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Highway investment in deindustrialization: A territorial analysis of office property transactions in Hong Kong, 2002–2013

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ABSTRACT

Transportation investment continues to grow in aid of economic competitiveness and environmental sustainability worldwide, but limited empirical research has been conducted on the changing value of highway investment in deindustrializing economies. This study examines the influences of highway proximity and traffic on office values in Hong Kong using hedonic price analysis on 13,670 transactions around highway interchanges for 2002–2013. Our hedonic regressions, controlling for unobservable district effects and incorporating instrumental variables, reveal that the associations of highway proximity and traffic with office prices appear to exhibit mixed results across Hong Kong’s three territorial divisions. The negative externalities generated by excess traffic cancel out the accessibility benefits of highway proximity on Hong Kong Island, where densely built-up office districts are suited for amenity-sensitive knowledge businesses that tend to create value-added services through face-to-face communications. By contrast, highway proximity uplifts the value of office properties with lower transportation costs and higher market accessibility in Kowloon and the New Territories, where spacious workplaces near hub-port and logistics facilities are advantageous for mobility-driven trade and transportation businesses that tend to increase value-added throughput in cross-border relations with mainland China. These territorial findings are of particular importance for progressive policymakers to deploy the strategic applications of underground bypasses, greenway creation, interchange improvement, congestion charges, and smart technology to manage mobility and alleviate disamenity, accompanied by supportive public transit services and adaptive land-use rezoning, in the dynamic and complex process of deindustrialization.

1. Introduction

With flows of people and goods concentrated in major cities, which offer greater competitive advantages than minor cities and peripheral territories in globalization, there is growing demand for urban mobility worldwide (Gwilliam, 2002; OECD, 2006; UNDP, 2009). Of various solutions, multibillion-dollar investments in transportation infrastructure have become increasingly critical for the economic competitiveness of heavily congested cities of the present and future. Controversially, while engineering-led, high-capacity highway systems have long been adopted by policymakers to enhance mobility and mitigate congestion in the industrializing and industrialized world, the political paradigm of urban transportation in post-industrial societies has shifted progressively toward environmental sustainability (Altshuler and Lubroff, 2003; Dimitriou, 2006; Ewing, 1996). This alternative approach typically calls for much greater resource allocations to public transit and non-motorized transportation systems, along with land use and climate change measures worldwide (Banister, 2011; Cervero, 1998; Newman and Kenworthy, 1999). However, scholarly debates and balanced views should maintain focus on the economic and environmental importance of both railway and highway investments in establishing strategic territorial development. While a large body of empirical research already presents the accessibility impacts of railway infrastructure and services on residential preferences mostly in developed economies (e.g., Debrezion et al., 2007; Higgins and Kanaroglou, 2016; Mohammad et al., 2013), this study reexamines the influences of highway infrastructure and traffic on office prices, particularly in the office properties in Kowloon and the New Territories, where spacious workplaces near hub-port and logistics facilities are advantageous for mobility-driven trade and transportation businesses that tend to increase value-added throughput in cross-border relations with mainland China. These territorial findings are of particular importance for progressive policymakers to deploy the strategic applications of underground bypasses, greenway creation, interchange improvement, congestion charges, and smart technology to manage mobility and alleviate disamenity, accompanied by supportive public transit services and adaptive land-use rezoning, in the dynamic and complex process of deindustrialization.
practitioners are increasingly witnessing the dense co-location of a wide array of transnational corporate headquarters and advanced producer services to conduct face-to-face meetings, share knowledge-intensive resources, and form productive business clusters in the central locations of major cities or so-called “global cities” (Sassen, 2001). By contrast, manufacturing activities largely move offshore and increase international trade flows to and from strategic industrial zones, characterized by low tax rates, low wage labor, and low-cost logistical advantages, in mainland China and other Asian countries (Farole and Akinci, 2011). World-class transportation infrastructure is designed to meet such dynamic and complex flow patterns of people and goods in emerging global cities and strategic industrial zones. However, little is known about the changing importance of highway investments in the new territorial divisions of industries observed across the Asia-Pacific region and beyond.

Hong Kong can be considered a real-world laboratory to empirically examine the territorial influences of highway investment in deindustrialization, with some distinctive characteristics. Essentially, the Hong Kong Special Administrative Region (HKSAR) in China has experienced persistent deindustrialization in relation to the emerging industrial hubs of Shenzhen, Dongguan, and Guangzhou in the Pearl River Delta (Shen, 2003). In fact, the share of manufacturing in Hong Kong’s total employment and gross domestic product during 2002–2013 shrank from 7.9% to 3.8% and from 4.8% to 1.4%, respectively (HKSAR Census and Statistics Department, 2015a,b). Instead, cross-boundary vehicle traffic between Hong Kong and mainland China grew substantially from 12.3 million to 15.5 million annual counts during the same period (HKSAR Transport Department, 2015).

The Territorial Development Strategy has proactively directed the competitive position of Hong Kong as “Asia’s World City” with world-class transportation infrastructure and services (HKSAR Town Planning Department, 2007, 2017). In particular, Hong Kong is globally known for its successful integration of railway investment and territorial development through government land leasing. The city’s extremely dense urbanization and high economic productivity could not have been sustained without intensive railway investments over the past decades (Cervero and Murakami, 2009; Loo et al., 2010). However, Hong Kong’s transit-oriented development model, which has been introduced globally, is only one side of the coin. Hong Kong also has the world’s most heavily used roadway system. In support of Hong Kong’s rapid throughput growth, the government has projected a series of massive highway capacity provisions since the early 1990s and by 2013, had developed an extensive highway network of about 242 km with 62 interchanges across its administrative territories, comprising 26 km with 14 interchanges on Hong Kong Island, 49 km with 15 interchanges in Kowloon, and 167 km with 33 interchanges in the New Territories. Nevertheless, the city’s exhaustive congestion, amplified by densely built-up areas and topographic bottlenecks, continues to require successive roadway projects for greater urban mobility and environmental sustainability, including multimillion- and multibillion-dollar investments in highways (see Appendix Table A.1 for a list of projects).

Despite growing expenditure on economic competitiveness and environmental sustainability, there is a paucity of evidence on the capitalization effects of highway investments in the progressively deindustrializing cities of Asia. Our research, therefore, sheds light on the value of highway infrastructure and traffic in Hong Kong’s knowledge-centered economies and transit-supportive environments by running hedonic price regressions on 13,670 office property transactions for 2002–2013 across three territorial divisions: Hong Kong Island (city core); Kowloon (inner city); and the New Territories (outer suburbs). The hedonic price analysis on office property transactions assumes that the premiums or discounts produced by highway infrastructure and traffic allow us to assess the territorial redistribution of economic advantage (mobility) and environmental disadvantage (disamenity) guided by highway investments in major cities’ dynamic and complex industrial shifts in Asia.

The remainder of this paper proceeds as follows. Section 2 reviews the hedonic price literature on accessibility, highway, traffic, and amenity worldwide. Then, Section 3 specifies regression models and describes the datasets collected and organized for hedonic price estimates. Section 4 presents the regression results. Finally, Section 5 summarizes our empirical findings, policy implications, and analytical challenges for future applied research.

2. Literature review

The literature investigating the urban land impacts of transportation investment essentially relies on the bid-rent theory developed by Alonso (1964), Muth (1964), and Mills (1972). According to this theory, railway and highway projects are assumed to reduce transportation costs, change locational advantages, and increase competitive firms’ willingness to pay for productive land. Specifically, the accessibility benefits produced by transportation investments or service improvements become capitalized in property prices around key nodes on the invested urban transportation network (Banister and Berechman, 2000, 2001; Giuliani and Agarwal, 2017). From this basis, many empirical works have estimated the capitalization effects of proximity to transportation access points (e.g., distances to stations and interchanges) as the accessibility benefits of major investments in railway and highway systems worldwide.

Over the past decades, much scholarly attention has been paid to the impacts of various railway systems, such as commuter rail, mass rail transit, light rail transit, and bus rapid transit in automobile-dependent housing markets in developed and developing countries (e.g., Debrezion et al., 2007; Higgins and Kanaroglou, 2016; Mohammad et al., 2013; Rodríguez and Mujica, 2009). This analytical trend does not mean that highway investments in non-residential property markets are insignificant. In addition, the body of literature points out that the capitalization effects of highways need to be considered in hedonic price analysis that aims to single out the effects of railways.

Measuring the accessibility benefits of highway investment capitalized into nearby housing prices is not new (Mohring, 1961). Nevertheless, the recent research on highways tends to indicate that the appreciation and depreciation impacts of highway proximity appear to be spatially and temporarily non-linear in amenity-sensitive housing markets (e.g., Chernobai et al., 2011). Seo et al. (2014, 2017) scrutinize whether the accessibility benefits adjacent to ground-level and elevated highway interchanges are more largely offset by the disamenity associated with node proximity (e.g., noise pollution, air pollution, and visual intrusion) in a non-linear way than those of below-grade interchanges and light rail stations in Phoenix’s single-family home market.

Little research has been conducted to measure the capitalization effects of highways on non-residential properties. Of the limited work in developing economies, Cervero and Susantono (1999) provide evidence that proximity to highway interchanges is significantly capitalized into office rents in the monocentric metropolitan expansion of Jakarta, where value capture schemes could be considered to finance expensive transportation projects and discourage speculative land investments. Analyzing the non-residential rents for 10 years across three different territories in San Diego, Ryan (2005) shows that highway proximity provides more benefits to office properties (but not to industrial properties) than light rail transit proximity and central business district accessibility do. This empirical evidence supports the hypothesis that highway projects play a critical role in fueling the territorial divisions of city core, inner city, and outer suburban office markets for mobility-driven and/or amenity-sensitive businesses in developed economies (Cervero, 1986; Garreau, 1991; Lang, 2003; Lee, 2007).

Another growing body of literature on highways investigates the
adverse impacts of traffic volumes on housing properties near highway interchanges or corridors to claim disamenity due to continuous roadway expansions for greater mobility. Numerous studies have shown substantial price discounts for heavy traffic, noise pollution, and/or air pollution, although the degrees of price discounts vary by estimation technique, traffic type, housing submarket, and territorial division worldwide (e.g., Allen et al., 2015; Andersson et al., 2010; Bae et al., 2007; Carey and Semmens, 2003; Hughes and Sirmans, 1992; Kawamura and Mahajan, 2005; Kim et al., 2007; Larsen, 2012; Nelson, 2008). On the other hand, existing research on traffic volumes has conducted limited analysis of the capitalization effects in non-residential properties on business productivity, whereas it provides rich evidence on price discounts in various residential estates for neighborhood livability.

Recently, there has been increased interest in the capitalization effects of alternative highway projects, such as toll road construction and elevated freeway deconstruction, which are expected to curb excess mobility and improve urban amenity in post-industrial economies. Some experiences of new high-occupancy toll roads with variable pricing after the late 1990s began to ease traffic congestion and raise housing values near highway interchanges in US suburbs (Boarnet and Chalermpong, 2001; Vadali, 2008). By contrast, the physical removal of elevated highway infrastructure has been adopted progressively as a catalyst for urban regeneration in the central waterfront districts of deindustrializing cities, such as San Francisco and Seoul (Cervero, 2009). Hedonic price analysis for residential property sales along two freeway-to-boulevard conversions in San Francisco demonstrates that the spatial re prioritization from mobility to amenity yields net benefits along the new greenways (Cervero et al., 2009). Similarly, a few studies on Seoul’s Cheong Gye Cheon project conclude that both elevated highway deconstruction and underground stream restoration stimulate land-use changes and cause non-residential property values to surge by appealing to knowledge-based office industries and creative-class workers (Jang and Kang, 2015; Kang and Cervero, 2009). The most controversial freeway removal is the Central Artery/Tunnel (CA/T) project in Boston, known as the “Big Dig,” with a project cost of US$24.3 billion and a series of construction failures. While traffic congestion and accidents induced by the new underground bypasses are debatable, the green spaces and waterfront passages created by this mega-project were predicted to increase the values of nearby condominiums and non-industrial estates in central Boston (Tajima, 2003).

Strategic highway projects, such as underground bypasses, urban links, and cross-boundary bridges, are currently proposed and partially delivered across Hong Kong’s city core, inner city, and outer suburbs as unique territorial features that make it increasingly difficult to provide additional mobility without loss of amenity in densely built-up areas. Indeed, there have been several hedonic price studies on the growing demand for mobility improvements and amenity recreation in Hong Kong’s rapid urbanization and drastic deindustrialization during the last 2 decades. The findings on housing price premiums (or discounts) reported from Hong Kong’s residential neighborhoods have typically been related to the positive externalities of public transportation systems (Chau and Ng, 1998; Choy et al., 2007; So et al., 1997), living amenity traits (Hui et al., 2007; Jim and Chen, 2010; Tang and Yiu, 2010; Tse and Love, 2000), and new transportation project announcements (Jayantha et al., 2015; Yiu and Wong, 2005) at specific line, district, and site scales. More recently, some studies have begun to inspect the localized spillover effects of large-scale urban regeneration programs, enhancing railway accessibility and waterfront amenity attributes for Hong Kong’s post-industrial economies, on office or retail property values within selected commercial districts (Jayantha and Ming, 2015; Jayantha et al., 2016; Liusman et al., 2017). However, there is still a paucity of research with a special focus on the non-linear influences of both subsequent highway investments and growing traffic volumes on non-residential property markets across the three territorial divisions of Hong Kong in deindustrialization.

3. Methodology

3.1. Model specification

Our research attempts to fill the abovementioned knowledge gaps with the application of the hedonic price method for a territorial analysis of office property transactions in the case of Hong Kong for 2002–2013. Such an analysis could add more comprehensive and counteractive viewpoints to the hedonic price literature on highway investment in both developed and developing economies. Based on bid-rent theory, spatiotemporal variations in office price revealed through market transactions are supposed to indicate differences in the productivity of land or “utility” of workplace by location and period for competitive firms (O’Sullivan, 2007; Sullivan, 1986). Under the assumption of utility theory, a marketable good comprises a bundle of attributes and one property price revealed in the competitive market can be decomposed into the element prices of key attributes by analyzing various transactions as a hedonic price formula (Rosen, 1974).

Following the theoretical framework, applied empirical research on private properties can be designed to estimate a variety of market transaction prices as a function of structural, neighborhood, and locational attributes, including public projects, environment externalities, and other spatiotemporal factors (Brookshire et al., 1982; Freeman III, 1981; Kanemoto, 1988). A range of such hedonic price applications for urban transportation investments and relevant environmental issues are summarized as the following generalized Eq. (1) (Higgins and Kanaroglou, 2016):

\[
P = f(S, N, L, T, C)
\]

where \(P\) is a vector of property unit price, \(S\) is a vector of structural attributes, \(N\) is a vector of neighborhood or business district attributes, \(L\) is a vector of location attributes, \(T\) is a vector of transportation and related environmental attributes, and \(C\) is a vector of controls for other spatiotemporal attributes.

With a chief interest in estimating the detailed capitalization effects of urban transportation and related environmental attributes, we incorporated public transit, highway interchange, and traffic volume variables separately into office price regressions. A set of numeric and/or dummy variables for proximity to interchanges were primarily used to measure the accessibility benefits as well as environmental externalities arising from highway investments in both linear and non-linear ways, as widely employed in many other hedonic studies on urban transportation. Moreover, we paid special attention to the multifaceted interpretation of traffic volumes in our model construction. Above all, traffic volumes at interchanges directly indicate the degree of both mobility and disamenity across different segments of the highway network. Next, traffic volumes at interchanges indirectly and partially represent the amount of market accessibility in diverse locations of the city. Furthermore, the temporal (time-lag or post-project) effects of highway investments are reflected as dynamic changes in traffic volumes at interchanges, since the growth of travel demand is induced by the provision of new transportation infrastructure in both short and long periods (Cervero, 2003).

Our hedonic study further worked on the issue of endogeneity derived from the direction of causality between highway investments and property prices, which the majority of other hedonic price studies reviewed in the previous section do not cope with. Indeed, it would be methodologically difficult to analyze the multiple-decade bidirectional relationships between transportation infrastructure provisions and office market formations using a limited number of office property transactions in Hong Kong for only 12 years (e.g., repeat sales or...
difference-in-differences). Instead, we considered the short-term interplays between highway traffic volumes and office property prices within our mid-term dataset. Hypothetically, more economic interactions (increased traffic volumes) are likely to influence the productivity of firms at offices around highway interchanges (increased or decreased office prices), and then more productive firms (increased office prices) are likely to generate more economic interactions (increased traffic volumes) around highway interchanges in a short period. To mitigate the potential estimation bias produced by such dynamic interplays in Eq. (1), we applied the technique of two-stage least squares (2SLS) regressions, in which the endogenous variable for traffic volumes is instrumented by a few exogenous interchange-related variables. Note that the age of the highway interchange variable and multiple year lags were originally tested to capture the aforementioned temporal effects and causal associations in ordinary least squares (OLS) regressions; however, the 2SLS regression approach resulted in better model fitness and more significant estimates. Corresponding to the generalized Eq. (1), our 2SLS regression models are expressed as more specific Eqs. (2) and (3):

\[ P_{ijt} = \alpha x + \alpha_1 S_{ijt} + \alpha_2 N_{ijt} + \alpha_3 L_{ijt} + \alpha_4 TP_{ijt} + \alpha_5 TH_{ijt} + \alpha_6 T\bar{T}_{ijt} + \alpha_7 Y_{ijt} + \mu_{ijt} + \epsilon_{ijt} \quad (2) \]

\[ T\bar{T}_{ijt} = \beta_1 + \beta_2 S_{ijt} + \beta_3 N_{ijt} + \beta_4 L_{ijt} + \beta_5 TP_{ijt} + \beta_6 TH_{ijt} + \beta_7 I\bar{C}_{ijt} + \beta_8 Y_{ijt} + \gamma_{ijt} + \nu_{ijt} \quad (3) \]

where \( P_{ijt} \) is the office price (logged) of transaction \( i \) in district \( j \) at year \( t \), \( S_{ijt} \) is a vector of structural variables (logged), \( N_{ijt} \) is a vector of neighborhood (or business district) variables (logged), \( L_{ijt} \) is a vector of location variables (logged), \( TP_{ijt} \) is a vector of public transit variables (logged or dummy 1/0), \( TH_{ijt} \) is a vector of highway interchange variables (logged or dummy 1/0), \( T\bar{T}_{ijt} \) is a vector of traffic variables (logged), \( Y_{ijt} \) is a vector of year variables (dummy 1/0), \( I\bar{C}_{ijt} \) is a vector of interchange-related exogenous variables (logged), \( \alpha_0 \) and \( \beta_0 \) are constants, \( \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \gamma_0 \) and \( \beta_0 \) are coefficients for independent variables, \( \mu_{ijt} \) and \( \nu_{ijt} \) are district-specific errors, and \( \epsilon_{ijt} \) and \( \theta_{ijt} \) are general errors.

In Eqs. (2) and (3), the district-specific error terms \( \mu_{ijt} \) and \( \nu_{ijt} \) are incorporated to denote the effects of omitted district characteristics (called “spatial heterogeneity”) on office prices, as applied in several hedonic price studies (Anselin and Arribas-Bel, 2013; Goodman and Thibodeau, 2003; Higgins and Kanaroglou, 2016; Kang and Cervero, 2009; Kuminoff et al., 2010). This means that the residuals of regressions have heterogeneous variance and are correlated with each other, for which the OLS estimator tends to generate biased estimates (Rabe-Hesketh and Skrondal, 2012). After preliminarily testing other spatial analysis techniques, such as spatial lag, spatial error, and general spatial models (Anselin, 2013), we found spatial fixed-effects regressions as a logically suitable and statistically stable estimator for Hong Kong’s territorial datasets on office property transactions, because the heterogeneity of variance appears to be identical between well-defined planning units or district boundaries and is correlated with independent variables.

### 3.2. Data on highway interchanges and traffic volumes in Hong Kong

Detailed geographic information system (GIS) data on all Hong Kong’s highway interchanges in 2013 were developed with table information on location, shape, size, and age, using an online satellite imagery (OSI) technique (Monkkonen, 2008). The locations of total 62 highway interchanges were associated with the traffic counting stations reported by the Annual Traffic Census for 2002–2013 (HKSAR Highways Department, 2014). When multiple counting stations were located at one highway interchange, a mean value of the annual average daily traffic was computed at each interchange for the 12 census years. Note that Hong Kong’s breakdown traffic counts by vehicle type and peak hour at each interchange are not publicly available.

Fig. 1 illustrates the territorial distribution of 62 highway interchanges on the total network length of 241.62 km across Hong Kong Island (22.6%), 15 interchanges Kowloon (24.2%), and the New Territories (53.2%) opened in three different periods—before 1990 (35.5%), from 1990 to 2000 (40.3%), and after 2000 (24.2%). Covering territory-wide interchanges in different construction periods, our analysis was able to have a large sample size near interchanges, hold variations in attributes across cases, and examine marginal changes in highway-related attributes on multivariate regression models.

### 3.3. Data on office property transactions in Hong Kong

Of Hong Kong’s common non-residential estate categories (e.g., retail, industrial, and hotel), we selected office space to investigate the capitalization effects of highway interchanges and traffic volumes for some practical reasons. First, the government has repeatedly stressed the importance of a steady provision of Grade A offices in strengthening Hong Kong’s international headquarter functions and value-added service activities through the Territorial Development Strategy for 2030 and 2030+ (HKSAR Town Planning Department, 2007, 2017). Second, since 2009, the government has intensively permitted non-compliant zoning codes to optimize former industrial buildings into sizable office spaces for Hong Kong’s new creative economies, such as arts, entertainment, convention, education, and information and communication technology (HKSAR Development Bureau, 2017). Third, Hong Kong’s major shopping malls and local retail streets are located predominantly on and around railway stations, but not near highway interchanges. This is due in large part to the residents’ transit-centered lifestyle and low private car ownership—about 72 vehicles per 1000 residents in 2013 (HKSAR Transport Department, 2015). Fourth, an office-focused study on highway investment in Hong Kong is internationally comparable to the hedonic price literature on roadway network extensions in developed and developing economies, as reviewed in Section 2—specifically the territory-wide and/or non-linear capitalization effects of freeway (de)constructions on office properties presented by Cervero and Susantoso (1999), Kang and Cervero (2009), and Ryan (2005).

Data on Hong Kong’s office property sales for 2002–2013 were extracted from EPRC Limited’s transaction database (http://eprc.com/hk/), containing street-level address, name of building, floor level, gross floor area, net floor area, date of sale, open year of building, and sales price. After excluding all incomplete records, 13,670 transaction cases remained for our analysis. To control for Hong Kong’s inflation (or deflation) effects, the transaction prices recorded for 2002–2013 were adjusted monthly using Hong Kong’s consumer price index (CPI) in December 2014. The CPI-adjusted transaction price per gross floor area was calculated as a dependent variable to indicate the profitability of each office unit for property buyers to use as competitive firms or lent out to competitive firms, capturing firms’ willingness to pay for productive workspace with a bundle of attributes relevant to knowledge- and service-based business activities. In addition, the ratio between net and gross floor areas was computed to control for the usability of actual workspace more accurately in regressions.

The data on office property transactions with street-level address and date of sale were spatially and temporally related to the data on highway interchanges and territorial boundaries by applying the OSI/GIS techniques. Fig. 2 presents the territorial distribution of the 13,670 transactions collected. Importantly, 10,812 transactions (79.1%) were made within 800 m of the 32 interchanges across the three territorial
Fig. 1. Territorial distribution of 62 highway interchanges in Hong Kong Island, Kowloon, and the New Territories.
Source: Authors
Note: CBD = central business district; HKIA = Hong Kong International Airport.

Fig. 2. Territorial distribution of 13,670 office property transactions (2002–2013) in Hong Kong Island, Kowloon, and the New Territories.
Source: Authors
divisions: 5334 of 5536 cases (96.4%) on Hong Kong Island, 4819 of the 7053 cases (68.3%) in Kowloon, and 659 of the 1081 cases (61.0%) in the New Territories. The spatial proximity between office properties and highway interchanges was measured in two ways: straight distance and dummy variables for four distance ranges (within 200 m, 200–400 m, 400–600 m, and 600–800 m), enabling us to test both the linear and non-linear effects of highway proximity on office prices. In this spatial relation process, the closest interchange's traffic, size, age, and network distance to the immigration control point on the mainland China border were assigned to each transaction.

In Hong Kong's real estate markets, regional locations or “accessibility” to railway stations and other public transit services have generally been considered far more important determinants of property values than highway interchanges are. To control for such accessibility effects in price regressions, straight distances to the central business district (CBD), nearest mass transit railway (MTR) station, nearest light rail (LR) stop in the New Territories, and the number of bus lines to the nearest MTR station were measured for each transaction.

To account for unobservable district effects, the identification codes for 282 tertiary planning units (TPUs) and 18 district councils (DCs) provided by the HKSAR Census and Statistics Department were related to the 13,670 transactions. In addition, our analysis accounted for unobservable seasonal effects on office prices for 12 years (2002–2013) by incorporating 11 year dummy variables (using 2002 as the reference year) into the regression models specified, which is generally crucial as we use time-series property transaction data. If not incorporated, the capitalization effects of a series of highway and railway investments on office properties under Hong Kong’s rapid economic growth tend to be seriously upward biased.

While many housing studies generally include population density, demographic proportion, crime rate, urban park, and/or local school variables as neighborhood characteristics in residential price regressions, our study specifically used employment density and cross-industrial proportion variables as neighborhood or business district attributes in office price regressions. Hong Kong’s cross-industrial employment data by TPU for 2002–2013 were obtained from the HKSAR Census and Statistics Department (2015c) and associated with the 13,670 transactions. To grasp the essence of Hong Kong’s deindustrialization, the Hong Kong Standard Industrial Classification Version 2.0 was re-categorized into five large industries: transportation, trade, knowledge, manufacturing, and others. Fig. 3 presents the five industries’ percentage changes in employment for 2002–2013 across the three territorial divisions. The whole of Hong Kong experienced decreases in the range of 33.1–52.0% in the manufacturing industry but increases in the range of 24.4–59.8% in the knowledge industry. Remarkably, Hong Kong Island recorded decreases of 9.7% and 6.4% in the transportation and trade industries, respectively. On the contrary, Kowloon and the New Territories scored increases in the range of 23.4–37.8% in the transportation industry and 5.2–15.5% in the trade industry. We hypothesized that the capitalization effects of highway investments estimated from our office price regressions would be associated with these contrastive cross-industrial employment figures across the three territorial divisions.

Table 1 summarizes the descriptions and sources of all variables collected and organized for our analysis. Table 2 provides the descriptive statistics of candidate variables entered into the 2SLS regression models.

4. Results

The results of the regressions on Hong Kong Island, Kowloon, and the New Territories are shown in Table 3. Since Distance to IC and Distance Dummy 1/0 were alternately incorporated into the regressions to test the linear and non-linear spatial relations with office prices, a pair of models are comparatively reported with overall fitness (R-squared = 0.685–0.771) and F-statistics (p < 0.001). Note that spatial fixed effects (unobservable district characteristics) appeared more significantly on the TPU scale on Hong Kong Island and on the DC scale in Kowloon and the New Territories. For unbiased estimates, we checked the potential of multicollinearity problems among independent variables with a correlation matrix and variance inflation factors (VIFs) < 5.0 by territorial division. Most of the independent variables
Table 1: Variable descriptions and data sources.

| Variables Descriptions | Sources |
|------------------------|---------|
| Dependent Office price | Office property transaction price per gross floor area adjusted by the monthly CPI for December 2014 (HK$ per sq. ft.) | EPRC Limited |
| Structure Floor level | Floor level of office property | EPRC Limited |
| Gross area | Gross floor area (sq. ft.) | EPRC Limited |
| Net-gross ratio | Ratio of net floor area to gross floor area (%) | EPRC Limited |
| Property age | Age of office property in transaction year (sales year of newly completed property = first year) | EPRC Limited |
| Neighborhood Emp. density | Employment density in TPU (# of people engaged in all industries per sq. km) | HKSAR Census & Statistics Department |
| Manufacturing % | Proportion of people engaged in the manufacturing industry in TPU (%) | HKSAR Census & Statistics Department |
| Transportation % | Proportion of people engaged in the transportation industry in TPU (%) | HKSAR Census & Statistics Department |
| Trade % | Proportion of people engaged in the trade industry in TPU (%) | HKSAR Census & Statistics Department |
| Knowledge % | Proportion of people engaged in the knowledge-based industry in TPU (%) | HKSAR Census & Statistics Department |
| Others % | Proportion of people engaged in the other industries in TPU (%) | HKSAR Census & Statistics Department |
| Location & public transit Distance to CBD | Straight distance to the central business district (m) | OSI/GIS shapefiles |
| Distance to MTR | Straight distance to nearest MTR station (m) | MTR Cooperation/GIS shapefiles |
| No. of bus lines | Number of bus lines to nearest MTR station | MTR Cooperation/GIS shapefiles |
| Distance to LR | Straight distance to nearest LR stop in the New Territories (m) | MTR Cooperation/GIS shapefiles |
| Highway IC & traffic Distance to IC | Straight distance to nearest highway interchange (m) | OSI/GIS shapefiles |
| IC < 200 m | 1 if < 200 m to nearest highway interchange, otherwise 0 | OSI/GIS shapefiles |
| IC in 200–400 m | 1 if 200–400 m to nearest highway interchange, otherwise 0 | OSI/GIS shapefiles |
| IC in 400–600 m | 1 if 400–600 m to nearest highway interchange, otherwise 0 | OSI/GIS shapefiles |
| IC in 600–800 m | 1 if 600–800 m to nearest highway interchange, otherwise 0 | OSI/GIS shapefiles |
| Traffic at IC | Average daily traffic volume of nearest highway interchange in transaction year | HKSAR Annual Traffic Census |
| IC site | Site area of nearest highway interchange (ha) | OSI/GIS shapefiles |
| IC age | Age of nearest highway interchange | HKSA Highways Department |
| IC to ICP | Network distance from nearest highway interchange to nearest immigration control point on the mainland China border (m) | OSI/GIS shapefiles |
| Year dummy Year 2003 | 1 if transaction was made in 2003, otherwise 0 | EPRC Limited |
| Year 2004 | 1 if transaction was made in 2004, otherwise 0 | EPRC Limited |
| Year 2005 | 1 if transaction was made in 2005, otherwise 0 | EPRC Limited |
| Year 2006 | 1 if transaction was made in 2006, otherwise 0 | EPRC Limited |
| Year 2007 | 1 if transaction was made in 2007, otherwise 0 | EPRC Limited |
| Year 2008 | 1 if transaction was made in 2008, otherwise 0 | EPRC Limited |
| Year 2009 | 1 if transaction was made in 2009, otherwise 0 | EPRC Limited |
| Year 2010 | 1 if transaction was made in 2010, otherwise 0 | EPRC Limited |
| Year 2011 | 1 if transaction was made in 2011, otherwise 0 | EPRC Limited |
| Year 2012 | 1 if transaction was made in 2012, otherwise 0 | EPRC Limited |
| Year 2013 | 1 if transaction was made in 2013, otherwise 0 | EPRC Limited |

Note: IC = interchange; ICP = immigration control point; CBD = central business district; MTR = mass transit railway; LR = light rail; CPI = consumer price index; TPU = tertiary planning unit; OSI = online satellite imagery; GIS = geographic information system; HKSAR = Hong Kong Special Administrative Region.

included in the six models perform at the 1, 5, or 10% significance level, except a few predictors, such as Year Dummy 1/0 for 2003–2004 (mainly for the epidemic of Severe Acute Respiratory Syndrome from late 2002 to early 2004 in Hong Kong) and Distance to IC on Hong Kong Island. The coefficients obtained from these log-linear regressions can be read as elasticities, which indicate the relative sensitivity of office unit prices to marginal changes in the right-hand side predictors, including Distance to IC and Traffic at IC.

4.1. Effects of proximity to highway interchanges

The coefficients of Distance to IC attained from Models 1, 3, and 5 are linearly illustrated as marginal changes in estimated office prices within 100–800 m of highway interchanges across the three territorial divisions of Hong Kong, all else fixed with mean values (Fig. 4). These slopes reveal that distances to highway interchanges negatively affect office prices in Kowloon and the New Territories, whereas the capitalization effects of proximity to highway interchanges are statistically insignificant on Hong Kong Island. Notably, the result of Model 5 further infers that proximity to highway interchanges (elasticity = −0.629, z-value = −19.01) can be regarded as a stronger determinant of office values than proximity to MTR stations (elasticity = −0.067, z-value = −3.99) in the New Territories.

Similarly, the coefficients of IC < 200 m, IC in 200–400 m, IC in 400–600 m, and IC in 600–800 m dummy variables obtained from Models 2, 4, and 6 are non-linearly expressed as office price premiums or discounts for four 200-meter ranges, which are relative to transaction cases beyond 800 m, around interchanges across the three territorial divisions, all else being equal (Fig. 5). These plots show that the premiums of proximity to highway interchanges are 11.1–19.8% and 68.5–72.8% for the two ranges within 400 m in Kowloon and the New Territories. However, the capitalization effects of highway interchanges in Kowloon seem redistributive within 800 m, since price discounts are observed to be 7.8–10.4% for the other two ranges beyond 400 m. By contrast, the price discounts of proximity to interchanges or disamenity generated by highways are more explicitly found to be 15.2–21.2% for
4.2. Effects of traffic at highway interchanges

Fig. 6 summarizes the effects of highway traffic volumes on office prices around interchanges across the three territorial divisions, using the six coefficients of Traffic at IC from the 2SLS regressions. Post-instrumentation by interchange-related exogenous variables, traffic volumes (economic interactions) at highway interchanges are positively associated with nearby office property sales (business productivity) in Kowloon and the New Territories: all else being equal, office prices increase 1.7%–2.0% and 1.7%–2.6%, respectively, as traffic flows surge by 10% at the nearest interchange. By contrast, the coefficients imply that excessive traffic at interchanges negatively influence nearby office property transactions on Hong Kong Island: all else being equal, office prices decline 0.991%–0.997% as traffic volumes grow 10% at the nearest interchange in the densely built-up business districts.

4.3. Effects of other variables

The structural characteristics of office units were estimated as basic determinants of market transaction prices, except Gross Area and Net-Gross Ratio in the New Territories. Commonly, upper floors, larger and more usable spaces, and newer properties are favored to produce office premiums in the dense business climates of Hong Kong Island and Kowloon. However, Distance to CBD was statistically excluded from the six models because of relatively small differences in locational advantages within each territorial division. In addition, No. of Bus Lines and Distance to LR appeared statistically insignificant in determining office prices, which could further highlight the importance of highway proximity for office businesses in Kowloon and the New Territories. Instead, the slopes of Distance to MTR station (elasticities = −0.018 and −0.101) are steeper than those of Distance to IC (elasticities = −0.004 and −0.062) on Hong Kong Island and in Kowloon. Likewise, the effects of neighborhood (business district) variables

4.2. Effects of traffic at highway interchanges

Table 2 Descriptive statistics of candidate variables.

| Variables                        | Hong Kong Island (N = 5536) | Kowloon (N = 7053) | New Territories (N = 1081) |
|----------------------------------|-----------------------------|--------------------|---------------------------|
|                                  | Mean | S.D. | Min. | Max. | Mean | S.D. | Min. | Max. | Mean | S.D. | Min. | Max. |
| Distance to CBD                  | 2361 | 1535 | 35   | 9504 | 4059 | 1488 | 1759 | 7771 | 13,641 | 5630 | 8749 | 23,628 |
| Distance to MTR station          | 551  | 888  | 2    | 3600 | 287  | 214  | 1649 | 17 | 709 | 1042 | 15 | 11,818 |
| No. of bus lines                 | 15.5 | 7.7  | 3    | 34   | 6.18 | 4.134 | 1    | 15   | 14.0 | 7.5  | 5   | 43   |
| Distance to LR                   | –    | –    | –    | –    | 9845 | 6291 | 53   | 19,181 |
| IC in 200 m                      | 43,102 | 9,412 | 1    | 80,471 | 43,634 | 20,681 | 12,720 | 88,020 | 52,364 | 17,586 | 11,764 | 93,440 |
| –                                | –    | –    | –    | –    | –    | –    | –    | –    |
| IC in 400 m                      | 47,217 | 15,449 | 14,203 | 90,672 | 43,634 | 20,681 | 12,720 | 88,020 | 52,364 | 17,586 | 11,764 | 93,440 |
| –                                | –    | –    | –    | –    | –    | –    | –    | –    |
| IC in 600 m                      | 47,217 | 15,449 | 14,203 | 90,672 | 43,634 | 20,681 | 12,720 | 88,020 | 52,364 | 17,586 | 11,764 | 93,440 |
| –                                | –    | –    | –    | –    | –    | –    | –    | –    |
| Year dummy                       | –    | –    | –    | –    | –    | –    | –    | –    |
| Year 2003                        | 0.05 | 0.22 | 0    | 1   | 0.05 | 0.22 | 0    | 1   | 0.03 | 0.16 | 0    | 1   |
| Year 2004                        | 0.09 | 0.29 | 0    | 1   | 0.01 | 0.12 | 0    | 1   | 0.04 | 0.20 | 0    | 1   |
| Year 2005                        | 0.05 | 0.22 | 0    | 1   | 0.12 | 0.33 | 0    | 1   | 0.04 | 0.19 | 0    | 1   |
| Year 2006                        | 0.08 | 0.27 | 0    | 1   | 0.07 | 0.25 | 0    | 1   | 0.04 | 0.19 | 0    | 1   |
| Year 2007                        | 0.13 | 0.34 | 0    | 1   | 0.11 | 0.31 | 0    | 1   | 0.05 | 0.22 | 0    | 1   |
| Year 2008                        | 0.08 | 0.27 | 0    | 1   | 0.07 | 0.25 | 0    | 1   | 0.03 | 0.16 | 0    | 1   |
| Year 2009                        | 0.09 | 0.28 | 0    | 1   | 0.08 | 0.27 | 0    | 1   | 0.07 | 0.25 | 0    | 1   |
| Year 2010                        | 0.12 | 0.32 | 0    | 1   | 0.12 | 0.33 | 0    | 1   | 0.15 | 0.35 | 0    | 1   |
| Year 2011                        | 0.09 | 0.28 | 0    | 1   | 0.10 | 0.30 | 0    | 1   | 0.09 | 0.28 | 0    | 1   |
| Year 2012                        | 0.10 | 0.30 | 0    | 1   | 0.15 | 0.35 | 0    | 1   | 0.05 | 0.23 | 0    | 1   |
| Year 2013                        | 0.07 | 0.25 | 0    | 1   | 0.08 | 0.28 | 0    | 1   | 0.39 | 0.49 | 0    | 1   |

Note: IC = interchange; CBD = central business district; MTR = mass transit railway; LR = light rail; ICP = immigration control point.

all four ranges within 800 m on Hong Kong Island.
estimated clarify that extra Employment density decreases office prices on Hong Kong Island and in the New Territories (elasticities = −0.276/−0.303 and −0.322/−0.101), but increases workplace values slightly in Kowloon (elasticity = 0.079/0.046). Moreover, among the five industries, higher Trade percentage causes price discounts on Hong Kong Island (elasticity = −0.180/−0.207) but yields price premiums in Kowloon and the New Territories (elasticities = 0.217/0.298 and 0.155). Finally, the coefficients of Year Dummy 1/0 reflect Hong Kong’s upward market trends for 2002–2013 to the office prices adjusted by the CPI for December 2014, swerving 170.76–172.82% on Hong Kong Island, 162.39–163.56% in Kowloon, and 155.46–153.83% in the New Territories.

| Independent Variables                  | Hong Kong Island | Kowloon | New Territories |
|----------------------------------------|------------------|---------|-----------------|
| Structure                              |                  |         |                 |
| Floor level (logged)                    | 0.0993 (13.35)   | 0.0984 (13.27) | 0.1078 (14.73) |
| Gross area (logged)                     | 0.0707 (10.38)   | 0.0707 (10.45) | 0.0926 (16.34) |
| Net-gross ratio (logged)                | 0.5230 (12.52)   | 0.5198 (12.32) | 0.8301 (20.82) |
| Property age (logged)                   | −0.1622 (−13.41) | −0.1563 (−12.87) | −0.1237 (−15.11) |
| Neighborhood                            |                  |         |                 |
| Emp. density (logged)                   | −0.2758 (−4.03)  | −0.3027 (−4.43) | 0.0787 (9.03) |
| Manufacturing % (logged)                | −0.1476 (−15.73) | −0.1332 (−14.29) | 0.0666 (−2.33) |
| Knowledge % (logged)                    | −0.1800 (−2.55)  | −0.2069 (−2.93) | 0.2171 (6.35) |
| Location & public transit               |                  |         |                 |
| Distance to MTR (logged)                | −0.0177 (−2.26)  | −0.0199 (−2.59) | −0.1012 (−14.83) |
| Highway IC & traffic                    |                  |         |                 |
| Distance to IC (logged)                 | −0.0043 (−0.51)  | −0.0615 (−6.54) | −0.6285 (−19.01) |
| IC < 200 m (1/0)                        | −0.1515 (−3.63)  | −0.1593 (−4.65) | 0.1111 (7.40) |
| IC in 200–400 m (1/0)                   | −0.1781 (−4.36)  | −0.0776 (−6.38) | 0.3101 (3.19) |
| IC in 600–800 m (1/0)                   | −0.2117 (−5.61)  | −0.1040 (−7.73) | 0.2162 (3.65) |
| Traffic at IC (logged)                  | −0.0991 (−3.16)  | −0.0997 (−3.25) | 0.1713 (16.00) |
| Year dummy                              |                  |         |                 |
| Year 2003 (1/0)                         | −0.1556 (−5.65)  | −0.1293 (−4.66) | 0.0033 (0.13) |
| Year 2004 (1/0)                         | 0.2028 (8.13)    | 0.2243 (8.95) | 0.3782 (9.93) |
| Year 2005 (1/0)                         | 0.5006 (18.00)   | 0.5263 (18.80) | 0.5180 (23.72) |
| Year 2006 (1/0)                         | 0.6402 (26.21)   | 0.7027 (26.91) | 0.5900 (24.44) |
| Year 2007 (1/0)                         | 0.8429 (35.11)   | 0.8659 (35.64) | 0.7490 (33.39) |
| Year 2008 (1/0)                         | 1.0465 (40.17)   | 1.0667 (40.59) | 0.9051 (37.31) |
| Year 2009 (1/0)                         | 1.0480 (40.49)   | 1.0724 (40.87) | 0.8790 (37.26) |
| Year 2010 (1/0)                         | 1.2704 (51.06)   | 1.2942 (51.35) | 1.0911 (49.33) |
| Year 2011 (1/0)                         | 1.4621 (55.21)   | 1.4834 (55.35) | 1.2444 (54.38) |
| Year 2012 (1/0)                         | 1.5909 (59.35)   | 1.6104 (59.26) | 1.4547 (65.26) |
| Year 2013 (1/0)                         | 1.7076 (60.62)   | 1.7282 (60.60) | 1.6239 (67.90) |
| Constant                                | 9.84564 (9.98)   | 10.3770 (10.41) | 1.6300 (7.11) |

| IVs (logged)                            |                  |         |                 |
| IC size, IC age                         | 0.7276            | 0.7256    | 0.6847          |
| IC size, IC age                         | 0.6934            | 0.7625    | 0.7707          |
| IC size, IC age, IC to ICP              |                  | 109.65   | 71.01           |
| R-squared                               | 0.5900            | 0.5747    | 0.5967          |
| F-statistics                            | 67.47             | 60.66     | 96.11           |
| Estimator                               | 2SLS              | 2SLS      | 2SLS            |
| VIF < 5                                 | Yes               | Yes       | Yes             |
| Spatial fixed effects                   | Yes               | Yes       | Yes             |
| Number of districts                     | 31                | 32        | 6               |
| Number of observations                  | 1021              | 1081      | 1081            |

5. Conclusions

The results of our regressions suggest that successive highway investments with growing traffic volumes have territorially contrastive influences on Hong Kong’s office values in deindustrialization. More precisely, the social costs generated by excess traffic exceed the accessibility benefits around highway interchanges in the city core, where tightly developed high-rise office buildings around railway stations are preferred for amenity-sensitive knowledge firms that have a propensity to demand more frequent and complex face-to-face communications for creativity. On the contrary, highway proximity and traffic elevates office values with lower transportation costs and greater market accessibility around interchanges in the inner city and outer suburbs, where
sizable office estates near international seaport and logistics hubs are available for mobility-driven trade and transportation firms that have a tendency to make greater profits through cross-boundary interactions with mainland China. These territorial experiences with highway investment in Hong Kong are certainly consistent with the non-linear reconfiguration associated with freeway reinvestment and deconstruction in San Diego and Seoul in the stage of deindustrialization (Kang and Cervero, 2009; Ryan, 2005) but are rather dissimilar to the linear expansion with highway network in Jakarta during the process of industrialization (Cervero and Susantono, 1999).

Our territorial findings in comparison with other international experiences lend some credence to the generalized statement that the land-use and economic development impacts of urban transportation investment depend on the context of intermodal network development and overall accessibility (Banister and Berechman, 2000, 2001; Giuliano and Agarwal, 2017). In particular, our empirical results infer that the marginal economic benefits (social costs) of an additional highway interchange in a densely built-up city core with multiple railway stations and other public transit services are much smaller (greater) than those of an original highway interchange in an expansively stretching outer suburb with limited modal options. While Hong Kong’s railway investment integrated with territorial development is widely acknowledged by policymakers across developed and developing economies for sustainable urbanization, our empirical evidence from the world’s foremost railway-guided city is a reminder that strategic highway investments together with supportive public transit services and adaptive land-use rezoning must play a critical role in directing the territorial development of major Asian cities in the dynamic and complex process of deindustrialization for competitiveness and sustainability.

Our territorial findings, especially on price discounts on Hong Kong Island, could be of particular interest for progressive policymakers to deliberate the strategic applications of underground bypasses, greenway creation, interchange improvement, congestion charges, and smart technologies, aiming to manage mobility and restore amenity in heavily congested business districts of the world, like Boston, San Francisco, Seoul, London, and Singapore. Actually, on Hong Kong Island, the on-going Central–Wan Chai Bypass construction at an estimated cost of HK$ 36 billion is expected to divert excess traffic from surface to underground, provide recreational greenery, and yield

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Fig. 4. Distance to highway interchange and estimated office price in Hong Kong Island, Kowloon, and the New Territories. Source: Authors.

Fig. 5. Distance to highway interchange (dummy 1/0) and estimated office price in Hong Kong Island, Kowloon, and the New Territories Source: Authors.
property price premiums along harbor-front business districts (HKSAR Highways Department, 2015).

Based on the appreciation of office price premiums around interchanges in the inner city and extra suburbs, policymakers might consider adopting land-value capture techniques to recover the increasing costs of strategic highway projects. Our empirical results from office property sales could partially and indirectly support such financing; however, business gains basically are reflected as increases in corporate tax via operating revenues. In practice, Hong Kong’s highway expenditure is linked to capital revenues largely reserved from the government’s land-leasing program, called the Capital Works Reserve Fund. Therefore, to extend this fiscal argument, further research needs to be conducted to directly inspect the capitalization effects of highway investments on government land-leasing revenues, supplemented by our findings on market transaction prices.

In summary, we present some analytical challenges for future applied research. First, this research analyzed Hong Kong’s growing office property market for the past 12 years only. Hedonic price analysis of Hong Kong’s shrinking industrial estate market over the past few decades should be conducted to capture the changing value of highways in deindustrialization more profoundly and for a longer period. Second, Hong Kong’s traffic data obtained from a public source contain aggregate volumes only, although the proportion and concentration of private cars and industrial vehicles are very likely to have changed spatiotemporally during deindustrialization. Scrutinizing the capitalization effects attributed to vehicle types and peak hours could provide more profound implications if a detailed traffic or behavior dataset were to become available in Hong Kong or other Asian cities. Finally, our study addressed deindustrialization within Hong Kong’s administrative territories only. Future research should be comparably and/or extensively designed for near and remote major cities in the Pearl River Delta, such as Shenzhen, Macau, Dongguan, and Guangzhou, to obtain a more comprehensive perspective on the value of highway investment in deindustrialization for region-wide competitiveness and sustainability.

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Appendix A

Table A.1

Roadway projects completed in the past 10 years and under construction/planning/design in Hong Kong.

| Division         | Project                                                                 | Status     | Cost (HK$) | Commission   |
|------------------|-------------------------------------------------------------------------|------------|------------|--------------|
| Hong Kong Island | Reconstruction of Causeway Bay Flyover and Associated Widening of Victoria Park Road | Completed  | 142 Million | Jul 2007     |
|                  | Central–Wan Chai Bypass and Island Eastern Corridor Link Pound Lane Escalator | Construction | 36 Billion | End 2017     |
|                  | Road Improvement Works for West Kowloon Reclamation Development (Phase 1) | Planning/Design | Under Review |              |
| Kowloon          | Retrofitting of Noise Barriers on Tseung Kwan O Road                   | Completed  | 137 Million | Nov 2009     |
|                  | Central Kowloon Route                                                  | Planning/Design | Under Review |              |

Fig. 6. Office price elasticities to traffic at highway interchanges in Hong Kong Island, Kowloon, and the New Territories.

Source: Authors

Note: IC = interchange.
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