than one hour, implying an enlarged spatial range of feasible commuting opportunities. The implicit price of HSR accessibility is estimated using hedonic price functions for the residential property market. The results of pre-specified and Box-Cox hedonic price functions are compared. The estimated functions show that HSR accessibility has at most a minor effect on house prices. High ticket prices and entrenched residential location patterns prevent otherwise feasible daily commuting opportunities between Tainan and other cities.

1. Introduction

The opening of a high-speed rail line (HSR) in early 2007 drastically reduced travel times along Taiwan's west coast. Investments in transportation infrastructure have often played key roles in the restructuring of urban land use and land price patterns, both in Taiwan and elsewhere. When the Japanese colonial government built Taiwan's first railway network in the early 20th century, it resulted in restructured urban land use patterns. Regional accessibility and land value maxima shifted from ports and harbors to emerging downtowns around urban stations. Later, as the first freeways opened in the late 1970s, new towns and high-priced neighborhoods evolved in proximity to freeway interchanges.

According to the Bureau of high-speed rail, the new rail link is "designed to promote balanced regional development while minimizing impact on the environment and natural ecology. In order to ensure safety at operating speeds of 250 to 300 KPH, the HSR route avoids earthquake faults and soft ground as much as possible" (www.hsr.gov.tw). The total length of Taiwan's HSR line is 345 km. The line has primarily relied on imported technology and hardware from Japan's *Shinkansen* line, supplemented with a European (TGV and ICE) traffic management system. With an investment cost of approximately US$15 billion, it set a new record as the world's most expensive build-operate-transfer project. Fig. 1 is a map of the line with its eight stations, while Table 1 gives downtown-to-station access times by car and public transportation, and city and metropolitan area[1] population figures for 2007 (Directorate General of Budget, Accounting and Statistics, 2008).

The Taipei and Banciao stations are both located within the Taipei metropolitan area and are integrated nodes in the metropolitan commuter rail and rapid transit networks. The Taichung and Zuoying (Kaohsiung) HSR stations can be reached within 15 min from downtown railway stations by commuter train or rapid transit. In the smaller metropolitan areas of Taoyuan, Hsinchu, Chiayi, and Tainan, access to HSR is confined to motor vehicles, resulting in minimum access times of between 20 and 40 min from downtown locations. New light rail transit and commuter rail projects are being planned for Taichung, Tainan, and Taoyuan. The new projects aim at reducing access times by 10 to 15 min.

The high-speed rail line has greatly expanded overall accessibility in time cost terms along the western urban corridor. One-way travel times between the Taipei and Kaohsiung metropolitan areas have been cut from about four hours to one and a half hour. From Tainan HSR Station, it is possible to reach Kaohsiung–Zuoying in 17 min, Chiayi in 19 min and Taichung in 43 min. All these time distances are below the critical 50-min one-way threshold after which commuting frequencies tend to drop, according to a number of empirical studies from Western Europe and North America (Andersson and Andersson, forthcoming). However, Kaohsiung's Railway Station was already at a feasible commuting distance from Tainan's Railway Station before 2007, with a geographical distance of 41 km and a time distance of about 30 min. Even so, Tainan's labor and housing

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[1] A metropolitan area is defined as an economically and socially integrated area. For a suburban township to be included in the metropolitan area, it must be less than 25 kilometers from the center and at least 1.5% of its population must commute to the core city.

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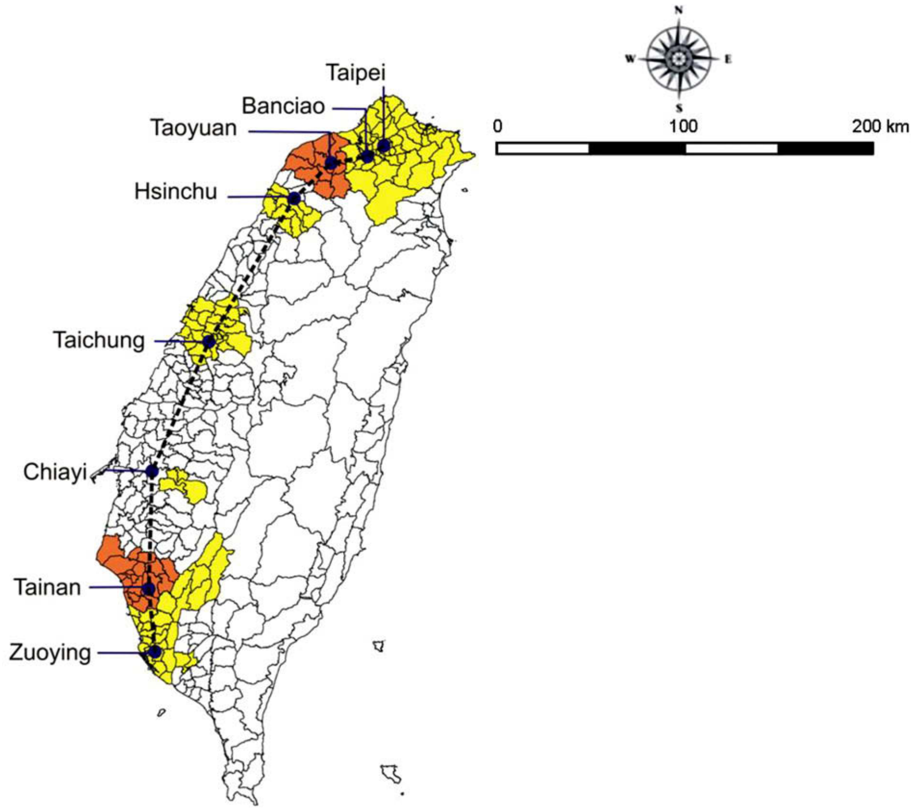

Fig. 1. Stations of the Taiwan high-speed rail line.

markets remained largely separate from those of Kaohsiung, with little commuting activity taking place.[2] Unlike the area surrounding the old railway station, the area around the new Tainan HSR station at Guiren in Tainan County exhibits low population and land use densities.[3] The database used in this study – which includes all residential property transactions in the Tainan metropolitan area in 2007 – shows that only 2.7% of all sold dwellings were located in the same township as the HSR station, which is even lower than its population share of 2.9%.

The aim of this paper is to use hedonic price techniques to estimate the impact of HSR station accessibility on land values in the Tainan metropolitan area. We estimate several functional forms that are all compatible with the underlying economic theory. A comparison of separate estimation results allow us to draw conclusions regarding the robustness of attribute effects.[4]

2. Access to railway stations and house prices

Most studies of the impact of rail accessibility on property values have analyzed local transit networks. Empirical studies of the effects of long-distance rail accessibility on real estate prices are relatively rare. Among the exceptions are Armstrong and Rodriguez (2006), which analyzes a slightly more extensive rail network than is typical in hedonic studies of rail accessibility. The study estimated local and regional accessibility benefits of commuter rail services in eastern Massachusetts, while controlling for proximity-related negative externalities and other confounding influences. It used GIS to measure both multimodal accessibility to commuter rail stations and distance from the rail right-of-way. The overall results were inconclusive, but estimates of the effect of proximity to commuter rail right-of-way indicated a significant negative effect on property values, which may be related to local noise and crime effects.

Bowes and Ihlanfeldt (2001) propose that railway stations should raise the value of nearby properties since they reduce commuting costs and should therefore be better able to attract retail activity than localities away from stations, other things being equal. Possibly countering these positive effects are negative externalities such as noise as well as less protection against criminals from other neighborhoods. Their results – from the Atlanta region

Table 1
Access time in minutes from CBD to HSR stations and metropolitan area population.

HSR station	Metropolitan area population (million)	Access time to CBD (car)	Access time to CBD (public transportation)
Taipei	6.7	0	0
Banciao	6.7	–	–
Taoyuan	1.9	20	30
Hsinchu	0.8	20	30
Taichung	2.3	25	15
Chiayi	0.3	30	40
Tainan	1.2	30	40
Zuoying (Kaohsiung)	2.7	20	15

[2] One reason for the lack of prior labor market integration may be due to greater average time distances between the metropolitan regions than the 41-kilometer distance between the railway stations of Tainan and Kaohsiung would seem to imply. Before 2008, there was no rail transit in Kaohsiung, resulting in average commuting times by public transportation between Tainan and Kaohsiung that amounted to well over one hour (one way, door-to-door). Likewise, the road system suffers from serious congestion problems, with similar or worse commutes, especially during rush hours (7–9 am and 5–7 pm).

[3] Guiren is a low-density "satellite city" with a population of 66 000 consisting of mixed agricultural, residential, and commercial land uses. Its mean income and education levels are lower than the means for the Tainan metropolitan area.

[4] The main attribute effects tend to be similar across functional forms, while many of the less important attributes tend to produce different quantitative and qualitative conclusions depending on the choice of functional form and the specification of independent variables (see Butler, 1982).

– suggest that plans to raise urban densities should consider both the direct and the indirect effects of transit stations on the attractiveness of nearby neighborhoods. Nevertheless, stations that are located sufficiently far away from the urban core will tend to attract new residential development.

In a study of the Izmir region in Turkey, Celik and Yankaya (2006) claim that investments in commuter rail have altered the land rent gradient in the vicinity of railway stations. They contend that their empirical results should convince decision-makers in developing countries that railway and transit investments will provide additional economic value beyond direct ticket revenues.

Debrezion et al. (2006) use a hedonic pricing model to analyze the impact of the railway network on house prices in the Netherlands. They use several railway access variables, including distance to railway station, train service frequency and distance to railway tracks. The data used in the analysis covered sales transactions in the housing market for a period of seventeen years; from 1985 to 2001. Controlling for a wide range of other housing attributes, they found that housing in close proximity to railway stations command market prices that are about 25% more expensive than equivalent housing at a distance of 15 km or more. A doubling of the train service frequency was associated with a price increase of about 2.5%, ranging from 3.5% for houses close to the station to 1.3% for houses at the periphery of the catchment area of the station. Finally, they found a negative price effect associated with railway track proximity, probably due to higher levels of noise. Two railway station accessibility measures were used: the nearest and the most frequently chosen station in the post code area. The results indicate that railway station accessibility is a more complex concept than one might think; it sometimes involves competition between several accessible railway stations.

Studies of the regional enlargement of the Stockholm region in Sweden show that the radius of the price-distance gradient increased as a result of improved rail accessibility. Residential property prices in Uppsala could be partly explained by their time distance from downtown Stockholm after the introduction of a frequent 45-min commuter train service with discounted fares for daily commuters (Andersson and Andersson, forthcoming).

With sufficiently good information flows, the effect of improved accessibility should be capitalized in land values as soon as the decision to build is announced. The normal case for infrastructural investments is however that market participants have highly imperfect information, in part due to uncertainties regarding the credibility of decisions as well as future impacts of investments on the economy as a whole. It is therefore likely that the overall effect is gradually incorporated into house prices, with distinct temporal price effects that correspond to the temporal sequence of relevant events: station location decisions; the commencement of construction; the opening of the line; and the cumulative experience from consuming transportation services. The first three effects should have been fully incorporated in the land value observations that we analyze in this paper, while the service experience component may have been capitalized in land values to a limited extent.

A related topic is the spatial structure of infrastructural impacts. This is particularly relevant in the present context, since Tainan's HSR station has a remote suburban location. Sasaki et al. (1997) contend that market forces that are external to the infrastructure developer cannot increase the degree of geographical dispersion of economic activities even when an extensive network is implemented. The reason is that the stock effect of existing lines favors previously developed regions, implying that construction of new lines in remote regions improves the accessibility of central regions as well.

Such reinforcement of pre-existing agglomeration economies does however not imply that a property developer with substantial land holdings around stations will necessarily fail in bringing about development dispersion, since unified land ownership leads to an avoidance of transaction costs associated with the search for information and exchange partners as well as contracting (negotiation and measurement) costs. Thus, transaction cost savings may offset the sunk cost of agglomeration economies to the extent that long-established areas have more dispersed land ownership.

3. Hedonic prices

Hedonic price theory is usually traced back to a paper by Sherwin Rosen (1974). In that paper, Rosen uses a conventional utility-maximizing approach to derive implicit attribute prices for multi-attribute goods under conditions of perfect competition. The basic idea is that goods such as housing, which are differentiated rather than homogeneous, can be decomposed into homogeneous attributes, where each attribute has a unique implicit price in equilibrium. Perfect competition, however, rests on assumptions of perfect information, which is not normally approximated in markets for experience goods such as housing. The concepts of multi-attribute goods and hedonic prices are however not invalidated if we relax Rosen's assumptions.

In the 1960s, Lancaster (1966) first developed the general idea of approaching goods in general as bundles of objective attributes rather than as homogeneous entities. Barzel (1989) subsumes these insights into his theory of economic property rights, where he analyzes transactions in the market not as exchanges of material goods, but instead as exchanges of rights to the permanent or temporary control of various attributes of a good, where attributes may be combined and subdivided in ways that are not obvious from the physical manifestation of a good.

Hedonic price models aim at disentangling such attributes of a good from one another for the purpose of estimating implicit prices. The normal assumption in hedonic price functions for housing is that the price or rent is a function of various attributes, typically divided into structural, neighbourhood, and accessibility attributes. Individual buyers or renters attempt to maximize their expected utility, subject to various constraints, such as their money and time budgets.

Regression techniques make it possible to estimate the implicit price for each attribute. A linear function implies constant marginal implicit prices. In non-linear models, the price of an additional unit of an attribute depends on the quantity already supplied and in the most common specifications also on the quantity of other attributes. The assumption of constant marginal implicit prices is however only tenable if there are constant returns to scale in production or costless repackaging of two or more bundles (Goodman, 1989). Non-linear models are generally to be preferred, since linear functions are unrealistic when applied to the typical housing market.

The most popular functional forms are log-linear, semi-logarithmic and linear Box-Cox functional forms, which are all theory-compatible and relatively simple. The analysis in this paper makes use of these three types, which in this case includes four different Box-Cox functions.

One of the most difficult questions regarding hedonic price functions concerns the geographical extent of the market. A statistical consideration for empirical studies is that we can expect biased parameter coefficients if the assumed market is larger than its real size. If the assumed size is smaller, it leads to parameter estimates with lower precision (Palmquist, 1991).

Variable multicollinearity sometimes causes problems in hedonic studies, leading to insignificant parameter estimates. Researchers then tend to omit some of the original variables so that the remaining ones subsume parts of the effects of the omitted variables, which may cause interpretation problems. An empirical study of multicollinearity problems (Palmquist, 1983), indicated, however, that the only cases of potentially degrading multicollinearity tend to be between neighbourhood attributes and between different mathematical transformations of the same variable.

4. The Box-Cox transformation

The purpose of this paper is to use hedonic price estimation to estimate transport infrastructure impacts. We use the most common functional forms in hedonic price estimation, which are the log-linear, semi-logarithmic and Box-Cox-transformed forms. The use of several functional forms provides an indication of the robustness and reliability of estimated price effect of HSR accessibility as well as other housing attributes.

Box-Cox estimation is popular in hedonic price studies because data-specific transformations of functions can substitute for a priori specifications of the functional form when theory fails to suggest a specific form. Tukey (1957) argues that the purpose of a transformation is one or more of the following: to stabilize the error variance, to create a model with a symmetrically distributed error term, and to find a more nearly linear model.

The most general and flexible form of the linear Box-Cox transformation is

$$X_1^{\lambda 1} = \beta_1 + \beta_2 X_2^{\lambda 2} + \cdots + \beta_i X_i^{\lambda i} + \cdots + \beta_k X_k^{\lambda k}; \quad \lambda_i = \lambda_1, \ldots, \lambda_k; \qquad (1)$$

where

$$X_i^{\lambda i} = (X_i^{\lambda i} - 1)/\lambda_i \text{ for } \lambda_i \neq 0; \quad \ln X_i \text{ for } \lambda_i = 0.$$

The linear Box-Cox transformation with a pre-specified right-hand side but with a transformed dependent variable, as well as the Box-Cox function with a uniform transformation parameter for all variables are, according to Davidson and MacKinnon (1993), mainly concerned with obtaining residuals that are homoscedastic and symmetrical, while treating the functional form as being essentially given. By contrast, models in which independent variables are transformed separately imply that the functional form depends on the transformation parameter. A problem with the latter type is that there is an implicit assumption that the transformation should yield both the appropriate functional form and disturbances that are approximately homoscedastic and normally distributed. The correct specification may therefore be discarded in the case of true heteroscedasticity.

Zarembka (1974) shows that heteroscedastic residuals imply transformation parameters that are biased. The bias will be in the direction that makes the transformed dependent variable exhibit error terms that are closer to homoscedasticity. Models with more than one transformation parameter will transform the dependent variable parameter in a way that primarily affects the properties of the error term, while the transformation parameters of the independent variables mainly affect the functional form (Davidson and MacKinnon, 1993).

The techniques most often used for estimating Box-Cox functions are either an iterative ordinary least squares method (Halvorsen and Pollakovski, 1981) or one of several maximum likelihood techniques (Spitzer, 1999). Spitzer (ibid.) shows that iterative ordinary least squares result in overestimated t-values, while Amemiya and Powell (1981) show that the assumption of normally distributed error terms, which is a necessary condition for obtaining correct t-values in maximum likelihood estimation, cannot hold for all values of the Box-Cox transformation parameter.

5. Description of the data

The observations on transaction prices and structural characteristics were obtained from the Department of Land Administration of the central government, and cover all 1 550 residential property transactions in 2007 in the Tainan Metropolitan Area (Fig. 2). The data on socio-economic neighborhood characteristics are for 2004 and were obtained from the Ministry of Finance. The neigh-

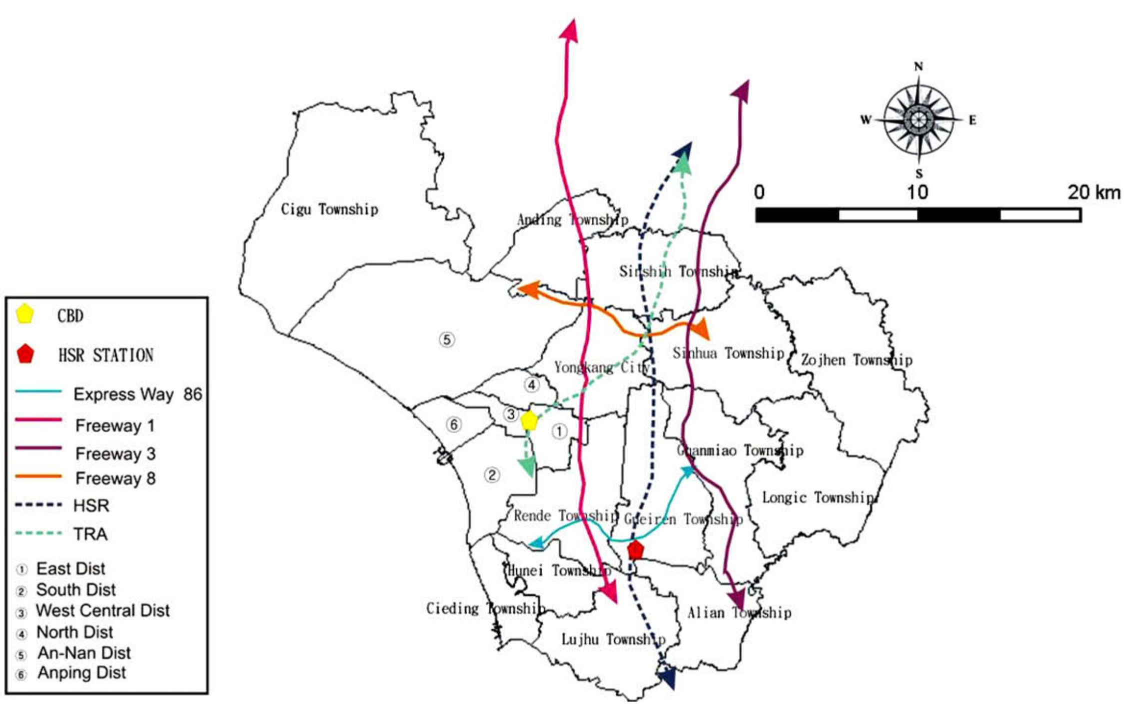

Fig. 2. Tainan metropolitan area.

Table 2
Descriptive statistics.

Variable	Unit of measurement	Mean	Standard deviation	Minimum	Maximum	Expected sign
Sales price	NT$ million	5.6	4.0	.4	43.2	
Structural attributes						
Floor area	Square meters	177.5	126.2	31.0	2449.0	+
Lot size	Square meters	95.1	39.1	13.0	487.0	+
Age	Years	16.8	12.5	1.0	78.0	–
Height	Number of stories	3.2	1.1	1.0	9.0	+
Shop/dwelling use	Yes = 1; No = 0	.1	.4	.0	1.0	+
Street frontage	Yes = 1; No = 0	.3	.5	.0	1.0	+
Neighborhood attributes						
Road width	Meters	15.6	7.3	3.0	55.0	+
Commercial zone	Yes = 1; No = 0	.1	.3	.0	1.0	+
Residential zone	Yes = 1; No = 0	.9	.3	.0	1.0	+
Mean household income in district	NT$ thousand	732.9	116.4	472.0	911.0	+
College-educated in district	Share with junior college or more	.3	.1	.1	.4	+
Accessibility attributes						
Distance to CBD	Kilometers	6.1	4.4	.2	26.7	–
Distance to HSR station	Kilometers	16.7	6.1	1.0	43.5	–
Distance to freeway interchange	Kilometers	5.8	2.8	.4	14.0	–
Distance to TSIP	Kilometers	17.0	4.5	4.0	33.3	–

borhoods correspond to districts in Tainan City and townships in the rest of the metropolitan area (see Fig. 2). The distance measurements are proxies[5] for house-specific access to Tainan's HSR station, the city center, the Tainan Science-based Industrial Park (TSIP), and the nearest freeway interchange, respectively. The distance data correspond to the shortest route for motor vehicles according to a popular GIS program that covers the entire road network of Taiwan; *PaPaGo R12*.

The hedonic analysis makes use of sales prices rather than rents, since owner-occupied housing accounts for more than 80% of Taiwan's housing market. In addition, sales prices reflect expectations of future developments, and should therefore – unlike rents – reflect potential long-term future benefits of new or planned infrastructure investments.

Table 2 gives descriptive statistics for all variables. The tested independent variables encompass six structural, five neighborhood and four accessibility attributes. Pair-wise correlation analysis[6] reveals very high positive correlations between neighborhood income and education and relatively high negative correlations between both socio-economic neighborhood variables and the distance-to-CBD variable. The latter correlations imply an income elasticity of demand for accessibility that is on average greater than the income elasticity of demand for space in Tainan's housing market. Correlations between different accessibility variables are all quite low.

The neighborhood attributes "commercial zone" and "residential zone" refer to Taiwanese zoning regulations, which are more flexible than in many other jurisdictions. Taiwan's cities have retained a mixed-use character since "residential zones" allow commercial use on the first and second floors of apartment houses and townhouses. "Commercial zones" allow for some residential use on higher floors. For example, downtown residential zones are often used for high-rise apartment blocks with high-value commercial use such as banks and luxury retailing on the first two floors.

6. Results

The estimation of hedonic price functions comprises eight different models (see Tables 3 and 4). Models 1 and 2 consist of all tested variables, using the common log-linear and semi-logarithmic functional forms, respectively. Models 3 and 4 use the same pairing of functional forms, but exclude three of the original independent variables. Height in number of stories is deleted because of multicollinearity problems associated with its high correlations with floor area and age, while the mean income of the neighborhood is excluded because of its high correlation with the percentage of residents with at least a junior college education. The freeway accessibility variable was excluded solely on account of its negligible *t*-values in both Model 1 and 2.

Models 5 through 8 are Box-Cox functions. All forms represent relatively simple applications of the Box-Cox transformation: the simple left-hand-side Box-Cox model; the simple both-side Box-Cox model; the separate both-side Box-Cox model; and a Box-Cox model with four transformations (i.e. for the dependent variable and for structural, neighborhood, and accessibility attributes, respectively).[7]

The results show that all structural and neighborhood variables have the expected signs, and most of them are highly significant. In models 3 to 8, house height and income have been eliminated from the specification, leading to more robust models where the floor area and age variables pick up some of the price effects of height variability and education controls for most income variability. The log-linear function explains more of the variance and has greater log likelihood in both its all-variable and reduced versions. All the Box-Cox functions have slightly greater log likelihood than the log-linear function, with the exception of the simple left-hand side model (Model 5). The transformation parameter of the simple both-hand side model is significantly different from $\lambda = 0$, which would correspond to the log-linear model. Even so, it is in the same general neighborhood as the log-linear function, and offers identical qualitative conclusions. The results of models 7 and 8 are also very similar to the simple both-side model (Model 6) and the log-linear function. Each type of functional form has its own advantages and drawbacks: pre-specified functions are simple and easy to interpret, transformations improve the distri-

[5] We use the distance to the (old) Tainan Railway Station as our "distance to CBD" measure. The accessibility variables measure distances from the center of the census tract in which the housing unit is located to the facility in question (i.e. Tainan Railway Station, HSR station, TSIP). Exact locations of property transactions are unavailable since the identity of the transacting parties is confidential.

[6] The correlation matrix is included in the Appendix as Table A2.

[7] All Box-Cox functions were estimated using maximum likelihood techniques.

Table 3
Hedonic price functions for the residential property market in the Tainan metropolitan area, 2007; pre-specified functional forms.

Variable	Model 1: log-linear model coefficient (*t*-value)	Model 2: semi-log model coefficient (*t*-value)	Model 3: log-linear model coefficient (*t*-value)	Model 4: semi-log model coefficient (*t*-value)
Constant	.249	−.067	1.561	.412
Structural attributes				
Floor area	.523**	.053**	.550**	.100**
	(15.57)	(5.76)	(26.87)	(12.85)
Lot size	.487**	.543**	.468**	.470**
	(16.43)	(23.02)	(19.45)	(20.59)
Age	−.118**	−.163**	−.121**	−.221**
	(−17.28)	(−17.83)	(−19.72)	(−32.47)
Height	.037	.110**		
	(.92)	(9.20)		
Shop/dwelling use	.141**	.163**	.144**	.175**
	(6.35)	(6.69)	(6.49)	(7.04)
Street frontage	.190**	.241**	.186**	.245**
	(11.91)	(14.01)	(11.73)	(13.87)
Neighborhood attributes				
Road width	.102**	.060**	.096**	.062**
	(6.61)	(5.82)	(6.31)	(5.87)
Commercial zone	.373**	.384**	.328**	.404**
	(6.98)	(6.51)	(6.49)	(6.91)
Residential zone	.280**	.215**	.234**	.206**
	(6.27)	(4.44)	(5.75)	(4.26)
Mean household income in district	.439**	.029		
	(2.62)	(.91)		
College-educated in district	.175	.161**	.448**	2.359**
	(1.53)	(2.54)	(10.42)	(13.07)
Accessibility attributes				
Distance to CBD	−.114**	−.199**	−.107**	−.193**
	(−7.18)	(−6.83)	(−6.97)	(−7.19)
Distance to HSR station	−.034	.016[a]	−.040*	.002[a]
	(−1.54)	(1.01)	(−1.95)	(.17)
Distance to freeway interchange	.012[a]	−.016		
	(.81)	(−.51)		
Distance to TSIP	−.072**	−.025	−.075**	−.037*
	(−3.07)	(−1.24)	(−3.55)	(−2.12)
Function statistics				
Adjusted R^2	.805	.765	.804	.753
Log likelihood	−2455.0	−2904.1	−2481.6	−3675.6

N = 1550.
* Represent significant result at the one-tailed 0.05 confidence level.
** Represent significant result at the one-tailed 0.01 confidence level.
[a] Opposite of the expected sign.

bution of error terms, but increasingly complex transformation leads to increasing data specificity (and increasing levels of "data mining").

The estimated accessibility effects point to the essentially monocentric character of the Tainan metropolitan area. The contribution of the distance-to-CBD attribute (which is defined as distance to the old railway station) to residential property prices is similar and highly significant in all eight specifications. The estimates of the log-linear function imply that a halving of the distance is associated with a price increase of about 11% (i.e. a price-distance elasticity of −.11). The TSIP is a suburban high technology cluster that is located in the north-eastern part of the metropolitan area; it is a daytime population center for more than 50,000 workers, many of which are high-income managers and engineers. The effect of TSIP accessibility is smaller and less robust: it is insignificant (at one-tailed .05 significance) in two of the functions and is associated with a price-distance elasticity of about −.07.

HSR accessibility is even less robust and significant. It is only significant at one-tailed $\alpha = .05$ in three of the eight functions, and never at $\alpha = .01$. Moreover, in two of the functions the parameter estimate takes the wrong (+) sign. Even if we tentatively accept the existence of a price-distance effect, it amounts to no more than a 3% or 4% price premium for, say, an otherwise equivalent house at a distance of four instead of eight kilometers from the station. This would correspond to only about half the effect of proximity to *any* railway station in the Netherlands (Debrezion et al., 2006), regardless of the frequency of trains and network connectivity. In this context it should be mentioned that Tainan HSR station offers a total of 70 departures per day, with connections to all major cities and the transit systems of Taipei and Kaohsiung.

A comparison with the Netherlands is especially appropriate since Taiwan has an even higher population density, implying that its potential for rail-based commuting is even better: increasing the population density reduces the per capita cost of a given infrastructural investment. As in the Netherlands, the population of Taiwan mainly lives along a concentrated urbanized corridor. Taiwan's corridor is a linear built environment of residential areas and industrial parks – interspersed with pockets of intensive agriculture – that stretches from the northern suburbs of Taipei in the north to Kaohsiung Xiaogang Airport in the south. In the Netherlands, the corridor is more circular, connecting the previously separate cities of Amsterdam, The Hague, Rotterdam and other towns (i.e. the *Randstad* conurbation). However, while intercity commuting by rail is common in the Netherlands, it is still the exception in

Table 4
Hedonic price functions for the residential property market in the Tainan metropolitan area, 2007; Box-Cox-transformed functional forms.

Variable	Model 5: simple LHS Box-Cox model coefficient (*t*-value)	Model 6: simple both-side Box-Cox model coefficient (*t*-value)	Model 7: separate both-side Box-Cox model coefficient (*t*-value)	Model 8: Box-Cox model with 4 transformations coefficient (*t*-value)
Constant	.301	2.133	2.180	2.610
Structural attributes				
Floor area	.220**	.648**	.585**	.592**
	(11.71)	(21.53)	(15.85)	(16.03)
Lot size	.674**	.634**	.621**	.618**
	(13.46)	(14.30)	(14.38)	(14.10)
Age	−.280**	−.178**	−.189**	−.184**
	(−18.28)	(−12.78)	(−12.83)	(−11.96)
Shop/dwelling use	.245**	.198**	.194**	.193**
	(6.59)	(6.56)	(6.57)	(6.57)
Street frontage	.327**	.247**	.247**	.243**
	(11.19)	(10.59)	(10.76)	(10.57)
Neighborhood attributes				
Road width	.092**	.122**	.116**	.084**
	(5.92)	(6.47)	(6.45)	(3.89)
Commercial zone	.511**	.404**	.397**	.418**
	(6.08)	(6.11)	(6.10)	(6.15)
Residential zone	.243**	.254**	.248**	.261**
	(3.60)	(4.91)	(4.85)	(4.56)
College-educated in district	3.167**	.739**	.826**	1.745*
	(10.15)	(7.66)	(7.19)	(2.07)
Accessibility attributes				
Distance to CBD	−.244**	−.169**	−.180**	−.200**
	(−6.28)	(−6.69)	(−6.82)	(−6.42)
Distance to HSR station	−.003	−.047*	−.041*	−.034
	(−.17)	(−1.93)	(−1.77)	(−1.57)
Distance to TSIP	−.010**	−.055**	−.043**	−.025
	(−4.26)	(−3.03)	(−2.98)	(−1.57)
Transformation parameters				
Left-hand side or both-side parameter (λ_1)	.228	.168	.259	.154
Right-hand side parameter (λ_2)			.159	
Structural attribute parameter (λ_S)				.236
Neighborhood attribute parameter (λ_N)				.806
Accessibility attribute parameter (λ_A)				.463
Performance statistics				
Log likelihood	−2643.8	−2453.7	−2450.0	−2447.8

N = 1550.
* Represent significant result at the one-tailed 0.05 confidence level.
** Represent significant result at the one-tailed 0.01 confidence level.

Taiwan, even for short well-established routes such as that between Tainan and Kaohsiung.

An economic explanation for why there has so far been little in the way of high-speed intercity commuting is expensive HSR fares. By way of example, daily (Monday to Friday) HSR commuting between Tainan and Taichung would – in 2008 – incur a direct ticket cost of NT$23,900 (US$775) per month, which amounts to about 70% of the median monthly wage in Taiwan. This could be compared with commuting a similar time distance by train between cities in Western Europe, where a one-month commuter ticket typically amounts to only about 10% of the median monthly wage.[8]

One may expect people to react to long-term, stable differences in local wage rates by commuting or by moving to the higher-wage location. Other relevant factors, such as educational opportunities, service quality and purely subjective factors may of course reinforce or weaken the propensity to move. The choice to commute is decided by whether the difference in real income – taking account of the opportunity cost of not living in the destination community – is at least as great as the cost of travelling to and from work. If we assume that a Tainan resident prefers the Tainan to the Taichung residential package (for example due to housing affordability or subjective attachment), he would need to be offered a salary in Taichung that compensates for the total transportation cost, other job attributes being equal. The total transportation cost in the HSR case amounts to the sum of the direct cost (NT$23,920) and the subjective time cost (i.e. at least 33 h of traveling). Though wage rates are higher in Taichung, it is unlikely that a large group of Tainan residents will find jobs in Taichung that pay *substantially more* than an additional NT$23,900 per month, if we make the realistic assumption that train commuting is not their highest-valued leisure activity.

The main conclusion of this study is that the small or negligible effect of HSR accessibility on residential property prices in the

[8] A specific example is commuting costs between the Swedish cities of Uppsala and Stockholm, a 40-minute one-way trip. The price of a one-month commuter ticket is about US$300.

Tainan region is a reflection of expensive fares in combination with the inaccessible location of the HSR station. Yet we should bear in mind that the high ticket prices and the distant location of the station are not preordained. One way of increasing the economic impact is acquisition and development of large-scale freeholds or leaseholds around HSR stations in conjunction with information and marketing campaigns. Buchanan and Tullock (1962) explain how positive externalities may be internalized through unified land ownership within the "catchment area" of a territorial public good. An example is Hong Kong's MTR, which combined property development of land adjacent to MTR stations with inexpensive fares by rich country standards, thereby achieving a revenue structure that resembles the theoretical ideal of land rent covering fixed costs and user charges covering marginal costs (Webster and Lai, 2003, pp. 111–112).

7. Final remarks

While we have been unable to find any substantial and consistently significant effects of HSR accessibility in the Tainan metropolitan area, this does not necessarily imply that there are no effects on land values. It could be the case that that commercial activities have a higher willingness to pay for HSR station proximity, for example if they engage in frequent business meetings with customers or suppliers from other metropolitan regions. In a well-functioning land market, however, it is the highest bidder for a location that determines the land value, which means that a high valuation in the commercial property market should spill over into the housing market. Under such conditions, only home buyers with an exceptional willingness to pay would be able to outbid commercial property developers in commercially attractive locations.

The land market is however often not "well-functioning" in this sense. There may be substantial transaction and reconstruction costs associated with land use conversions. Moreover, zoning and other land use regulations may perpetuate the separation of different segments of the real estate market. An additional problem in Taiwan has been that many infrastructural investments have been subject to substantial delays or revisions, which has the effect of impeding the dissemination of reliable information from planners and developers to other market participants, thus delaying the discovery of the highest-valued land uses in various locations.

In Europe and North America, long-distance commuting has become increasingly common as households demand larger houses and lots. In particular, a single-family home has become a common aspiration among families with children. For most people, such properties are only affordable in suburban areas, small towns or in the countryside.

The quest for ever-larger housing has no real parallel in Taiwan. There are almost no single-family homes, with the new and old housing stock almost exclusively consisting of medium-sized apartments and row houses with minuscule lots. The implication is that it is virtually impossible to convert extra income into larger housing, beyond a relatively modest size.

Finally, the empirical evidence in this study, as well as income statistics from other regions in Taiwan, indicate that the income elasticity of demand for accessibility is greater than the income elasticity of demand for residential space for the modal Taiwanese household. And it is exactly higher-income workers who tend to be the first to take advantage of new commuting opportunities, as a reflection of their pursuit of larger spaces in tranquil upscale neighborhoods. Unlike America, and to some extent Europe, the inner cities of Taiwan are associated with the highest income levels and are perceived as having the best schools.

Appendix 1

See Tables A1 and A2.

Table A1
Correlation matrix variable codes.

Variable	Code
Transaction price in NT$ million (log)	P
Floor area in square meters (log)	S_1
Lot size in square meters (log)	S_2
Age of house in years (log)	S_3
Height of house in number of stories (log)	S_4
Shop/dwelling use dummy	S_5
Street frontage dummy	S_6
Road width in meters (log)	N_1
Commercial zone dummy	N_2
Residential zone dummy	N_3
District mean income in NT$ thousand (log)	N_4
Share of district residents over 15 with junior college or more (log)	N_5
Distance in kilometers to CBD/old railway station (log)	A_1
Distance in kilometers to HSR station (log)	A_2
Distance in kilometers to nearest freeway interchange (log)	A_3
Distance in kilometers to Tainan Science-based Industrial Park (log)	A_4

Table A2
Correlation matrix.

	P	S_1	S_2	S_3	S_4	S_5	S_6	N_1	N_2	N_3	N_4	N_5	A_1	A_2	A_3	A_4
P	1.00															
S_1	.79	1.00														
S_2	.51	.51	1.00													
S_3	−.50	−.50	−.21	1.00												
S_4	.59	.77	.09	−.63	1.00											
S_5	.27	.18	.03	.07	.10	1.00										
S_6	.30	.20	.06	−.05	.10	.36	1.00									
N_1	.11	.04	.02	.02	.02	.15	−.12	1.00								
N_2	.12	.08	−.06	.18	.01	.30	.14	.06	1.00							
N_3	.01	−.08	.01	−.14	.01	−.21	−.10	.02	−.81	1.00						
N_4	.33	.13	−.10	.06	.13	.07	.01	−.01	.10	.04	1.00					
N_5	.34	.12	−.10	.09	.10	.08	.00	.05	.12	.10	.96	1.00				
A_1	−.24	−.03	.13	−.22	−.00	−.14	.02	−.10	−.27	.05	−.66	−.75	1.00			
A_2	−.11	−.01	.11	−.01	−.05	.02	−.18	.09	−.00	−.07	−.41	−.37	.17	1.00		
A_3	.08	−.02	−.01	.10	−.08	.02	−.05	.04	.07	−.10	−.21	−.14	−.08	.34	1.00	
A_4	.01	−.02	−.07	.07	−.02	.01	.03	.12	−.00	.02	.11	.16	−.20	−.25	.31	1.00

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